Otago Regional Council

Environmental impacts of different land uses

A brief review of published literature

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Land use

Sheep and Beef farming

Sheep and beef farming is the most extensive land use in Otago (Figure 1). The major environmental issues associated with this land use are impacts on water quality, soil degradation and loss and greenhouse gas emissions. Multiple studies have shown that water quality is reduced by increased nitrogen (N) and phosphorus (P) from fertilizers, sediment and faecal matter load into waterways (1–12). Nutrients (N and P) related to sheep and beef farming are often associated with eutrophication of freshwater ecosystems (5, 13). High median P loads identified in watersheds have been associated with sheep and beef farming activities (5). In addition to N and P, fertilizers are also often enriched in heavy metals. Particularly the heavy metal cadmium (Cd) has been found associated with P fertilizers (14). Studies have shown that cadmium can accumulate in the environment and reach toxic levels that can be harmful to plants and animals (15–19). The impact of faecal matter on water quality is measured via the concentration of *Escherichia coli* in freshwater. Faecal coliforms (i.e., bacteria) can be associated with all types of animal farming and their concentrations in water often increase after rain events when significant amounts of faecal matter are washed from pastures into streams (20, 21). It is important to remember that faecal matter persists on pastures after animals have been moved and contamination of waterways by faecal bacteria can therefore happen up to two years later (5, 22). Glyphosate, a herbicide that is commonly used in New Zealand pastoral farming (23) potentially poses human (24) and ecological health risks (25). In addition, the profitable farming of unploughable hill country achieved by advances such as topdressing, spread the environmental pressures discussed above to larger and more natural areas (23).

Soil physical quality can be degraded from animal treading that compacts or consolidates the soil (26). Soil compaction reduces soil porosity and reduces water infiltration, while consolidation from treading in wet conditions (pugging) can cause considerable pasture damage and increase susceptibility to erosion (26). In both cases, soil damage can persist over months to years and lead to increased release of nutrients and sediments into waterways (26). Cattle exert greater treading pressures on the soil compared to sheep (27).

Sheep and beef farming has been found to contribute substantially to annual agricultural greenhouse gas emissions (28). The emissions are predominantly in the form of enteric methane (produced in the stomachs of ruminant animals). While the vegetation growth on sheep and beef farms removes carbon dioxide from the atmosphere, it is estimated that this only offsets around a third of the total greenhouse gas emissions from this land use (29).

