6.3 Lowland forest extent

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Preamble: This discussion is focussed on lowland *indigenous* forest extent and does not focus on exotic forest. It should also be noted that there is no universal definition of lowland: 100m, 200m and 400m are all used in the literature. It is difficult to provide ecological comment on the relationship of this attribute to ecological integrity (in QA1) if the IPBES definition is used. The definition is meaningless in a New Zealand terrestrial ecological context. For example, a wholly exotic plant community (such as ryegrass pasture) could have high ecological integrity if it could maintain its processes and community of organisms. I therefore base my response on the definition arrived at[1] in relevant discussions in the NBEA development process over the last few years. Key points are that ecological integrity cannot be site-based (as it is in the NPS-IB, where it was envisaged to apply only to a particular site) and it must include representation as well as attributes that relate to species occupancy (all species that should be present, are present) and native dominance (indigenous species predominate in composition, structure, and process).

State of knowledge of the "Lowland forest extent" attribute: Good / established but incomplete – general agreement, but limited data/studies

Section A—Attribute and method

A1. How does the attribute relate to ecological integrity or human health?

Survival of native vegetation has been uneven across New Zealand's landscape, with the most extensive tracts of native forest occurring in environments unsuited to intensive human land uses because of their cool temperatures, high rainfall, and/or steep terrain [1,2]. The greatest clearance occurred in warm, dry climates on lowland and mid-elevation landforms prone to fire and/or suited to agriculture such as the Waikato, Manawatū, and in the east from East Cape to Southland. Most of

[1] ecological integrity means the ability of the natural environment to support and maintain the following:
(a) representation: the occurrence and extent of ecosystems and indigenous species and their habitats; and
(b) composition: the natural diversity and abundance of indigenous species, habitats, and communities; and
(c) structure: the biotic and abiotic physical features of ecosystems; and
(d) functions: the ecological and physical functions and processes of ecosystems

NZ's lowland indigenous forests have now been cleared, and few extensive lowland forest tracts remain outside the wettest lowland environments of Westland and Fiordland (see evidence below).

Lowland forests are characterised by relative warmth, moisture and productivity [2,3], and therefore support different suites of species from those in higher, drier and lower-productivity environments. The biological character of lowland forests in the past would also have varied greatly around New Zealand in response to differences in environment. Loss of lowland forests has therefore led to poor representation (a key attribute of ecological integrity) of the indigenous biota and ecological processes that once occupied and occurred in New Zealand's forest ecosystems. In particular, the northern warmer and eastern drier lowland forests which once occurred in New Zealand are now extremely poorly represented.

Indigenous species that could potentially have occurred in the lowlands no longer occur there (loss of species occupancy). For example, loss of forest, and not predation, is the primary limiting factor for indigenous forest birds in most of lowland New Zealand [4], and the same applies for all other forest-specialist biotic groups.

Composition and structure of many remaining indigenous forests has been modified by logging, and/or altered by predators and weeds. In many cases species, processes and ecological functions have been lost, and/or displaced those that are different and non-indigenous. Native dominance of lowland ecosystems has therefore also decreased and in many environments has been lost entirely.

A2. What is the evidence of impact on (a) ecological integrity or (b) human health? What is the spatial extent and magnitude of degradation?

There is no universal definition of lowland, and Figure 1 below shows three possible definitions based on elevation (below 100m, below 200m and below 400m).

Spatial databases show that NZ has lost 90% of its pre-human indigenous forests below 100m elevation, 86% below 200m and 80% below 400m (Fig. 1). As the elevation of a chosen contour increases, the amount of 'lowland' forest remaining increases from 10% to 20% (Fig. 1), because the expanded lowland zone includes proportionally more land that has historically been less suitable for human habitation and exploitation.

