7.3 Soil nitrogen and phosphorus

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Preamble: There are multiple ways to measure soil nitrogen (N) and phosphorus (P) individually, including:

- Total P concentrations in soils.
- Olsen P – a measure of plant available P in soil [1], commonly used as an indicator of soil fertility and of the risk of excess phosphorus loss to the wider environment [2]. Olsen P can be measured gravimetrically or volumetrically, with these methods producing different values, although it is possible to convert between them if the volume weight or bulk density of the soil is known [3]. The gravimetric method is specified for State of the Environment (SOE) reporting [40] while the volumetric method is predominantly used for fertiliser recommendations.
- Anion sorption capacity/P retention – an inherent soil property that measures the ability of a soil to bind P in the soil matrix. This measure can inform soil characterisation and inherent risk of P loss from soils. Irrigation with high P-loading has been shown to decrease the anion sorption capacity of soils over time, leading to increased risk of P loss [4].
- Alternative estimates of plant available P, based on different extraction methods are also available e.g., Melich P, Bray P [5].
- Several less common measures of soil P include using fractionation methods to identify organic and inorganic forms of soil P to inform the mechanisms controlling the plant availability of soil P over time [5], spectroscopy methods (e.g., NMR, XAS, NanoSIM) that identify P concentrations and bonding forms, and novel methods to trace soil P reactions (e.g., 33P isotope dilution, zymography, DGT) [6].
- Total N concentrations in soils.
- C:N ratio – this measure can indicate whether there are potential N limitations to plant growth and has therefore been used to indicate mineralisation rates of organic matter in soils [7]. This measure provides information about the nature of the biological communities in soils – soils with higher C:N ratios have more fungal-dominated communities [8]. Other nutrients are also linked to SOC cycling, including P and S,

therefore nutrient stoichiometry of soil organic matter may be appropriate to use if considering organic matter cycling.

- Anaerobically mineralisable N (AMN) has been used as a measure of the nitrogen available to plants over the course of a growing season and correlates well with microbial biomass [7,8].
- Hot water extractable N (HWEN) is suggested as a more robust, replacement measure for AMN, measuring biological activity in soils [9,10,11].
- Hot water extractable carbon (HWEC), like HWEN has been proposed as a replacement for AMN in regional soil quality monitoring, also used as a measure of biological activity in soils [12,13].
- Mineral N, comprised of nitrate and ammonium forms of nitrogen in soils, measures the nitrogen available to plants and can be used as a measure of soil fertility.
- Quick N – a measure developed to help with fertiliser decisions, that estimates the nitrate available in soils for plant uptake.
- Nitrous oxide emission losses measure the loss of excess N as a greenhouse gas from soils to the atmosphere.

State of knowledge of 'Soil nitrogen (N) and phosphorus (P)' attribute: Good / established but incomplete (movement to and impact on waterways), and Medium / unresolved (impact on ecological integrity on soil)

There are a plethora of studies that provide information on the concentrations of P (typically as Olsen P) and N (various measures), primarily in agricultural soils (specifically, see sections A3 and B1). These studies most often assess the state, or relationship to agricultural production of pasture or plant crops, or to inform fertiliser requirements. There are few studies that assess the response of soil biota to P or N additions – with the response of the microbial community most frequently assessed. Studies that provide soil N and P under indigenous vegetation have also been undertaken and most often provide an assessment of state (noting that work on chronosequences has assessed nutrient cycling, ecosystem development and retrogression), rather than assessing impact of changes or additions over time.

However, the primary concern about soil N and P is in agricultural areas and relates to impacts on aquatic systems, in particular freshwater systems. There is considerable knowledge about the factors influencing loss of P and N from soil to water, which is strongly influenced by land management practices. Movement of N and P to waterways requires that there is a transportation pathway of N and P from soil to water, and that there is a lack of attenuation processes along this pathway and is exacerbated by the presence of N and P that is surplus to plant requirements. There is also considerable knowledge of the effects of excess soil P and N on aquatic systems.