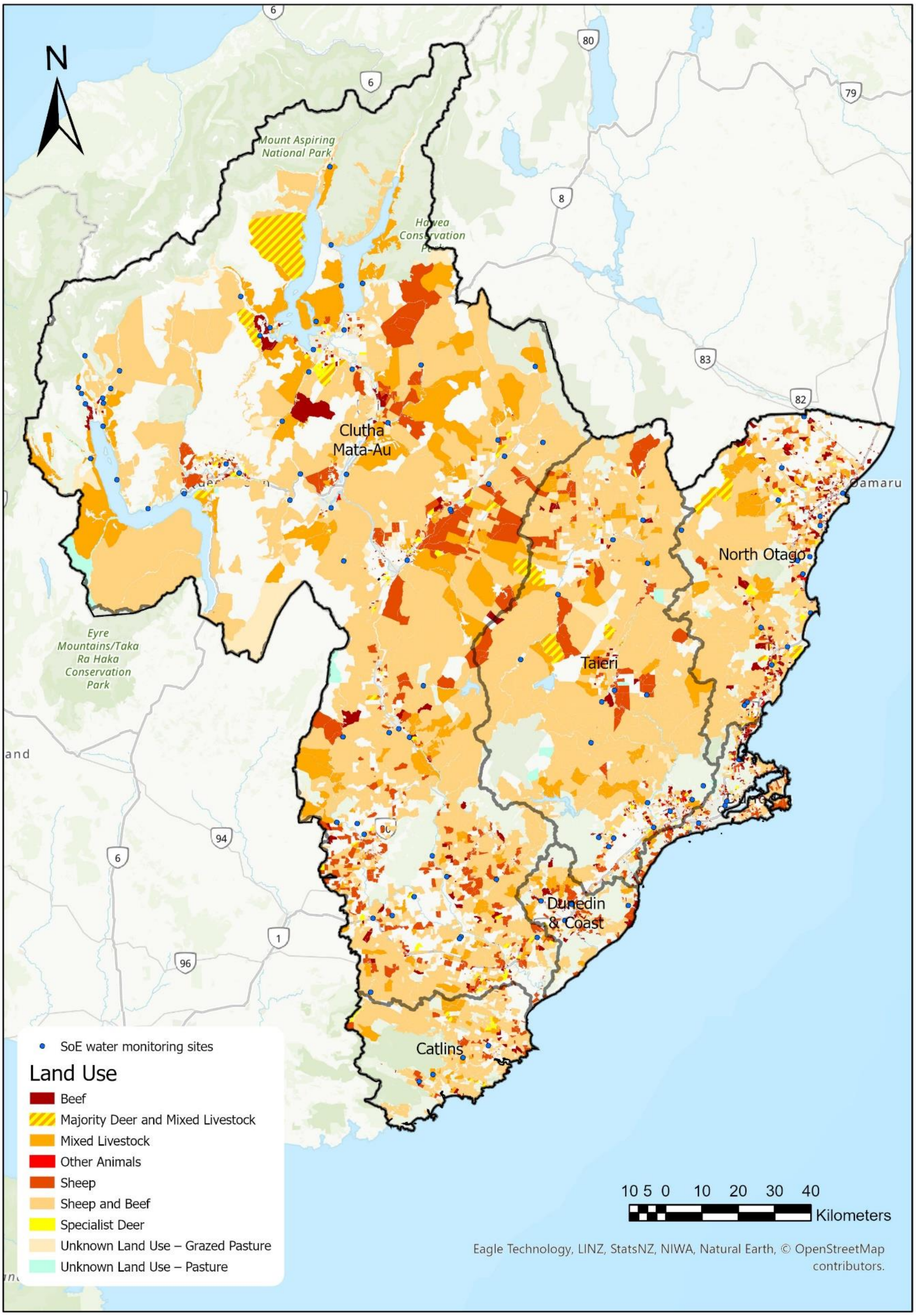

Figure 1 The extent of livestock farming (excluding dairy farming and associated activities) land uses in Otago with the SOE water monitoring sites and FMU boundaries.

Forestry

Commercial plantation forestry of non-native species, such as pine (*Pinus radiata*), is concentrated in East and Southeast Otago (Figure 2). Forestry monocultures have been found to have a low biodiversity value compared to native forests (33), but sometimes equal to other farming activities (34). The greatest impacts of forestry are associated with the establishment and early growth (use of fertilizers and pesticides) and the harvesting (clear felling – the most common harvesting technique in New Zealand) of trees. Between these stages, trees sequester large amounts of atmospheric carbon over the years before harvest (35–37), though the overall balance of the carbon sequestered depends on the end use of the timber. Another potential concern of large-scale plantations is their effects on catchment water yields.

Fertilizers are used in forestry establishment to enhance tree growth (38), the effects of which are similar to the other farming activities discussed. However, these fertilizers often contain more P than N, especially in plantations with soils of low P status (38, 39). Aerial application of fertilisers can be harmful to freshwater environments as they can easily disperse via wind into nearby waterways, potentially leading to eutrophication of freshwater or coastal ecosystems. Forestry fertilizers often contain high levels of boron and copper to prevent malformation of trees (39). These heavy metals are toxic to many aquatic species (40–42) and can negatively impact overall ecosystem health. Like other farming activities, forestry also uses pesticides (43–45) that can end up in waterways and negatively impact macroinvertebrate or fish communities (46). The use of glyphosate, commonly applied aerially over large areas (43), is of concern for ecosystem and potentially human health. Glyphosate is banned in several countries worldwide, due to the potential health risks for humans (24) and its negative impact on ecologically important insects, such as bees (25).

