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**Saving logged tropical forests: closing roads will bring
immediate benefits**

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18 There is growing recognition that selectively logged tropical forests are of high conservation
19 value (Gibson *et al.* 2011). In their recent editorial on this subject, Laurance & Edwards
20 (*Front Ecol Environ* 2014; **12**: 147) draw attention to the vulnerability of forests following
21 logging and propose a number of highly pertinent strategies to minimize subsequent
22 biodiversity loss. One of these, the closure of logging roads, warrants closer scrutiny. To date
23 it has been under-acknowledged in the context of selectively logged forests, but this single
24 action could pay immediate dividends to tropical biodiversity. To illustrate using Kalimantan,
25 Indonesian Borneo, we show that rates of forest loss during 2000-2012 were nearly two times
26 higher in areas where logging roads were present pre-2000 (Fig. 1a).

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28 Across the tropics, forestry authorities lease production forests to companies, for the harvest
29 of timber via selective logging. During the lease period, corporations are responsible for
30 management of their concessions, and other land-uses (e.g. agriculture) are typically
31 prohibited or heavily restricted. For companies invested in the long-term fate of the timber
32 through involvement in forest certification schemes, road closure after harvesting is
33 recommended in order to maintain forest cover (FSC 2010). Indeed, we find that rates of
34 forest loss across Kalimantan were higher in uncertified concessions compared to those that
35 were certified (Fig. 1b).

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37 Across Kalimantan, 25% of the land allocated for timber production in 2000 later had its
38 status changed for conversion to industrial plantation (Gaveau *et al.* 2013). This most
39 frequently happens under the “cut and run” scenario emphasised by Laurance & Edwards,
40 whereby logging concessions are abandoned after harvest and, consequently, face
41 exploitation for illegal timber extraction, agriculture and mining, all of which are facilitated
42 by the logging roads (Wilkie *et al.* 2000; Laurance *et al.* 2001; Meijaard *et al.* 2005). In such

43 instances, logging estates are classified as ‘degraded’, making the likelihood of the land being
44 re-allocated for conversion much greater.

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46 Logging concessions therefore follow one of two broad destinies: (1) companies ensure high
47 production for the next harvest through responsible management and restricted access; or (2)
48 timber corporations having little incentive to protect the forest, resulting in eventual land-use
49 change. Under these two scenarios, biodiversity follows much the same fate as the forest
50 (Fig. 2) (Edwards *et al.* 2014).

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52 Spatial determinants of tropical deforestation, other than roads and linear transport routes
53 (e.g. rivers, train lines), include additional factors associated with accessibility (e.g. slope,
54 topography, distance to settlements) and the suitability of the land for conversion to
55 alternative uses (Laurance *et al.* 2002; Gaveau *et al.* 2009). While the relationship between
56 deforestation, logging roads and certification highlighted here could thus potentially be
57 confounded by a number of additional variables, roads into tropical forests are a well-known
58 precursor to much more high-impact forms of disturbance. For example, in the Brazilian
59 Amazon, 95% of deforestation is within 5 km of roads (Barber *et al.* 2014).

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61 Given that more than 4 million km² of the world’s tropical forests are officially designated
62 for future timber production, it has never been more critical to consider the fate and
63 biodiversity value of logged forests. Road closure between harvests is fundamental, and can
64 be easily and inexpensively achieved by deconstructing bridges and installing physical
65 barriers (Applegate *et al.* 2004). However, ensuring roads stay closed requires investment,
66 monitoring and enforcement to prevent illegal behaviour. To incentivise the logging industry,
67 forestry authorities should lease concessions over multiple cutting cycles, thus placing more