Part A—Attribute and method

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

Ecological integrity. N and P are essential elements for the growth and functioning of all soil organisms, including plants. Beyond this critical role, P additions to soils affect soil microbes' (bacteria and fungi) population composition and function. Strong correlations were identified between relative abundances of individual soil taxa and concentrations of Olsen P [14]. Prolonged soil P additions can lead to microbial growth becoming C and N limited, in the absence of additions of these elements [15], and decoupling of the interactions between plants and soil organisms, resulting in plant reliance of fertiliser P rather than on biological mineralisation of P [16]. Arbuscular mycorrhizal fungi functioning is suppressed by excess P can negatively affect the productivity and temporal stability of plant communities [17].

The primary concern associated with elevated P in soils is surface run-off and movement into surface waters, negatively affecting freshwater quality and aquatic ecosystems [18]. This loss to surface water occurs when nutrients surplus to plant requirements are present in the soil, there is a transport pathway from soil to surface water, and there is a lack of sufficient attenuation processes along this transport pathway to decrease the P (and N) lost [19]. These factors can be influenced by land use and management. Excess P and N can also leach into deeper soil horizons, and may enter groundwater, negatively affecting groundwater quality [20,21]. Leaching of P to groundwater has been observed in soils under intensive land use receiving P additions, and is more likely in soils that support rapid transport of P, i.e., soils that are sandy, stony, shallow, or recent with low anion sorption capacity [20].

Addition of N to soils through fertiliser, cow urine, and effluent applications also affects microbial community function. Fertiliser N additions can lead to lower levels of biological N fixation [22]. Excess soil N further negatively affects ecological integrity by resulting in leaching of nitrate to groundwater which negatively affects groundwater quality [23,24], runoff of N to surface water [25], and emissions of nitrous oxide, a greenhouse gas, to the atmosphere [26].

Human health. Effects on human health arise indirectly through contamination of surface water with excess soil nutrients resulting in the growth of harmful algae e.g., cyanobacteria. If groundwater sources used for drinking water become sufficiently polluted to exceed drinking water standards for nitrate and nitrite, there is a risk to human health through consumption of this water [27,28,29]. There are no human health effects directly associated with elevated soil P and N.

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

The impact of P and N additions to soil on the ecological integrity of soil is largely unknown. A handful of studies have addressed the relationship between soil P and N and soil biology, primarily bacteria and fungi composition and function (Section A1). One study assessed the impacts of long-term P and N additions on soil biology, namely bacteria, fungi and earthworms [30], finding prolonged additions of both P and N decreased fungal biomass, N additions decreased microbial biomass, and higher earthworm abundance was associated with increasing P.

The evidence of impact of P and N on the ecological integrity of freshwater is strong: Studies have established the management factors and transport pathways involved in the loss of soil P and N to surface and groundwater [2,18,20,31], and have demonstrated evidence of this occurring in New Zealand [21,23]. Specifically, where nutrient additions (including fertiliser, effluent and wate-water applications) exceed plant requirements, and there is a transport pathway with limited attenuation of nutrients, the risk of negative impact on surface and groundwater quality increases due to the potential for transfer of soil P and N to drainage and to direct discharge to surface waters [19,21,32].

The extent and magnitude of degradation of waterways due to excess soil P and N varies by land use, soil type, catchment characteristics, topography, and farm management practices. Losses are not uniform or nationally consistent, with some intensive land uses are more prone to excess nutrients in soils due to larger quantities of fertiliser used or effluent and/or waste-water applied to soils, e.g., dairy farming [23]. Losses from critical source areas on farms and from soils with low anion sorption capacity and/or macropore flow contribute disproportionally to total nutrient losses, and can be influenced by farm management practices [33,34].

