Review Article

Dynamics of logging in Solomon Islands: The need for restoration and conservation alternatives

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Abstract
Forests of Asia-Pacific islands have undergone degradation by some of the worst-known selective logging practices in the tropics. It is unclear whether severely damaged forests can return to a pre-logging state via natural regeneration, or whether active restoration is required. In this review, we highlight how the socioeconomic dynamics in the Solomon Islands promote excessive logging, resulting in highly degraded forests. We detail seven key elements currently promoting excessive logging in this region: (i) economic interests, (ii) corruption, (iii) poor employment conditions in the logging sector, (iv) high forest accessibility, (v) resource limitations for forest monitoring, (vi) contention over logging benefits, and (vii) a paucity of information for policy development. Though research on the regeneration capacity of logged forests in the Solomon Islands remains extremely limited, we suggest that some logged forests in the country may require active restoration—especially those that have been most heavily damaged. Our argument is based on previous tree planting initiatives in logged forest in the 1970s and 1980s. We propose three broad restoration techniques—enrichment planting, direct seeding, and the use of artificial perches—as viable options to help restore logged forests in the Solomon Islands. Lastly, we recommend the conservation-concession model to aid forest restoration, given its recent success in the region.

Key Words: Selective logging, Natural regeneration, Active restoration, Biodiversity, Conservation

Received: 1 May 2015; Accepted: 4 August 2015; Published: 28 September 2015

Cite this paper as: Katovai, E., Edwards, W. and Laurance, W. F. 2015 Dynamics of logging in Solomon Islands: The need for restoration and conservation alternatives. *Tropical Conservation Science* Vol. 8 (3): 718-731. Available online: www.tropicalconservationscience.org

Introduction

Worldwide, tropical forests are highly vulnerable to industrial exploitation. During the past century, tropical Asia-Pacific islands, ranging from Malaysia to the Solomon Islands and westward across the equatorial Pacific, have experienced severe forest loss and degradation, exacerbated by some of the worst-known land-use practices, including heavy industrial logging (*e.g.,* Fig. 1A-B) [1-3]. Sustainable forest management strategies have achieved some success by reducing forest damage and maintaining biodiversity and ecological functions needed for spatio-temporal recovery through natural regeneration [4-8]. However, logging practices in this region are usually unsustainable, leaving little chance for natural regeneration processes to restore forest stands to pre-cut levels of biodiversity, carbon storage, and ecological functioning (*e.g.,* Fig. 1C-D) [9-10].

Some studies have suggested that natural regeneration in logged forests is capable of achieving nearly complete recovery of biodiversity [*e.g.,* 7, 11-12]. Nonetheless, without adequate protection, previously logged forests are usually vulnerable to unsustainable repeated logging or complete deforestation [2, 5, 12]. Further, it is unclear whether excessively logged and highly degraded forests will naturally recover their original species composition and ecological functioning if protected indefinitely without intervention. Active restoration could therefore become necessary for tropical Asia-Pacific islands, because large areas of once-forested landscapes on these islands either have been permanently altered or have plant species compositions that are largely novel and of unknown value for biodiversity conservation.

Fig. 1. A-B show damage associated with excessive logging. Non-compliance with logging legislation has exacerbated such damage. C-D show post-logging natural regeneration. This process alone may not be adequate to sustain floristic diversity in extensively damaged forests in Solomon Islands

Selective logging has been practiced globally as a preferred alternative to deforestation [13]. It is defined as the felling of selected trees based on species preference and/or cut-size limitations (*e.g.,* 50-60 cm diameter at breast height [DBH]) [5]. Selective logging is normally initiated in the most accessible and fertile areas within logging concession boundaries, and gradually shifts towards lower-fertility forests that are commonly associated with unfavourable topography, such as higher elevations, steep ridges, and ravines [14]. If properly managed, this approach can achieve healthy economic gains with minimal forest damage, after which the forest stand is left unmanaged to recover through processes of natural regeneration [14]. However, the overly broad definition of "selective logging" has resulted in highly varied logging practices throughout the tropics, some of which fail to achieve their conservation goals.