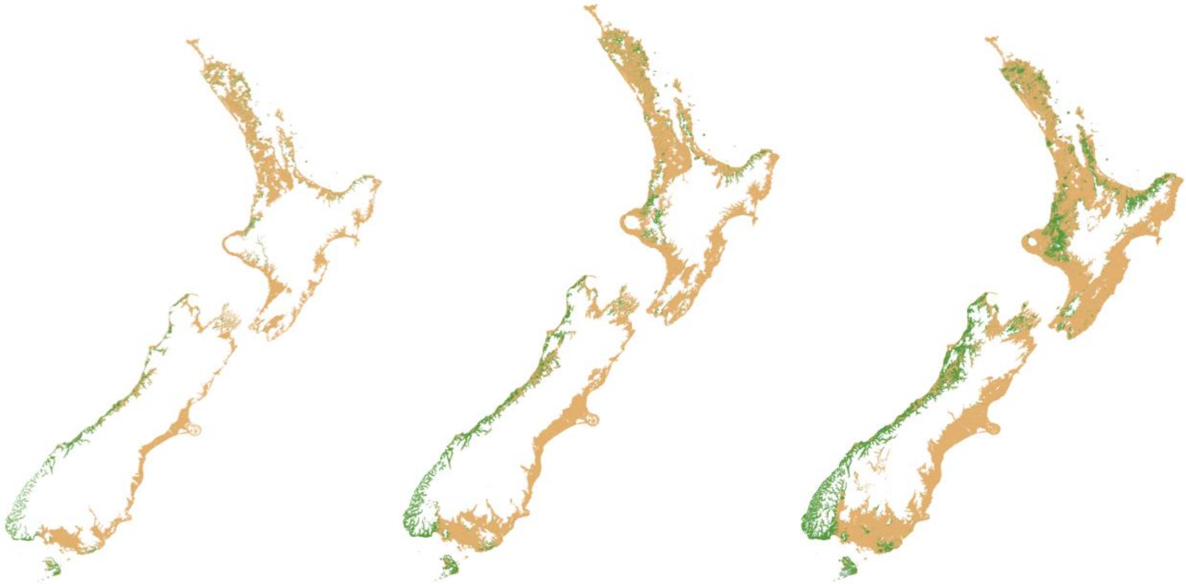

Figure 1. Three different extents of lowland areas defined by elevation (0-100m above sea level left, 0-200m centre, and 0-400m right). The maps show the extent of indigenous forest remaining (green, based on the Ecosat forest layer [5]) and those areas which were forested in prehuman times (assumed to be the extent of the 20 forest classes in the Potential Vegetation of New Zealand dataset [1]) and have now been cleared (brown).

Whichever contour is used to define lowland, most of New Zealand's lowland indigenous forest has been cleared and the majority of lowland forest remaining is in the west and south of the South Island, which are areas that have historically been environmentally unsuitable for habitation or exploitation by humans.

The 'right' contour cannot be chosen using ecological characteristics, because these vary greatly with latitude as well as elevation around New Zealand [3], and it is unlikely that a threshold in any forest ecological characteristic occurs at or near any particular contour.

This is illustrated by Table 1, which shows that the narrowest possible zone (defined by the 100m contour) has the highest proportions of the pure 'Podocarp forest' Ecosat class [5], the 'Unspecified Indigenous forest' class, and the 'Coastal forest' class. The representation of these three classes decrease as elevation increases and the zone increases in size, while the representation of 'Kauri forest', 'Beech forest', and three mixed beech-podocarp-broadleaved classes increase. All classes of Ecosat forest occur in lowland zones irrespective of the contour; it is simply the proportions that change.

Some considerations for choosing a lowland zone are:

- the breadth of ecological characteristics that the attribute is intended to capture, and
- whether the indicator should focus on the narrow elevation zone where the most loss has occurred and national representation of the ecosystems therein is lowest, or whether slightly better represented forests are also relevant.

Table 1. The composition (percentage of Ecosat vegetation classes) of the remaining indigenous forests in lowland zones defined by different lowland contours (100, 200 and 400 m above sea level).

	Lowland contour		
Ecosat vegetation class	**100 m**	**200 m**	**400 m**
Subalpine scrub	0.2	0.3	0.7
Coastal forest	0.6	0.4	0.2
Kauri forest	1.3	2.3	2.9
Podocarp forest	9.4	4.7	2.2
Podocarp-broadleaved forest	29.6	30.3	28.8
Beech forest	5.0	5.8	10.0
Broadleaved forest	3.7	5.8	6.6
Podocarp-broadleaved / Beech forest	13.6	17.3	19.8
Beech / Broadleaved forest	1.2	1.5	1.6
Beech / Podocarp-broadleaved forest	11.9	13.8	15.5
Unspecified Indigenous forest	23.6	17.8	11.6