N-additions to soil also impact on greenhouse-gas emissions as 94% of New Zealand's N_2O emissions are from agriculture with N_2O emissions from N fertiliser use making up approximately 3.9% of agricultural emissions [35].

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 are limited studies that assess the change in soil P concentrations over time, and even fewer studies assessing the change in soil N over time. The most extensive study assessing P concentration over time analysed ~450,000 samples collected over 2001-2015 and processed by commercial laboratories [36]. This study found a national mean rate of increase in the median concentration of Olsen P in soils in different regions by land use and soil order group combinations of 1.2% [36]. Median concentrations varied from 9 to 52 mg/L in the different groups. Across the 124 combinations, there were 32 significant trends – both increases and decreases – over this time period. In terms of specific land uses, Olsen P in soils under drystock and cropping sites increased between 1996-2018 while total N decreased in cropping and indigenous vegetation soils over this time period [37,38]. Analysis of data from the Greater Wellington region over 2000-2018 showed statistically significant increases in Olsen P concentrations in cropping systems and total N concentrations in drystock systems [39].

The pace or trajectory of change in the future 10-30 years is unknown, and depends on the extent to which known management practices are adopted e.g., ensuring application of fertilisers is sufficient and not excessive for agricultural crop-growth. Elevated soil P and N is reversible, where ongoing inputs are reduced or stopped and plant growth uses the available P and N. Predicted median timeframes to decrease Olsen P in soils with elevated concentrations across New Zealand to a water-extractable P concentration proposed as an environmental target of 0.02 mg/L has been assessed as within a year for most soils, while some land uses are predicted to take up to 11.8 years [36]. However, as some environmental targets are more conservative than the one used in the above prediction, timeframes for reductions to actual targets may be longer.

The pace and trajectory of change of N and P in aquatic systems is beyond the scope of consideration in this attribute.

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?

Most regional councils in New Zealand monitor some measure of soil nutrients under their soil quality monitoring programmes for SOE reporting. Olsen P, total N and AMN have been three of the seven key soil quality indicators since the implementation of SOE monitoring in the early 2000s. More recently, HWEC has been more widely monitored since it has been proposed as a replacement for AMN [9,10,13]. The NEMS for soil quality and trace elements [40] specifies a standard for sampling analysis of soils for Olsen P, total N and AMN. Data are usually compared to provisional target values for these soil quality indicators [41]. Long-term field trials at Winchmore and Ballantrae have also assessed and reported soil P (as Olsen P) and N (Ballantrae only, as mineralisable N and C:N ratio) under grazed grassland in multiple reports and journal papers [30,42,43].

Soil P and N, generally as Olsen P and mineral N, are also measured in relation to crop requirements to inform fertiliser requirements by farmers. The Fertiliser Association of New Zealand has produced multiple guides for this with agronomic targets for different crops and production systems [44].

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

For all direct soil measures, there is a need to access privately owned land to collect repeat samples for monitoring of this attribute. Landowners may be more, or less, willing to provide access to land for sampling and to have data from their land used for regulatory informing purposes.

Indirect measures of this attribute, i.e., measures that indicate cumulative losses from soil such as total P and DRP in surface water, nitrate in groundwater and nitrous oxide emissions to the atmosphere are less straightforward to attribute to a specific source or location. However, the general health over time of receiving waters can be measured and this may require access to privately owned land to access rivers and lakes to collect repeat samples.

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).

Variables estimates provided by Regional Council scientists to MfE:

- $10,000 per year estimated by Marlborough Regional Council, broken down as: Chemical laboratory analyses of which Olsen P, total N and AMN are included, for ~20 sites/ soil samples. Two people sampling eight full time days per year.
- $85,000 total cost per year (pers comm Waikato Regional Council), broken down as follows: ~$1000 per sample/site for all seven basic soil quality indicators (including Olsen P, total N and AMN). For approximately 30 sites, one scientist spends approximately one third of their time on soil quality monitoring.
- $80-100,000 per year (pers comm Horizons Regional Council), for monitoring of the seven soil quality indicators, not including staff training and farmer outreach.
- $250,000 per year monitoring costs plus Regional Council soil scientists' time (unspecified, 5 staff in team) (pers comm Environment Canterbury).