68 responsibility on companies to safeguard the future timber stocks, even those that do not seek
69 certification. The ability of forestry authorities to achieve these moderate changes to
70 management and regulations may be constrained by local contexts, and could even require
71 governments to sanction timber corporations that do not adequately protect forest cover in
72 their concessions. In many forests, closing roads is an important step in protecting timber
73 stocks, and consequently, this action could make a significant contribution to protecting the
74 long-term sustainability of forestry, as well as biodiversity within managed tropical
75 landscapes.
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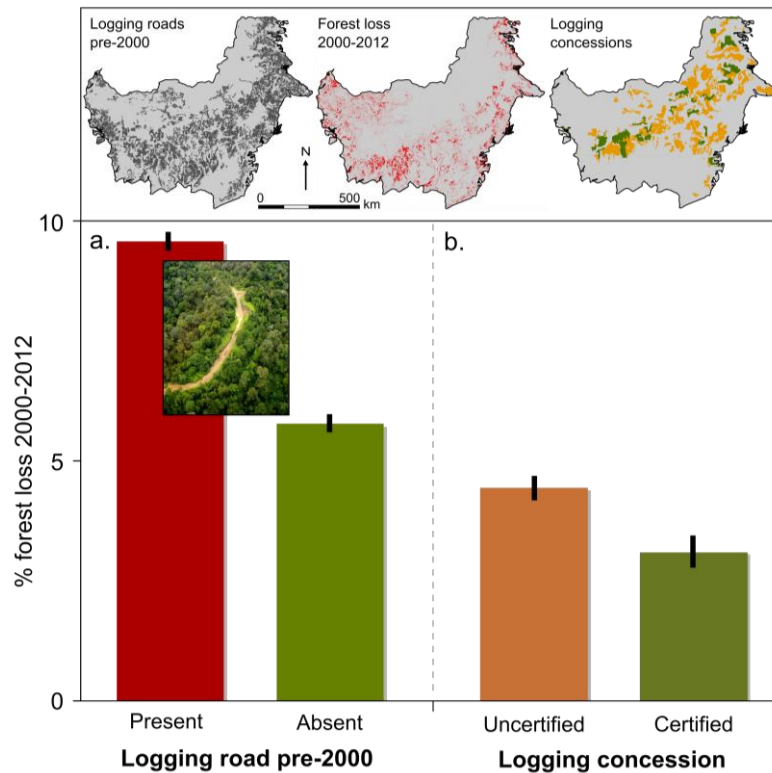
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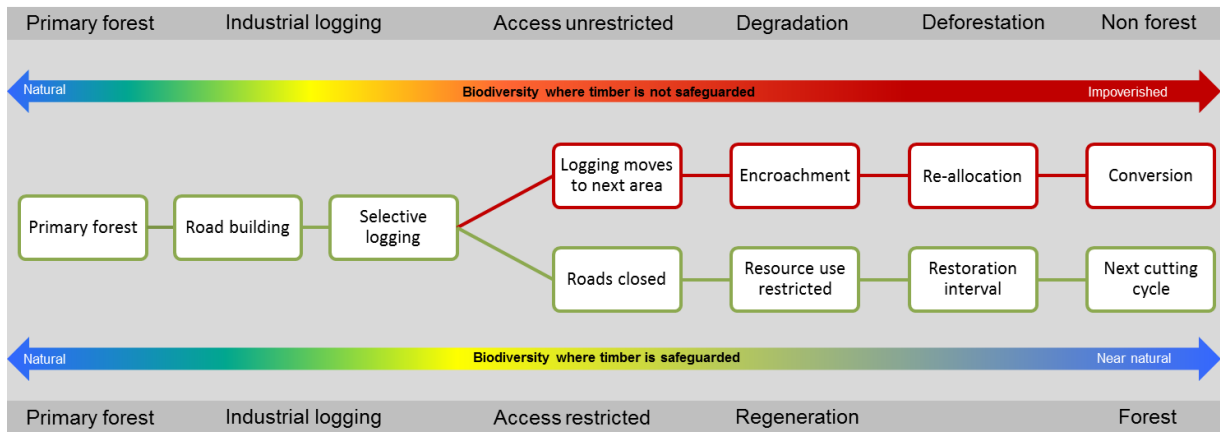
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Fig. 1. Mean (\pm SE) % forest loss in 10 x 10 km grid cells during 2000-2012: (A) where primary logging roads were present (red) or absent (green) pre-2000 - photo shows a typical primary logging road through Borneo's timber production forests; (B) in certified (green) and uncertified (orange) logging concessions. Maps show primary logging roads pre-2000, forest loss 2000-2012 and certified and uncertified logging concessions in Kalimantan. Concession data was acquired from the Ministry of Forestry of Indonesia. Forest loss was measured using high-resolution global maps of 21st century forest cover change (Hansen *et al.* 2013). Primary logging roads were mapped using LANDSAT images classified in Gaveau *et al.* (2014) and do not include secondary logging roads that infrequently open the canopy. Primary roads are typically unsurfaced and are designed for use by heavy machinery to extract and transport timber. To account for misclassification or possible regeneration, small patches of forest loss were first removed using the generalisation tool in ArcGIS. Strictly protected areas were excluded from the analysis and, to account for access provided by rivers, a 1 km river buffer was also excluded.



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138 Fig. 2. The consequences for biodiversity of two logging concession scenarios: (Top) forests

139 that are unmanaged with unrestricted access; and, (Bottom) forests that are managed,

140 including access restriction.