Lowland indigenous forest extent is strongly linked to all components of ecological integrity. So declines in extent and fragmentation of these ecosystems will reduce ecological integrity. Declines the size and number of lowland forests directly reduces **representativeness** of indigenous-dominated vegetation. The composition of remaining forests is affected by losses of indigenous taxa, but also increased threats from weeds, pests and diseases from fragmentation itself, and proximity to other land uses. Similarly, the structure of lowland forests differs from intact or baseline forests because of edge effects (e.g. more wind, larger temperature fluctuations, reduced moisture) and increased disturbances such as grazing, selective harvesting of tree species, and invasion of weeds in the understory. All of these changes affect multiple ecological and ecosystem functions, which are rarely quantified (e.g., Didham et al. 2015).

A3. What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10 - 30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

There was a pulse of deforestation by fire following human arrival, and another when Europeans arrived and settled [6]. The easily exploitable resource ran out more recently.

Compared to historical clearance rates, there has not been a high rate of lowland primary forest clearance since the 1990s [7]. Nevertheless, some areas continue to be cleared in diverse environments, for example on private land on the South Island west coast, and in urban Auckland. Cumulatively, Dymond et al (2017) [8] estimated that about 10,500 ha of indigenous forest was cleared across all of NZ between 1996/97 and 2012/13 (15 years). This suggests that the status quo is for 7,000 to 8,000 ha of indigenous forest to be cleared nationally per decade. Dymond et al (2017) [8] do not provide an estimate of how much of the recent indigenous forest clearance has been of *lowland* indigenous forest, but this could be calculated given a defined ‘lowland extent’ spatial layer.

If New Zealand policy settings change to remove or weaken current legal protection for remaining lowland indigenous forest, it is reasonable to expect that indigenous lowland forest clearance will accelerate again. However, there likely to be only so much now that it would be economic or socially acceptable to clear, in the author's experience.

Forest stewardship certification (FSC) schemes theoretically help to incentivise protection for indigenous remnants embedded in exotic forest plantations, although the extent to which those schemes have protected indigenous remnants in practice is unclear, because outcomes are rarely measured in the author's experience. FSC protections are market-driven and would not necessarily be weakened if NZ policy or legislation changed.

There is now likely to be an increased rate of loss of extent of indigenous forest through more flooding, slips, and inundation, as climate change sets in [9,10]. For example, swathes of lowland forest are often removed by floods in South Westland – both along the river margins and at the river mouths as the estuaries switch back and forth. Recent changes in the lower Haast and Arawhata rivers in response to storm events have removed sizeable areas of primary forest, for example. Cyclone Ita blew down sizeable areas of west coast forest. Some of this loss would have occurred historically, and then regenerated again, but there may be a step change in scale now, along with a lower likelihood of eventual recovery of forest structure and composition in the changed context of predators, ungulates and weeds.

Mature indigenous lowland forests are centuries old and take at least many human generations to re-establish. Therefore loss of present extent is certainly irreversible within a human generation and given the current changed environmental context, is likely to be permanent.

A4-(i) What monitoring is currently done and how is it reported? (e.g., is there a standard, and how consistently is it used, who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

LCDB mapping [11] of indigenous forest and of broadleaved indigenous hardwoods is the only data on extent that is being collected as far as I know. That data collection has been funded as part of NZ's land cover data investment. Those investments have been ad hoc and subject to changes in science and technical funding, and therefore may not continue in future. Larger councils such as Auckland Council and Waikato Regional Council may be collecting their own information, but the author has no knowledge of any such initiatives. There is no baseline monitoring of the background frequency of extreme events and their ecological consequences for lowland forest extent as far as the author knows.

A4-(ii) Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

Lowland forest can typically be seen in remote-sensing (satellite and aerial) images and its extent is mapped from these. Therefore there is little to prevent or impede implementation. The principal requirement is that New Zealand agencies keep collect or purchase the relevant remote imagery and process it; and the trend is for this to be becoming cheaper and easier.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples).