Various measures of soil P and N are available from commercial laboratories, often as part of a suite of different tests e.g., Basic soil profile analysis (includes Olsen P), organic matter suite (includes Total N), with costs ranging from $27 to $140.

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

Although N and P monitoring by representatives of iwi/hapū/rūnanga may be uncommon, measurement of P and N via standard techniques is common in Māori agribusiness. Perhaps the question here is whether iwi/hapū/rūnanga are using techniques other than standard Olsen P measures to measure the nutrient profiles of soils? We are not aware of any mātauranga Māori-led measures of N and P specifically, but emphasise that Te Ao Māori measures of soil health take a holistic approach (a measure of the overall mauri of the soil ecosystem).

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

Soil attributes –

- Bacteria composition: There are known nutrient changes with composition, however the specific and defined relationships are not yet fully described.
- Soil C: Through the C:N ratio of soils. Lower C:N ratios with high total N are associated with increased losses of N [50].
- Soil contaminants: Trace element contaminants including Cd, F and U can originate in phosphate fertilisers. As such, applications of phosphate fertilisers can lead to accumulation of these trace elements in soils [51,52]
- Surface erosion/runoff (and other erosion related attributes): Soil P is often lost through erosion and runoff, as it adheres to soil particles. Therefore, erosion and runoff of soil to surface water can also result in loss of P to surface water.
- Soil compaction: Runoff of P and N are more likely from compacted soils (indicated by low macroporosity) [53]. Compaction reduces soil porosity, which can result in runoff that can contain unattenuated P and N due to the soil's reduced ability to infiltrate and store water [54,55].
- Soil water storage, capacity and fluxes: As noted in the point above, when the water storage capacity of soil is reduced due to human activities, runoff and leaching of soil P and N are increased.

Freshwater attributes –

- Multiple National Policy Statement for Freshwater Management (NPS-FM) attributes can be influenced by the movement of soil P and N into freshwater including N, P, plants and algae (specifically phytoplankton and periphyton, as trophic state attributes), and cyanobacteria [56].
- Groundwater nitrates: Groundwater nitrates are a direct result of N losses from soils, where there are excessive N inputs, e.g., fertiliser application, livestock (urine), effluent or wastewater application

- Riparian margin establishment/protection: This can reduce the loss of P and N to surface water from surrounding agricultural land [57,58].

Estuaries and coastal waters –

- Nutrients in water (trophic state and toxicity): Nutrients P and N in water, causing changes to trophic state and toxicity risks, result from P and N losses from surrounding soils.
- Cyanobacteria in water: Cyanobacteria blooms are caused by excess nutrients in water, which can result from P and N losses from surrounding agricultural soils.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

Olsen P and total N are measured for SOE and were last reported at a national scale in *Our Land 2021* [38]. Recently, *Our Land 2024* was released however soil N and P were not updated in this report. Data in *Our Land 2021* includes data up to 2018. Therefore at a national scale, we have some understanding of the state of this attribute, however, the representativeness of the current SOE monitoring framework for providing a national assessment has not been determined. Olsen P status of soils varies depending largely on land use. *Our Land 2021* reports that 61% of sites under both cropping and dairy, 46% of sites under orchard/vineyards, and 30% of monitored dry stock sites exceeded targets. As detailed in A3 above, Olsen P has increased in soils over the past ~30 years. Total N concentrations in soils monitored between 2014-2018 were within the target range for more than 72% of monitored dairy, drystock and forestry sites [38]. Cropping and orchard/vineyards sites do not currently have target ranges for total N to compare data to due to the variations in N requirements of different crops. Despite the majority of dairy, drystock and forestry sites being within total N targets, between 2016-2020, 69% of New Zealand's river length had modelled N concentrations indicating risk of environmental impairment compared to reference conditions [59].