New Zealand studies have observed 30-80% reductions in annual water yields following the afforestation of pasture (47). Water yields in plantations are also commonly lower than in indigenous forests (48). Clear felling operations increase water yields and severely affect soil structure and the cycling of soil organic matter and nutrients in the short-term (49, 50). As such, heavy rainfall during the period between clear felling and establishment of the next rotation (three years later) and can lead to significant soil erosion events (51, 52). Sediment and nutrient losses can lead to eutrophication of freshwater systems and the degradation of aquatic habitats (33, 51–54). The long-term (multi-rotations) impacts of plantation forests on soil quality vary depending largely on the specific management practices and the inherent soil characteristics of the forestry plantation (50, 55).

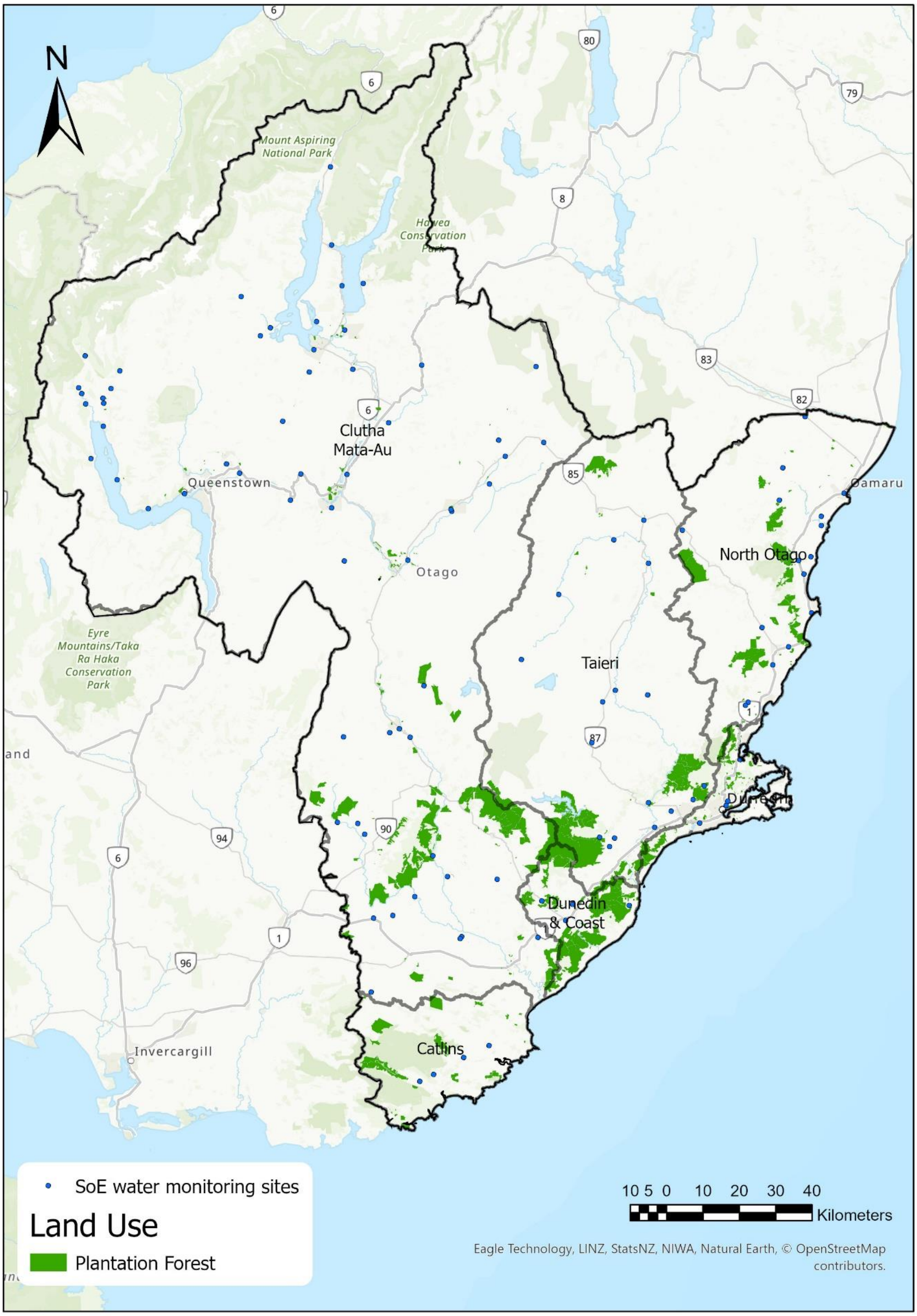

Figure 2 Plantation forestry extent in Otago with the SOE water monitoring sites and FMU boundaries.