While selective logging attempts to minimise overall impacts of forest degradation, some studies have reported excessive and highly detrimental effects to the forest environment. When felling is based entirely on tree size, all tree species above the cut-size limit are usually harvested [15]. Harvest intensity *per se* depends on the quantity of timber trees above the cut-size limit, averaging 10 – 17 trees per hectare in densely wooded forests [5, 16]. When felling is species-based, all individuals of target tree species are frequently harvested [17]. This usually includes trees well below the conventional cut-size limits [12, 18]. Both species and cut-size restrictions may be violated due to the relentless demand for tropical hardwood [17, 19]. In this case, harvest intensity is extremely high, often reaching 30 cut trees per hectare, leaving behind a residual stand of severely damaged immature trees. If not properly monitored by forest authorities, this strategy frequently violates legislation restricting export of timber species that are protected for cultural, biological, and conservational reasons [20].

Excessively heavy selective logging practises are widespread in most of the tropical Asia-Pacific islands, despite legislation to curtail such practices [21-22]. The Solomon Islands present an ideal case for exploring the dynamics of these excessive practices because research on logging and its ecological outcomes in the country is poorly reported (Fig. 1). In this review we (i) highlight the dynamics for selective logging in the Solomon Islands, (ii) stress the need for active restoration in logged forests in the country, and (iii) propose several active restoration techniques already employed in tropical Islands of Southeast Asia that could aid recovery in excessively logged forests in the Solomons.

The dynamics of logging practices in the Solomon Islands

The Solomon Islands are a group of tropical oceanic islands east of Papua New Guinea with a modest forest estate. Logging began in the Solomons in the early 1920s, first on state-owned land, and eventually encroaching into native-owned lands in the 1980s [18, 23]. Logging practices in this country are mainly driven by synergisms among i) economic interests; ii) corruption; iii) poor employment conditions in the logging sector; iv) high forest accessibility; v) resource limitations for forest monitoring; vi) contention over logging benefits; and vii) paucity of information for policy development.

1. Economic interests

Logging has been a major contributor to the Solomon Islands' national and rural economies for several decades. Log exports alone contribute between 50 - 70% of the country's annual export revenue [9, 24]. Timber stocks in the country have been severely over-harvested during the last two decades. Harvesting within this time period revealed an average yearly increase of 68,500 m^3yr^{-1}, reaching seven times the estimated sustainable level of 250,000 m^3yr^{-1} rate within the last five years [25]. Moreover, log production still continues to increase despite earlier assertions that peak production was reached in 2009 (Fig. 2) [9].

Native landowners receive smaller returns from their logs than the national government. Nevertheless, they usually perceive logging as a lucrative means of quick financial gain through royalty spin-offs, and therefore ensure requirements are met for logging to commence in their area [21]. This practice is likely to continue until all commercially viable wood stock in accessible forest estates is depleted, unless alternative viable economic opportunities become available to resource owners.

2. Corruption

Corruption among logging companies and various sectors of society has also contributed to excessive logging in the Solomon Islands [21, 26]. This involves opportunists (*i.e.,*, influential groups or individuals who cunningly pursue any foreseeable logging opportunities to make financial gains), mostly through illegal transactions [21, 26 – 27]. Such transactions are usually bounded by ambiguous agreements between the logging companies and the receiver. For instance, over the past three decades successive governments have been infiltrated by a political culture driven by logging money [21]. Such engagements undermine government policies and environmental protections pertaining to logging. Politicians and government officials benefiting from such illegal deals enable and protect logging interests, even compromising national interests by overstepping any resistance to logging [26, 28]. Several high-profile politicians, prominent government officers, and opportunistic individuals and groups have allegedly been associated with such illegal practices and been charged with illegal conduct [18, 26].

Logging companies have also been exposed for fraudulent conduct, including tax evasion through illegal logging, under-reporting of export volumes, transfer pricing, informal agreements between buyers, altering species names (using species names with low market value), and bribery [21, 26, 29-31]. The regularity of such fraud reveals the unprecedented levels of logging-driven corruption in Solomon Islands. For instance, in 1993 it was estimated that more than US$12 million of logging revenue was evaded through under-reporting [29]. During the ethnic tension in Solomon Islands (1998 – 2003), logging was the least-affected industry, with operations progressively expanding to new areas [25]. Surprisingly, log export volumes dropped substantially over these years (Fig. 2). While socio-political factors may have been blamed for low export levels, it is likely that opportunistic under-reporting of exported logs also contributed to this downturn. Government employees, particularly those in the forest sector, are usually implicated in such high-profile bribery and money-laundering activities (See examples in [26]).