Extensive additional information on the state of this attribute (both N and P) will be held by fertiliser companies or farm consultants as a result of soil-testing to inform fertiliser requirements. The most likely measures here are Olsen P and some measure of plant available N – e.g., mineral N or quick N.

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

SOE soil quality monitoring of Olsen P, total N and AMN in soils under indigenous vegetation could potentially represent reference states for these measures in New Zealand soils, however there are few indigenous sites included in SOE monitoring, and where included, they may not necessarily represent undisturbed indigenous vegetation. Additional studies of soils under indigenous vegetation could add to this knowledge base [60, 62]. However, New Zealand soils are known to be naturally low in plant available P due to New Zealand's geology and climate influencing soil development processes, and indigenous ecosystems are typically adapted to these soil conditions [61,62]. Thus, the relevance of this reference state to inform N and P concentrations in soils under primary production use is debateable since N and P requirements will be driven by requirements of specific crop or pasture, which can vary considerably. Similarly, this reference state is unlikely to be suitable for soils where exotic plants are desirable e.g., grass on sports fields.

SOE targets for this attribute are generally used in productive systems where optimum levels of soil fertility are targeted for crop and pasture growth. Suggested target values for these indicators have historically been grouped by soil type and/or land use [41], and as these measures can inform soil fertility, productive systems strive for higher levels (and specific levels vary by crop) [44,63]. Therefore concentrations under indigenous vegetation are unlikely to relevant for production land use.

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)

'Target values' have been developed for use in regional council state of the environment reporting, with a review of the derivation of these values recently undertaken by Manaaki Whenua – Landcare Research [41]. These values were based on combining production optima and environmental considerations, although limited environmental data was available at the time of development [41]. These values vary with land use and soil order, with the current recommendations for Olsen P concentrations in soils shown in Table 1. The values in Table 2 are similar but not identical to those used by MfE and StatsNZ in *Our Land 2021* [38]. Revision of these target values currently being contracted by MfE (Revision of Soil Quality Indicator Target Ranges).

Table 1. Suggested Olsen P target ranges. Units not specified but assumed to be mg/kg. Original source from Mackay et al. [64], taken directly from Cavanagh et al. [41].

Land use	Soil type	Minimum	Maximum
Pasture; horticulture and cropping	Volcanic	20	50
Pasture; horticulture and cropping	Sedimentary and Organic soils	20	40
Pasture; horticulture and cropping	Raw sands and Podzols with low P retention	5	5
Pasture; horticulture and cropping	Raw sands and Podzols with medium and above P retention	15	25
Pasture; horticulture and cropping	Other soils	20	45
Pasture; horticulture and cropping	Hill country	15	20
Forestry	All soils	5	30

Table 2. Olsen P target ranges used by MfE and StatsNZ [38].

Soil order	**Land use**	**Min**	**Max**	**Unit**
Raw	All	5	25	µg/g
Podzol	All excl. cropping and orchard/vineyard	5	25	µg/g
Podzol	Cropping, orchard/vineyard	20	50	µg/g
Allophanic, Pumice	Exotic forestry	5	30	µg/g
Allophanic, Pumice	All excl. exotic forestry	20	50	µg/g
Brown, Gley, Granular, Melanic, Oxidic, Pallic, Recent, Semi-arid, Ultic	Dairy, Drystock, Lifestyle, Scrub, Tussock, Urban Park/Reserve	15	45	µg/g
Brown, Gley, Granular, Melanic, Oxidic, Pallic, Recent, Semi-arid, Ultic	Cropping, orchard/vineyard	20	45	µg/g
Organic	All excl. exotic forestry	20	40	µg/g
Organic	Exotic forestry	5	30	µg/g

NB: Anthropic soils not mentioned

Total N targets used by MfE and StatsNZ [38] are those specified in guidance developed by the LMF for use in SOE monitoring [65](Table 3), summarised as 0.25-0.7% for pasture, and 0.1-0.7% for exotic forestry.