Dairy farming

Dairy farming is mostly concentrated in the Lower Clutha Rohe, Taieri plains, Hawea Flat, North Otago and some areas of Central Otago (Figure 3). Environmental impacts of dairy farming can include pollution of surface and groundwater, soil degradation (contamination and structural damage) and soil loss, greenhouse gas emissions and indirect degradation of freshwater and coastal habitats (2, 11, 27, 56–59). In addition, high water demands pose a risk to water quantity. The intensity and high stocking rates of dairy farming means the environmental impacts of this land use activity are relatively high compared to drystock systems (56).

Impacts on soil include compaction from animal and machinery tread (exacerbated by wet conditions, high stocking rates and winter grazing), accumulation of heavy metals in soil from fertilisers and other soil chemical and biological impacts (57). In Waikato, for example, monitoring revealed 80% of dairy farms did not meet one of a suite of soil quality targets and 30% failed to meet two or more (60). In addition, nitrous oxide from overapplication of N and animal waste and methane from waste and rumination (digestive process) by cattle result in a dairy farming contribution of about a quarter to New Zealand agricultural greenhouse gas emissions (57).

Significantly more N is lost to the environment by dairy farming than by any other farming practice, due to high synthetic and animal-derived (faeces and urine) fertilizer use (5). Studies have shown that these high loads of nutrients not only lead to an increased eutrophication risk, but also to potentially toxic levels of ammonia and other N forms in waterways (5, 61, 62). Cattle excreta produced on the farm dairy and yards generates large volumes of farm-dairy effluent, which is applied to the land. While this is relatively effective for preventing excessive nutrients leaching into waterways, high loading rates and preferential flow pathways can cause significant water quality issues (11). In addition, faecal matter deposited directly on pastures and close to water can be washed into waterways. While the sources of *E. coli* from faecal matter have been found similar to other animal farming practices (1, 5, 63), they are more concentrated in dairy farms (64). In addition, faecal input from oxidation pond leakages can act as significant point sources for faecal matter (65). Finally, dairy farming relies on irrigation for maintaining high production levels, the abstraction for which can reduce river flows, influence groundwater levels and has been linked to diminishing freshwater ecosystems health (56).