If the resources for LCDB are to continue, most of the up-front costs would be covered and this attribute would not incur much additional cost. Additional costs would be in (ideally) online manual checking of each polygon identified as a loss or a gain, and the costs of extracting and curating the data into the indicator and report. An extent of lowland would need to be decided on, but once that decision is made the time required to create and clip the overlay is negligible.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

There are few examples of lowland forest extent being monitored by Iwi/Māori, but the forest condition and tree health are being monitored as part of research programmes such as Ngā Rākau Taketake (https://bioheritage.nz/about-us/nga-rakau-taketake/). Both Kauri dieback and myrtle rust diseases have prompted recent work on Mātauranga Māori approaches to tree condition and surveillance largely in lowland forests. More generally, cultural frameworks to monitoring, including biocultural approaches (Lyver et al. 2019), do not focus on a specific attribute or metric like lowland forest extent, but could include this as part of more integrated assessment of forest condition.

There are many examples of hapū/iwi monitoring the health of indigenous forests (ngahere) utilising indicators drawn from mātauranga Māori. See for example Lyver et al. (2017a, b) and McAllister et al. (2019)[23-25]).

A specific example is the development and implementation of the ngahere ora framework to understand the health of the forest by evaluating health state using the perspectives and values of mana whenua. Data are able to be gathered digitally, using Survey123, which is then fed into ArcGIS Pro, a platform that allows creation of maps. This enables hapū/iwi to monitor the extent of forests as well as specific health indicators. (See Reihana et al. 2024 [26]).

A6. Are there known correlations or relationships between this attribute and other attribute(s), and what are the nature of these relationships?

There are likely to be similarities between mapping lowland forest extent and change and mapping wetland extent and change. Decreases in the extent of lowland forest will be strongly related to decreases in structural and functional connectivity (see landscape connectivity template). Canopy tree dieback may increase and indigenous plant dominance could decrease with lower lowland forest extent because indigenous tree species in these species are likely more exposed to weeds, pathogens or pests and disturbance in forest fragments (e.g., Didham et al. 2015). Lowland forest is usually easier to identify in remote images than wetland, but there may be efficiencies in doing both together (e.g., in the purchase and pre-processing of underlying imagery).

Part B—Current state and allocation options

B1. What is the current state of the attribute?

The current state of knowledge is good because LCDB [11] is available and has been updated quite recently [12]. Currently the total land area under lowland forest is far lower than before human settlement, but the magnitude of decreases varies widely among different forest vegetation classes (Table 1). Less than 2% of coastal and lowland beech/broadleaved forests remain, whereas about 30% of lowland podocarp-broadleaved forests remain (mostly due to relatively large remnant forest areas occurring in Westland). Across nearly all forest types, extent decreases at lower elevations (i.e., extent is smallest closest to the coast). However, as noted above, a 'lowland' definition would be needed before a lowland indigenous forest layer could be created from LCDB.

There are some matters that may need to be explored with land cover mapping experts. For example, there may be a question of whether to include 'broadleaved indigenous hardwoods' within 'indigenous forest'. The distinction between 'broadleaved indigenous hardwoods' with 'indigenous forest' in LCDB is not quantitative[1], and in practice decisions are made subjectively and manually by an operator on the day. And as LCDB is not produced totally *de novo* each time, there is probably a legacy bias (i.e., an operator may stick with a previous assignment, rather than make a change). Those administering the indicator may decide to accept those subjective and manual assignments and include one or both.

A related question is when a recovering (lowland) forest becomes an 'indigenous forest' rather than seral woody vegetation (such as broadleaved indigenous hardwoods), or (say) an induced wetland such as a pakihi. Again, those decisions are usually made subjectively and manually by an operator.

Consequently, quantitative analysis of changes in area between assigned classes may not yield reliable and reproduceable results.

B2. Are there known natural reference states described for New Zealand that could inform management or allocation options?

Pre-human cover in the Potential Vegetation of New Zealand dataset [1] is the most suitable available dataset to use as a baseline for extent. Unlike some classifications [e.g., 12] it is objective and derived from reliable data [2], and the data and the assumptions used to construct it can be revisited in future if necessary. The 25 classes of the Potential Vegetation of New Zealand can be cut down to the extent of the 20 potential *forest* classes in that layer, omitting duneland, wetland, and other non-forest classes. This was the method followed to construct Fig. 1 (above) and as the basis for determining the present extent of indigenous lowland forests remaining.

Accurate and objective estimates of extent of lowland forest from the times of Māori or European settlement are lacking (to the best of the author's knowledge).