Table 3. Total nitrogen target ranges (% w/w). Bold values indicate target values.

Land use	**Very depleted**	**Depleted**	**Normal**	**Ample**	**High**	
Pasture	0	**0.25**	0.35	0.65	**0.70**	1.0
Forestry	0	**0.10**	0.20	0.60	**0.70**	
Cropping and horticulture			excluded			

Source: LMF [65].

AMN targets used by StatsNZ [38] are those proposed by the LMF [65] (Table 4), summarised as a minimum of 20 mg/kg for cropping, horticulture and exotic forestry, and a minimum of 50 mg/kg for pasture. No land uses have maximum targets for AMN.

Table 4. AMN target ranges (mg/kg). Bold values indicate target values.

Land use	Very low	Low	Adequate	Ample	High	Excessive	
Pasture	25	**50**	100	200	200	250	300
Forestry	5	**20**	40	120	150	175	200
Cropping and horticulture	5	**20**	100	150	150	200	225

Source: adapted from LMF [65] using information from Mackay et al. [64].

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

Water extractable P is an additional measure that has been used to assess potential P loss via surface runoff [36]. This is a modelled attribute, derived from Olsen P and anion storage capacity. An environmental target of 0.02 mg/l was used in McDowell et al. [36]. This value was selected to limit eutrophication (and is based on all default guideline values for DRP concentrations across lowland rivers or lakes or cool climates set by the Australian and New Zealand Governments, ranging from 2-20 µg P/L [66]). However, pursuing low water extractable P concentrations may result in Olsen P concentrations lower than the agronomic target in many soils, impairing production [36].

There are various recognised 'changes' on ecological integrity arising from different nutrient conditions e.g., high nutrient conditions will favour pasture grass growth over native plant species, there are no specific thresholds or tipping points.

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?

As stated in Section A3, the trajectory of change of this attribute, and therefore lag times and legacy effects on the ecological integrity of soil depends on the extent to which known management practices are adopted. Elevated soil P and N is reversible, where ongoing inputs are reduced or stopped and plant growth uses the available P and N.

There is suggested to be a lag time between interventions to manage elevated soil P and N and the impacts of these excess nutrients on freshwater quality [36, 67]. An assessment of lag times for nitrates arising from livestock farms entering surface water in 34 New Zealand catchments found that the median lag time was 4.5 years, with a total range of 1-12 years [67]. Lag time was influenced by factors including catchment size and slope, illustrating legacy effects.

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.

As noted previously, soil health is an area of high interest to Māori and there are many tohu/indicators that are utilised according to mātauranga-ā-hapū and mātauranga-ā-iwi [78,79]. In addition to discussing this attribute directly with iwi/hapū/rūnanga, there is likely to be tikanga and mātauranga Māori relevant to informing bands, allocation options, minimally disturbed conditions and/or unacceptable degradation in treaty settlements, cultural impact assessments, environment court submissions, iwi environmental management and climate change plans, etc.

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?

Fertiliser application to soils in agricultural systems is a key factor influencing the state of this attribute [23,36]. Intensified land use in turn can drive fertiliser applications to soils. A fertiliser code of practice [68] and guides for fertiliser management of productive systems [44] have been developed by the Fertiliser Association of New Zealand to inform management of this issue through fertiliser application. Adoption of the code of practice is voluntary and adoption rates are not assessed.

Similarly, wastewater or effluent application – including municipal wastewater, dairy shed effluent, or wastewater from food manufacturing plants, e.g., dairy factories, to land can also negatively influence the state of this attribute.