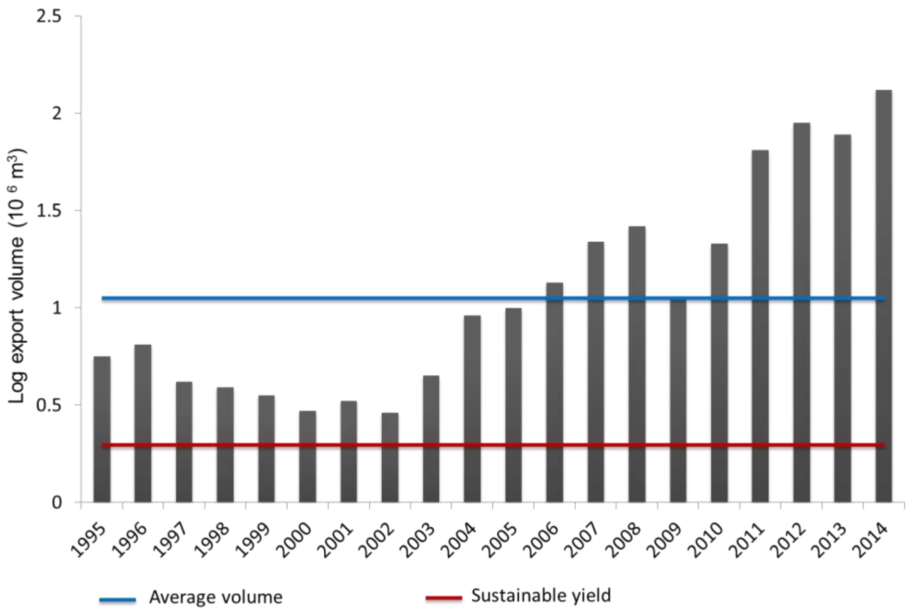

Fig. 2. Log export volume for the Solomon Islands between 1995 -2014. The rapid increase in logging licences issued during this period has resulted in a steep increase in logging activities in the country, with harvest quadrupling the sustainable yield.

3. Poor employment condition in the logging sector
When in operation, most logging companies employ their field workforces on a contract basis whereby employees are paid according to volume of wood harvested [K. Gideon 2013 pers.com]. Because salary rates are generally low and working benefits such as medical insurance and life-insurance policies, housing allowance, and risk allowance are almost non-existent, employees are obliged to maximize harvests to sustain their livelihoods [K. Gideon 2013 pers.com]. This tradeoff has contributed to high-intensity harvesting.

4. High Forest accessibility
Forests in the Solomon Islands are easily accessed due to the islands' geographical layout and land tenure system. Islands in the group are relatively small, with lower mean population density than the islands of New Guinea and Southeast Asia, and are in close proximity to each other (Fig. 3). This makes it more economical for logging companies to establish concurrent operations on multiple islands across the country than in larger countries in the tropical Asia-Pacific region. Land tenure in Solomon Islands is based on traditional arrangements whereby a large swath of land (usually extending inland from the coastline) is owned by a particular native tribe [32]. Logging concessions are usually demarcated within such tribal land, particularly in areas lacking human settlements [18, 32].

Where road access is required through non-concession areas, loggers offer cash payments to the primary landowners of the intended road-access area. In most instances this arrangement works in favour of the loggers, because opportunities to make money are sporadic and therefore welcomed by traditional landowners. This is particularly true as a cash economy rapidly replaces traditional non-cash practices [21].Having roads through non-concession forests creates avenues for both legal and illegal logging, as well as for other human encroachment [33].