B3. Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

There are numerous papers in the international literature which discuss lowland forest extent and loss. With respect to defining 'lowland', a non-exhaustive search for 'which countries report on lowland forest extent?' revealed that 200 and 300m contours have been used [13, 14]. In Ecosat forests Shepherd et al. (2005) [5] distinguished classes of forest based on spectral signature (e.g.,

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[1] Indigenous forest is defined as 'vegetation dominated by indigenous tall forest canopy species'.
While Broadleaved indigenous hardwoods are 'Typically found in high rainfall areas associated with Low Producing Exotic Grassland in hill country throughout New Zealand. However. the class also includes low-growing, coastal broadleaved forest. Characteristic is the presence of a mix of broad-leaved, generally seral hardwood species, such as wineberry (*Aristotelia serrata*), mahoe (*Melicytus ramiflorus*), *Pseudopanax* spp., *Pittosporum* spp., *Fuchsia* spp., ngaio (*Myoporum laetum*), and titoki (*Alectryon excelsus*), together with tutu (*Coriaria* spp.) and tree ferns. The presence of this class usually indicates an advanced successional stage back to indigenous forest. Canopy height ranges from 3 - 10m.

beech forests, kauri forests, various types of mixed forest). Those classes could potentially be reported on separately.

For forest extent, there are no quantitatively-defined thresholds based on data for habitat size, biodiversity or structure established within New Zealand. However, semi-quantitative ranks or qualitative goals or aspirations have been developed, for example;

- Setting a long-term restoration target of at least 15% cover over 100 years (Rout et al. 2021);
- The Threatened Ecosystem Classification (Walker et al. 2015) generated six categories based on indigenous vegetation extent (% remaining) and protection from the most highly threatened (Category 1: <10% indigenous cover remaining) to the least threatened (Category 6: >30% remaining and >20% protected);
- The NPS-IB requires that urban areas must have a target of at least 10 per cent indigenous vegetation, and more generally, no further loss of biodiversity or Significant Natural Areas.
- International standards often apply a 30% remaining extent goal for protection (e.g., The Kunming-Montreal Global Framework for Biodiversity Target 3: "Ensure that at least 30 per cent globally of land areas and of sea areas, especially areas of particular importance for biodiversity and its contributions to people, are conserved…").

There may be other relevant precedents and existing practice internationally.

B4. Are there any known thresholds or tipping points that relate to specific effects on ecological integrity or human health?

There are no reliable known thresholds or tipping points to the authors' knowledge. However, it is likely that multiple important thresholds for ecological integrity have already been exceeded in most parts of lowland New Zealand. The exceptions are clearly the largely still forested (but narrow) coast of Fiordland and some lowland parts of the South Island west coast, where forests is still continuous across natural environmental gradients.

There has been no objective test of the applicability to New Zealand of the classic 30% tipping point for forest birds and mammals derived by Andren (1994) [14] in the northern hemisphere. In New Zealand, there are likely to be different tipping points and thresholds for different ecological components (e.g., for different biotic groups, habitat generalists vs specialists) [e.g., 15] and processes and functions (such as regeneration, or provision of breeding or feeding habitat), and those tipping points will also depend on ecological context [16].

B5. Are there lag times and legacy effects? What are the nature of these and how do they impact state and trend assessment? Furthermore, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

It is likely that there will be many long lag times and legacy effects. For example, mature indigenous forests are old and therefore take centuries to re-establish, if they ever do given changed ecological contexts [17]. Deforested areas can undergo long lasting or permanent soil changes, and rates and patterns of sedimentation can change for decades or permanently. 'Priority effects' of weeds that invade while the sites have little or no vegetation cover [18, 19], and invasive ungulates [21], can have profound effects on long term trajectories. Seed sources are often missing or inadequate in cleared landscapes [22], along with the means to get propagules back into seral vegetation (e.g., key disperser species may be absent, or new ones may introduce unwanted propagules). Extinction debt (i.e. progressive loss of species which initially survived in remaining fragments) is likely to occur in lower forests, but has not been assessed to date. These lags and legacies will usually be so protracted that they are unlikely to affect state and trend assessment over the short-term, but can lead to ongoing declines in biodiversity despite protection or management of current lowland forests.