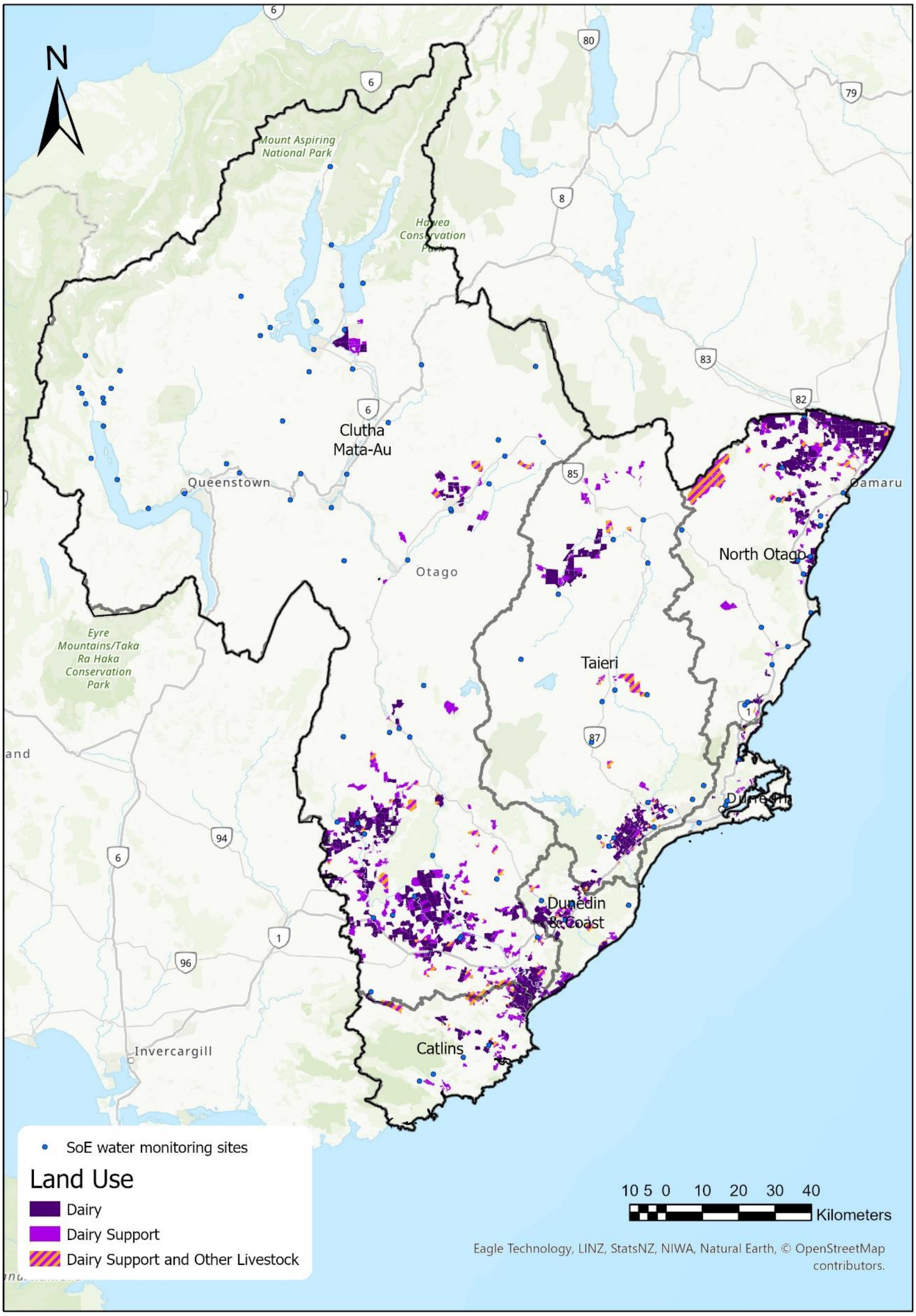

Figure 3 The extent of dairy cattle and dairy cattle support land uses in Otago with the SOE water monitoring sites and FMU boundaries.

Horticulture and Arable Farming

Horticulture (including orchards and vineyards) and arable farming cover a comparatively small area in Otago (Figure 4). Their main environmental pressures have been linked to the consequences of pesticide use (66–69), the overapplication of fertilizers (70–72), water use for irrigation (73) and soil degradation and soil loss (74).

Pesticides are applied to protect target plants and/or eliminate non-target plants. Their application and dispersal to the local environment has been linked to accumulation of pollutants over time (66, 68, 69, 75). Research has shown that these can take a long time to break down and have soil, water, animal, and human health consequences (66, 67, 76–78). Additional nutrients to the ones available in the soil are required to maximise horticultural and arable crop productivity (79). Studies have shown that overapplication of commonly used fertilizers can lead to elevated N, P and trace element (commonly contained in fertilisers) levels in freshwater (77–83) and groundwater (12, 13). This can cause water eutrophication (17–23). To achieve higher productivity, these land uses often rely on irrigation, especially in arid regions where most of the viticulture and fruit growing occurs (i.e., Central Otago; Figure 4). Water takes from natural sources used for irrigation can lead to lower than natural flows in rivers and negatively impact ecosystem health (72). Changing natural water levels and has also been linked to degrading river habitats (73, 84, 85).

Tillage of the soil and heavy machinery use common in arable, vegetable and fruit growing can reduce the health of the soil with potential impacts on the wider environment. Tillage breaks the natural structure of the soil and enhances the decomposition of organic matter, thereby releasing carbon dioxide, reducing soil fertility and enhancing the soil's susceptibility to erosion (86). Frequent heavy machinery traffic often compacts the layer below the topsoil (known as a hardpan), which limits the crop rooting and permeability of water into the soil and increases erosion potential (74). Loss of soil via erosion is unsustainable due to the slow soil formation rate and can lead to increased sediment loads in rivers that can reduce freshwater ecosystem health (24).