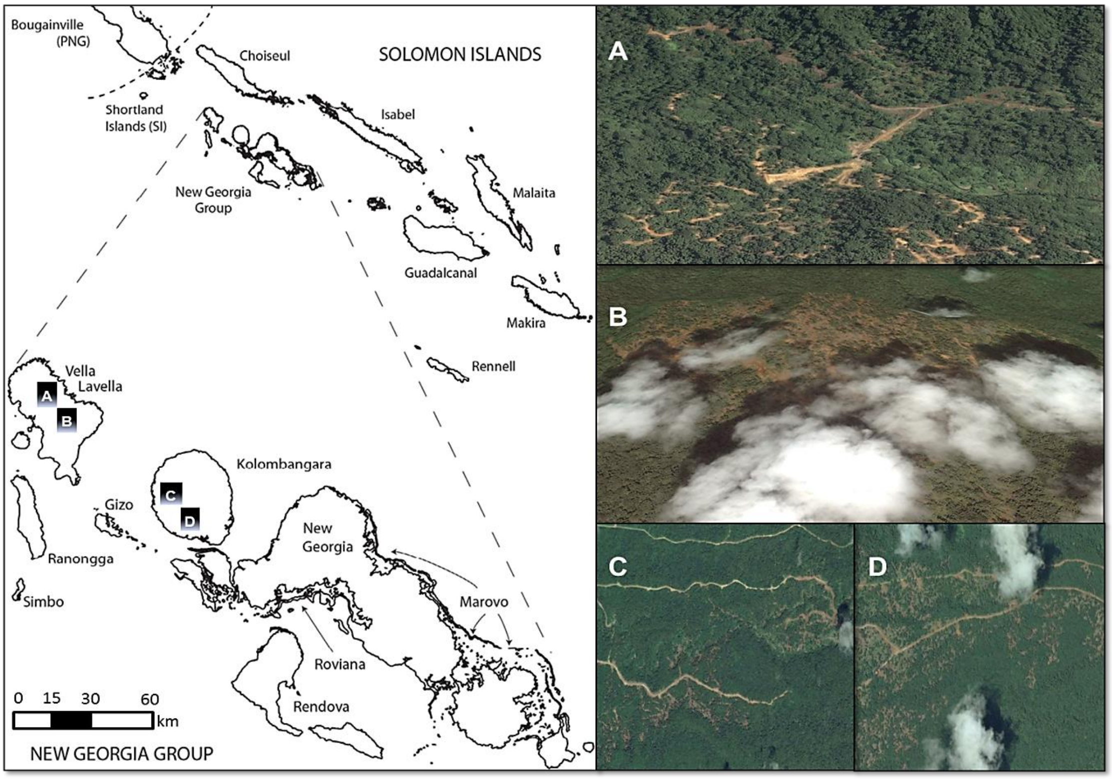

Fig. 3. Natural forests in the Solomon Islands have been excessively logged within the last two decades. Inserts A-D show recent excessively logged forests on Kolombangara and Vella Lavela within the New Georgia group. Such logging operations are rarely monitored due to lack of funds and trained human resources in the country.

5. Resource limitations for forest monitoring

Poor monitoring of logging activities in Solomon Islands has resulted in excessive logging subtly carried out over several decades (*e.g.,* Fig. 3 A-D). Forest authorities have insufficient funds and human resources to conduct effective monitoring [24]. Furthermore, remote areas are often difficult to access due to lack of transportation, and therefore are frequently neglected by authorities [34]. Yet these areas contain some of the largest timber stocks in the country [18, 35]. Resource owners may work alongside loggers by providing support to the logging operations, and their lack of knowledge of logging codes-of-practice may limit their ability to identify illegal practices.

6. Contention over landownership and logging benefits

The logging industry in Solomon Islands is undergoing a critical period as the last tracts of accessible unlogged forests in the country are being exploited [9]. Realizing that a plunge in the logging industry is inevitable, stakeholders are currently focusing on what remains of the once highly wooded forests. While the government and logging companies are ensuring that all remaining unlogged accessible forests are exploited, resource owners are also contesting for benefits. Nonetheless, unlike the recent past, when logging was a matter of disagreement among pro- and anti-logging factions within tribal communities, it is increasingly becoming a land-grabbing race [21], whereby who logs first becomes the winner of the modest benefits the loggers have to offer. Apparently, traditional landowners who have previously maintained sustainable forest use instead of industrial logging have realized that they are continuously fighting a losing battle against the logging industry and its inherent corruption [18, 31]. Therefore, they too have become facilitators of logging in order to reap benefits from what is left of their forests.

7. Paucity of information for policy development

In the last two decades, numerous logging licences were issued for concessions throughout the Solomon Islands [24, 26], causingthe near-complete depletion of unlogged forests, as well as prompting re-entry logging which is now increasingly common (Fig. 4) [36]. Logging companies are gradually diverting their focus to previously logged forests, where residual wood stocks are still profitable. Such practices inflict severe damage on the forest stand [5]. For example, re-entry harvesting in the Western and Isabel provinces in the Solomons have been extremely excessive, with cut-size limitation reaching as low as 15 cm DBH.