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

Although we cannot comment directly on māturanga Māori, we do provide suggestions from our experience that there should be condition or states of lowland forest extent or condition described from a te ao Māori perspective. More work is required here to understand place-based goals or aspirations for indigenous forests (e.g., [23]). As noted in A5, there are many examples of mana whenua utilising indicators that are derived from mātauranga-ā-hapū and mātauranga-ā-iwi to measure ngahere health. These indicators are based on knowledge within a local context. See for example [26]. See also the development of a forest health monitoring system with Tūhoe Tuawhenua utilising a Likert scale scoring system where 25 priority indicators were used to form the basis of a field survey approach to monitor forest health [24].

Part C—Management levers and context

C1. What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

The main 'stressors' on lowland forest extent through history have been a lack of conservation and environmental legislation and policy to protect lowland forests, or the non-enforcement of that legislation and policy where it did or does now exist. Aside from legal protect, declines in lowland forest extent are closely linked to multiple stresses and other attributes including:

- Historical, and in some regions, ongoing habitat fragmentation increases loss of biodiversity because of habitat size and loss of connectivity (see details in landscape connectivity attribute).
- Close proximity to more intensive land use increases impacts of pests, weeds and diseases, disturbance from wind, fire or grazing which can ultimately drive declines in biodiversity (see indigenous plant dominance and tree canopy dieback attributes).
- In many lowland forests, there are additional historical pressures from selective harvest of podocarps.

Many of these environmental stressors are well understood. Progressive increases in some drivers like extreme weather events under climate change and increasing number and abundance of environmental weeds could lead to further, cumulative, loss of extent [8,9].

C2. Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

C2-(i). Local government driven

C2-(ii). Central government driven

C2-(iii). Iwi/hapū driven

C2-(iv). NGO, community driven

Central and local government, iwi/hapū-driven, NGO and private and community driven interventions all apply, in the form of regulations and/or rāhui, and these vary widely across New Zealand depending on district and regional plans, administering authority and land status among other factors.

C2-(v). Internationally driven

It is not clear whether internationally-driven commitments drive local responses: the effects of those commitments and interventions are often indirect and New Zealand does not have experimental control areas to understand the likely trajectories in their absence. For example, it is unclear whether World Heritage status has translated into less active deforestation in South Westland, or whether changes in pace are due to economic or other factors such as social licence [18].

There has been no change in lowland forest extent in response to KunmingMontreal Global Framework for Biodiversity Target 3 as far as the author is aware.

Part D—Impact analysis

D1. What would be the environmental/human health impacts of not managing this attribute?

Assuming that not managing this attribute would result in further lowland forest loss, impacts would include further loss of indigenous plant and animal communities and species and the processes that sustain them, loss of stored carbon in soils and vegetation, changes in hydrology, changes in albedo, loss of flood protection. While beyond this author's expertise, indigenous forests are often of special importance to Māori, and there are spiritual, cultural, environmental and economic aspects to this.

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

Loss of carbon stored in the forests and their soils is likely to add to New Zealand's emissions, and any new land use replacing the forest is likely to be a net emitter of carbon. Those effects could be quantified. There is likely to be locally and/or regionally increased sedimentation and potentially also impacts of slash from deforestation, which may have impacts on agriculture and fisheries. Work could be done to clarify and quantify some impacts; for example, mapping could be used to determine whether areas under indigenous forest eroded and slipped less than exotic forests in cyclones, and research and modelling could quantify relative impacts on industries, businesses, and people.

Allowing indigenous lowland forest to be felled is unlikely to help the brand that export industries and tourism industries rely on. At a smaller scale there may be impacts on community wellbeing, recreation, and economic opportunities (e.g., local tourism) at multiple timescales (short-term to permanent).

This area would benefit from further exploration by economists.

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

As noted above:

"There is now likely to be an increased rate of loss of extent of indigenous forest through more flooding, slips, and inundation as climate change sets in (9,10]. For example, swathes of lowland forest are often removed by floods in South Westland – both along the river margins and at the river mouths as the estuaries switch back and forth. Recent changes in the lower Haast and Arawhata rivers have removed primary forest, for example. Cyclone Ita blew down sizeable areas of west coast forest. Some of this loss would have occurred historically, and then regenerated again, but there may be a step change in scale now, with lower likelihood of eventual recovery."

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