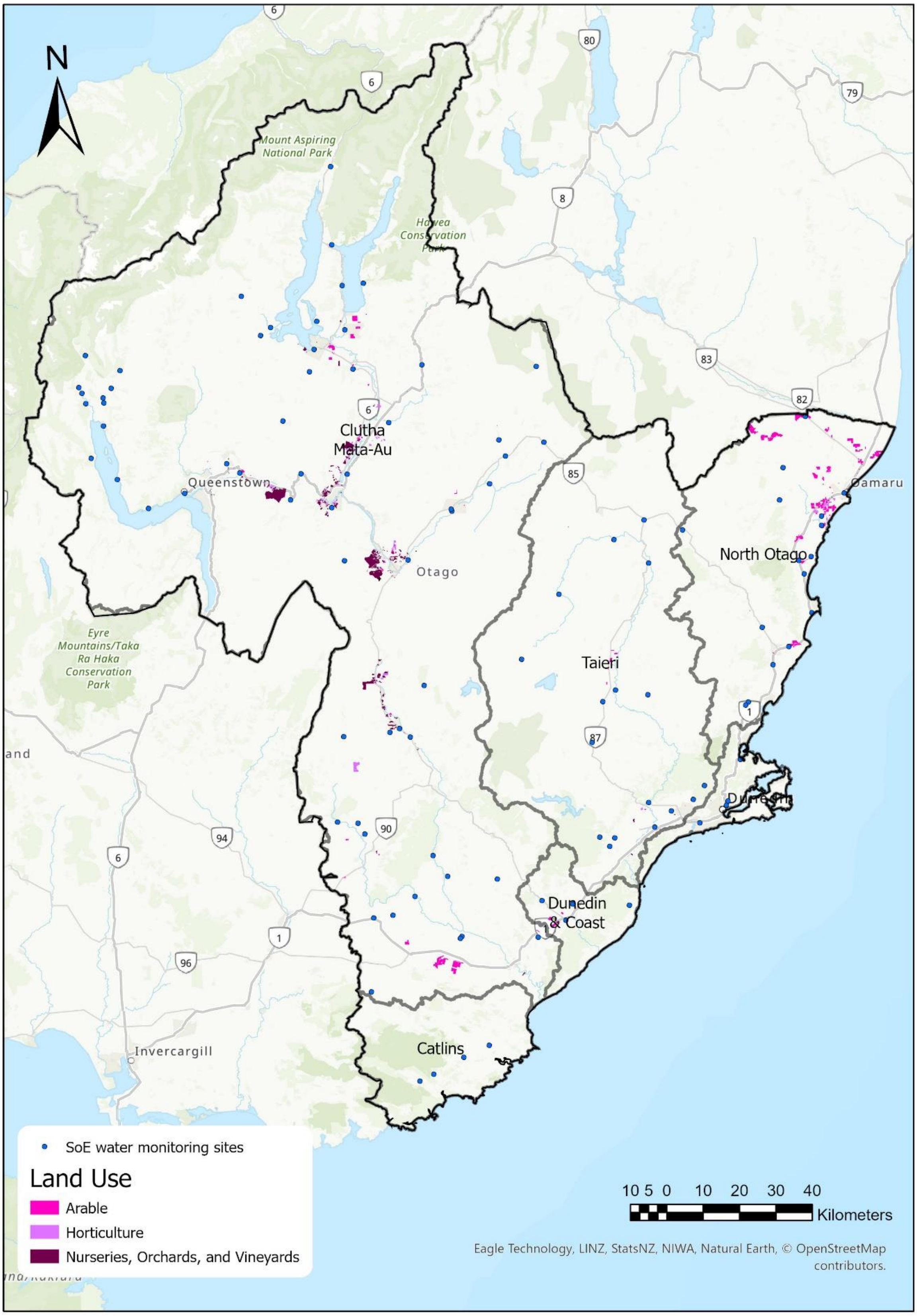

Figure 4 The extent of arable, horticulture (fruit and vegetable growing), nursery, orchard and vineyard land use in Otago with the SOE water monitoring sites and FMU boundaries.

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