The impacts of logging on natural regeneration and biodiversity are still poorly understood in the Solomon Islands. Lack of such information makes it difficult to implement restoration and conservation efforts where needed [37]. In addition, there are no policies pertaining to re-entry logging in the country. This has prompted premature re-entry harvesting, most of which is unregulated and excessive [36]. Consequently, natural regeneration alone may not be adequate for full forest recovery. Active restoration may also be required [5, 38-39].

Active restoration in logged forests of the Solomon Islands

Although wet tropical forests in Southeast Asia demonstrate strong recovery potential in post-logging regeneration [7, 10], this may not be the case for the Solomon Islands. Forests throughout these islands are increasingly vulnerable to highly destructive logging practices [9]. Nearly all of the commercially viable forests in the country have been impacted by logging (Fig. 4). The commercial depletion of round logs in the Solomon Islands is likely to occur very soon [12, 24].

Highly degraded forests in the Solomons may not achieve full recovery by natural regeneration (*e.g.,* Fig. 3). In the 1960s and 1970s, tree planting projects were undertaken by the British Solomon Island Protectorate in order to restock highly degraded forests with commercial species [23], because the rate of forest-stock depletion apparently could not be compensated via natural regeneration alone

[40]. Preliminary results from a current study on Kolombagara Island, in the New Georgia group (Fig. 3), revealed that tree community composition differed significantly from the pre-logged state even after 50 years of post-logging regeneration, suggesting a slow recovery (E. Katovai, unpublished data).

Research findings from Southeast Asia may also have implications for forest restoration efforts in the Solomon Islands. However, it must be noted that variability in forest formation and ecological and biodiversity structure among regions may affect outcomes in different and unique ways [41 – 46]. It is therefore essential to determine the ecological factors that govern forest responses to logging in Solomon Islands. Furthermore, a comprehensive re-assessment is urgently needed to determine how much timber remains in the country's forest estates. This information is vital for making strategic decisions about the fate of forest estates and to determine precautionary and remedial measures to address forest crises in Solomon Islands.