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

SOE monitoring by is undertaken by Regional Councils, however the extent of interventions to effect change in soil N or P status, is largely limited to reporting soil quality monitoring results, which may include reporting back to the individual landowners on whose properties the sampling has been undertaken. Elevated Olsen P concentrations have been reported in agricultural soils since the commencement of the 500 Soils programme in 2000 [69], and concentrations have continued to increase since this time [36].

Regional and District Plans and Policies may specify requirements and require resource consents for farming activities that are likely to result in P and N loss from soil. They may require the use of Overseer or other tools or plans to calculate and manage nutrient budgets.

C2-(ii). Central government driven

National Environmental Standard for Sources of Human Drinking Water [70] specifies that drinking water sources comply with the New Zealand Drinking-water Standard [29], which specifies maximum accepted values for nitrate and nitrite of 50 and 3 mg/L, respectively, also providing that the sum of the ratio of the concentrations of nitrate and nitrite to each of their respective maximum accepted values must not exceed 1.

The National Environment Standard for Freshwater [71] refers to the National Policy Statement for Freshwater Management [72]. This National Policy Statement regulates some of the same drivers (fertiliser inputs, animal stocking density) that are important for soil ecological integrity as affected by excess soil P and N, however there is no specific legislation or policy for soil P or N.

Freshwater Farm Plans are required in some regions for certain farming activities. These are legislated by the Resource Management (Freshwater Farm Plans) Regulations 2023 [73] and compliance is monitored by Regional Councils. They have no specific provisions for soil P and N however are intended to protect freshwater quality from farming activities.

New Zealand's national emissions reduction plan [35] includes N_2O emissions from agriculture in the net-zero emissions target for 2050.

C2-(iii). Iwi/hapū driven

As noted above, we note that hapū/iwi take a holistic approach to environmental monitoring. Iwi planning documents such as Environmental Management Plans and Climate Change Strategies/Plans may contain policies/objectives/methods seeking to influence soil quality outcomes for the benefit of current and future generations. We are not aware of any other interventions/mechanisms being used by iwi/hapū/rūnanga to directly affect this attribute.

C2-(iv). NGO, community driven

Catchment management groups to improve water quality outcomes, generally relating to farming activities, exist in many catchments throughout New Zealand.

C2-(v). Internationally driven

The Paris Agreement [74] on climate change includes mitigating N_2O emissions from agriculture in both the near-term target: close 10% of emissions gap by 2020 to achieve 2°C warming target; and the long term target: cumulative emission reduction of up to 60 Gt CO2e and 3500 ozone depletion potential kt by 2050.

Part D—Impact analysis

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

Changes in the attribute state affect ecological integrity and potentially human health as described in A1 above. Continuing to have excess P and N in agricultural soils leads to a greater risk of contamination of surface water and groundwater, negatively affecting freshwater quality and aquatic ecosystems. This can affect human health if surface water becomes eutrophic, causing the growth of harmful algal blooms, or if drinking water sources become polluted.

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)

The issue of excess P and N in soils primarily applies to agricultural land – in particular more intensive land uses including dairy and vegetable cropping that apply large quantities of fertilisers. The impacts of excess N and P in soils are likely mostly externalities, affecting other environmental domains. However, the application of excess P and N fertilisers is an inefficient use (waste) of money. This is often not realised, as application of fertiliser can be perceived as 'more is better', and growers can be risk averse to potential decreases in production.

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

Increases in extreme weather events may result in more leaching and runoff of excess P and N from soils to ground- and surface water, as the processes of runoff and leaching are stimulated by rainfall (and irrigation).

Warmer temperatures and wetter conditions are also predicted to increase nitrous oxide emissions from soils [75] resulting in a positive climate feedback, whereby emissions continue to increase [76].

Microbial cycling of soil nutrients will be affected by temperature variations. Specifically, warmer temperatures are likely to enhance N-cycle processes and P utilization [77] which may result in reduced losses from soils.

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