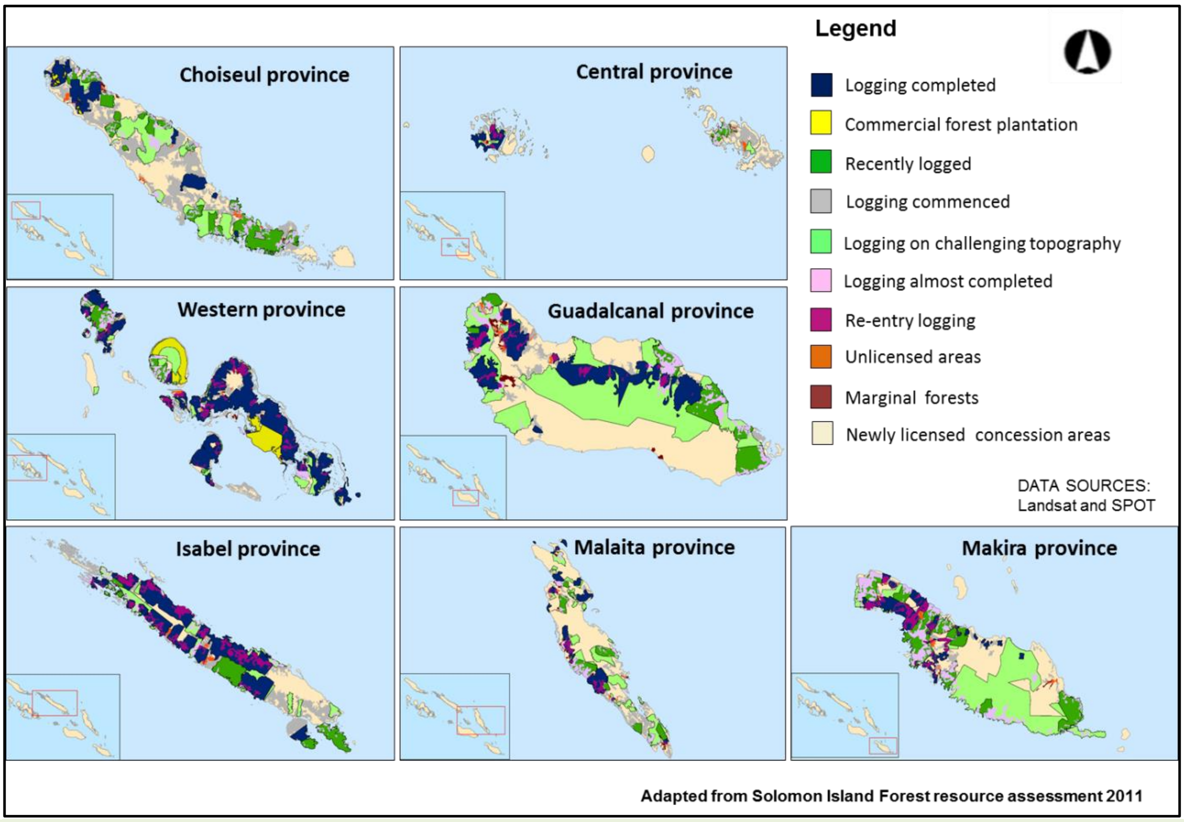

Fig. 4. The spatial extent of logging on accessible forests in the Solomon Islands. It is estimated that all accessible forests in the Solomon Islands will be logged by 2015.

Restoration alternatives for logged forests in Solomon Islands

Regeneration studies in Southeast Asia have urged active restoration of severely over-logged forests [47 – 50], and several of theri proposals have been implemented in that region. In cases where unaided recovery is not possible in the Solomon Islands, a number of restoration strategies have been proposed.

Enrichment planting

Enrichment planting involves the introduction of ecologically valuable pioneer species to degraded landscapes [51]. Though an expensive exercise, enrichment planting has proven successful in many instances (*e.g.,* 48 – 49, 51 – 54). These studies highlighted two distinct phases by which floral diversity can be restored through enrichment planting. The first phase includes planting a small number of light-demanding, short-lived nurse trees. These trees serve as pioneer species that overshade non-forest species such as grasses and other possible unwanted competitors. Such a process provides a microclimate conducive for the establishment of newly introduced or pre-existing secondary species that lie dormant, awaiting the right conditions for germination and growth [49, 55].

The second phase involves planting a large number of secondary species, thereby increasing the chance to generate the highest possible diversity in the climax stand. In situations where seed banks do not contain secondary species, this method ensures that the later-successional stages are reached. However, in this circumstance the climax stand would be mostly determined by artificially disseminated seedlings that may or may not resemble the pre-existing forest stand, depending on the selection of seed sources. Where seeds are collected near the disturbed landscape, local knowledge is important for selecting native species for re-seeding [56]. This may produce strong resemblances between old growth and recovering vegetation, and also ensure that the restored vegetation contains species of high cultural, economic, and ecological value to native communities, who depend on the forest for their livelihood [56].

Planting commercial tree species has proven to be an effective approach on very degraded and deforested landscapes [12, 57 – 58]. Studies have shown that monoculture tree plantations provide a favourable environment for restoration of native understory vegetation [58 – 61]. Tree plantations are also less expensive and less challenging to implement compared to mixed-species planting regimes [18, 51, 63, 67]. In the latter part of their growth and development, plantation trees often shade out light-demanding pioneer competitors such as lianas and woody shrubs, and allow the germination and establishment of late-successional species [64]. At this stage, the soil may have also accumulated nutrients from decomposed vegetation such as fallen branches and leaves, as well as decomposed biomass of the outgrown pioneer stand. Earlier studies have also shown that tree plantations attract a range of seed dispersers that aid soil seedbank recovery [60 – 61, 65].

Plantations are commonly established for economic gains. Large areas previously cleared for agriculture and cattle ranching are converted into commercial tree plantations [53]. The fate of such efforts depends on future management strategies for these restored landscapes. Regrettably, the worst-case scenario, where cyclic clear-cutting and replanting strategies have been used for many years, still predominates in many tropical regions [66]. It is still unclear how this process affects the regeneration ability of native vegetation in the tropics. However, repeated mechanical disturbances during log harvesting and extraction, and soil clearing during preparation for replanting, can cause further loss of soil seed banks.

A more recent approach, termed nucleation, involves planting selected tree species in strategic locations within heavily disturbed sites [67]. The planted trees develop into vegetation patches that attract seed dispersers, subsequently increasing seed rain into the disturbed landscape [58, 67]. This approach, however, does not work well for large-bodied dispersers such as forest-dwelling mammals, since they prefer to forage under continuous forests [58]. Nevertheless, nucleation is relatively inexpensive to implement and can be highly practical in large scale restoration efforts [67]. Although information on the impact of design and long-term viability of this approach is still lacking, the success of nucleation in an array of habitat types and species guilds seems possible [58, 67].

Direct seeding

In direct seeding, seeds are directly scattered throughout disturbed landscapes [68]. Seeding is usually undertaken at high densities (*e.g.,* 92,500 seeds per hectare [60]), and requires copious shade-tolerant species to increase chances of a full recovery [49]. Mature forest developing from direct seeding is a function of the competitive interaction between the seedlings in later succession [69]. Direct seeding can be used to initiate reforestation in open fields under appropriate conditions, but may be most useful to enhance diversity once tree cover is already established [49, 68]. This approach is not as versatile as enrichment tree planting, because eco-physiological conditions needed for initial germination are narrowly specific for most species.

Direct seeding with multiple native species has shown some success and great potential in the Solomon Islands (18, 70 – 72). However, there are also challenges. First, seed collection can be time-consuming and difficult on a broad scale. When phenological information on forest types is lacking , biased selection of seeds may limit genetic variability and increase the homogeneity of the regenerated stands [71]. Several studies have shown that shifting seeds from old-growth forests to disturbed landscapes can improve genetic variability in degraded landscapes [*e.g.,* 73-76]. However, the germination and establishment of native tree seeds may be generally poor, perhaps due to the sudden shift in microclimatic and soil conditions [72]. To overcome this challenge, much more information is needed on the germination and establishment ecology of individual species [70].

Artificial perches

Deforested landscapes in Southeast Asia have benefited significantly from seed rain brought in by birds lured to artificial perches (*e.g.,*78 – 81]. This is particularly true for small, deforested landscapes surrounded by forests. In degraded landscapes such as selectively logged forests, artificial perches are usually not as effective, because dispersers (mostly birds) have many natural perching sites to choose from, such as residual trees [82]. Studies have shown that birds prefer natural over artificial perches if both alternatives are available [80, 82 – 84]. Also, bird activity is mostly concentrated around the forest edge, decreasing with distance into cleared landscape despite the erection of artificial perches throughout the open landscape [82, 84].

Conservation concession model – A promising mechanism

We recognise that the previously mentioned efforts may only be successful if government policies on re-entry logging and forest restoration are implemented to boost investor confidence in such a cause [85]. It is equally important that landowning communities be an integral part of this initiative [21, 86-87]. Several models of natural resource management in Solomon Islands have proven successful within the last two decades [*e.g.,* 87 – 89]. The 'conservation concession' model has been highly effective [89]. Conservation concession allocates endowment funds to landowning communities in return for carefully outlined conservation outcomes [86, 89]. Such efforts have earned much community respect and ownership, harnessed a wealth of ethno-biological information needed to achieve conservation outcomes, and reduced labour costs through regular, voluntary community involvement [21, 32, 56, 87].

The Kolombangara Island Biodiversity Conservation Association (KIBCA), established in 2008, is a classic example of this model [89]. The endowment funds awarded to KIBCA are generally used to benefit its community through fee payments for school-aged children, establishing small, self-sustainable businesses, organizing life-skills workshops and training, building relevant community infra-structures (*e.g.,* schools and churches), and financing the operation of the association. We see potential in using such a model to initiate forest restoration efforts in Solomon Islands where required.

Summary and Conclusions

We describe the dynamics of selective logging in Solomon Islands and the potential need for aided restoration in the country. At the outset, we highlight the unsustainable practices of selective logging in tropical Asia-Pacific Islands and the regeneration potentials of these forests. Though studies in

Southeast Asia have revealed that natural regeneration alone can restore degraded forests to near pre-logging levels, we suggest that comparative research is needed in Pacific Island countries to verify such claims. This will provide critical information for implementing the measures required for effective restoration. For the Solomon Islands, research is immediately required as multiple re-entry logging practices continue to further degrade already-logged forests and reduce their regenerative potential. We also suggest several restoration alternatives tested in Southeast Asia that may be effectively implemented in the Solomons. Finally, we highlight community-based restoration concessions as a potential mechanism whereby savagely logged forests of the Solomon Islands can be restored.

Based on evidence discussed in this review, we conclude that the impact of logging on lowland forests of Solomon Islands have been disastrous and must be addressed immediately. However, without appropriate political, economic and social remedies to curtail the current dynamics of logging in the country, restoration efforts may not succeed.

Acknowledgments

This research was supported by the Australia-Pacific Science Foundation and an Australian Laureate Fellowship awarded to WFL. We thank the Forestry Department of the Solomon Islands for providing key data and logistical support.

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