LUCI-Ag Report

Makarewa Headwaters Catchment

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Executive Summary

The Makarewa Headwaters Catchment group has engaged Ravensdown Environmental to model N, P and soil losses from the catchment using LUCI-Ag. As part of the project 6 farms from within the catchment were modelled using a combination of OverseerFM and LUCI-Ag. Farm LUCI-Ag modelling was used to inform LUCI-Ag catchment modelling. Each farm was embedded into the catchment model, the remaining land use was predicted using aerial photos and the following databases: Land Information New Zealand – NZ Property titles, Manaaki Whenua – Land Cover DataBase, and Manaaki Whenua – Land-use intensity. The predicted values for average sheep/beef/deer farms in the catchment (e.g. fertiliser inputs, soil test results and RSU) were calculated using the average values from the 5 sheep and beef farms in the report; in addition the values were checked against Beef and Lamb's "*Otago, Southland: Sheep and Beef quintile analysis and forecast*". To predict the average dairy farm management for the catchment, the results from the dairy farm in the report were averaged against Overseer results for 10 other dairy farms in the Southland region. The remaining results (e.g. Exotic forest, Indigenous forest and Manuka and/or Kanuka) were based off standard LUCI-Ag values.

LUCI-Ag nitrogen (N), phosphorus (P) and soil loss tools were run for the catchment with the aim of identifying areas of high N & P load, pathways of high N & P accumulation and areas of high soil loss. In this report results from LUCI-Ag N, P and soil loss tools applied to the Makarewa Headwaters Catchment under likely current land management conditions are reported. Identified areas can be prioritised for mitigation action and possible mitigation actions are suggested. Mitigations have been tested via LUCI-Ag scenario modelling to assess their likely impact. The main method of mitigation modelling in LUCI-Ag relates to changes in land cover on productive land. This includes retirement of areas of high loss and the development of buffers downhill of areas of high loss. Buffers can have the capacity to intercept and filter water carrying soil particulates. Results from the scenario modelling are reported in this LUCI-Ag catchment report.

Results from LUCI-Ag catchment modelling for the Makarewa Headwaters Catchment under current management indicate:

- The intensity of the farm system impacted the N load; with the highest N load areas on dairy farms, particularly the dairy farms on the free draining Brown soils (compared with the poorly draining Gley soils). The less intense sheep/beef/deer farms generated lower N loads than the dairy farms, while the lowest N loads were generated under native or exotic forestry.

- The intensity of the farm system also impacted the P load; with the highest P load areas on farmed sloped Dairy land underlain by Pallic or other slower draining soils.

- Areas of highest soil loss are associated with harvested forest on steeper topography.

- It has been shown through individual farm reports (LUCI-Ag modelling), that work farmers have done fencing off waterways has resulted in significant reductions in N & P losses of 5-28% and 4-70%, respectively.

- Through increasing fencing, modelling showed over 50% of waterways saw reduced P concentrations, with over 20% of waterways showing a reduced P concentration of over 10%. Modelling also showed over 33% of waterways saw reduced N concentrations, with over 13% of waterways showing a reduced N concentration of over 10%. There are also other additional benefits of fencing/riparian planting including biodiversity gain and providing shade to waterways which reduces water temperature and excessive plant growth.

- In a catchment scenario, 990 ha of flat scrub land was intensified, and 990 ha of steeper farmed land was retired, this reduced catchment P losses by 9%. Individual farm reports have shown that retiring land around streams can offset N & P losses of intensification of better land.

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Dated: 18 July 2022	Dated: 18 July 2022	Dated: 18 July 2022

Introduction

The Makarewa Headwaters Catchment group has engaged Ravensdown Environmental to model N, P and soil losses from the catchment using LUCI-Ag. As part of the project 6 farms from within the catchment were modelled using a combination of OverseerFM and LUCI-Ag. Farm LUCI-Ag modelling was used to inform LUCI-Ag catchment modelling. Each farm was embedded into the catchment model, the remaining land use was predicted using aerial photos and the following databases: Land Information New Zealand – NZ Property titles, Manaaki Whenua – Land Cover DataBase, and Manaaki Whenua – Land-use intensity. The predicted values for average sheep/beef/deer farms in the catchment (e.g. fertiliser inputs, soil test results and RSU) were calculated using the average values from the 5 sheep and beef farms in the report; in addition the values were checked against Beef and Lamb's "*Otago, Southland: Sheep and Beef quintile analysis and forecast*". To predict the average dairy farm management for the catchment, the results from the dairy farm in the report were averaged against Overseer results for 10 other dairy farms in the Southland region. The remaining results (e.g. Exotic forest, Indigenous forest and Manuka and/or Kanuka) were based off standard LUCI-Ag values.

LUCI-Ag nitrogen (N), phosphorus (P) and soil loss tools were run for the catchment with the aim of identifying areas of high N & P load, pathways of high N & P accumulation and areas of high soil loss. In this report results from LUCI-Ag N, P and soil loss tools applied to the Makarewa Headwaters Catchment under likely current land management conditions are reported. Identified areas can be prioritised for mitigation action and possible mitigation actions are suggested. Mitigations have been tested via LUCI-Ag scenario modelling to assess their likely impact. Results from the scenario modelling are reported in this LUCI-Ag catchment report.

Catchment Details & Description

The Makarewa Headwaters Catchment is located west of Winton and the Oreti River in Southland (Figure 1). At 412km^2, the catchment outlet is located where the Makarewa River crosses SH96, from where it then drains into the Oreti River. Within the catchment the Otapiri Stream drains the western and upper catchment, before joining the Makarewa River approximately 4km north of the catchment outlet. The Makarewa River drains the eastern side of the catchment.

Topography within the lower catchment is flat, while in the upper catchment it ranges from rolling to steep hill. The upper catchment is mostly underlain by Brown soils with Gley soils on flatter areas close to the rivers and streams. In the flatter, lower catchment Gley, Pallic, Organic and Melanic soils are present (Figure 3).

Approximately 66% of the catchment is agriculturally productive land, 7% is in plantation forest, with the remaining area covered in a mix of native forest, shrub and tussock grass land. Of the agricultural land, the majority is pastoral land with both grazing and fodder rotations. In the upper catchment the majority of land is sheep & beef farming, with some dairying in the lower catchment. Of the 6 farms embedded within the catchment modelling, 5 are sheep and beef farms and 1 a dairy farm.

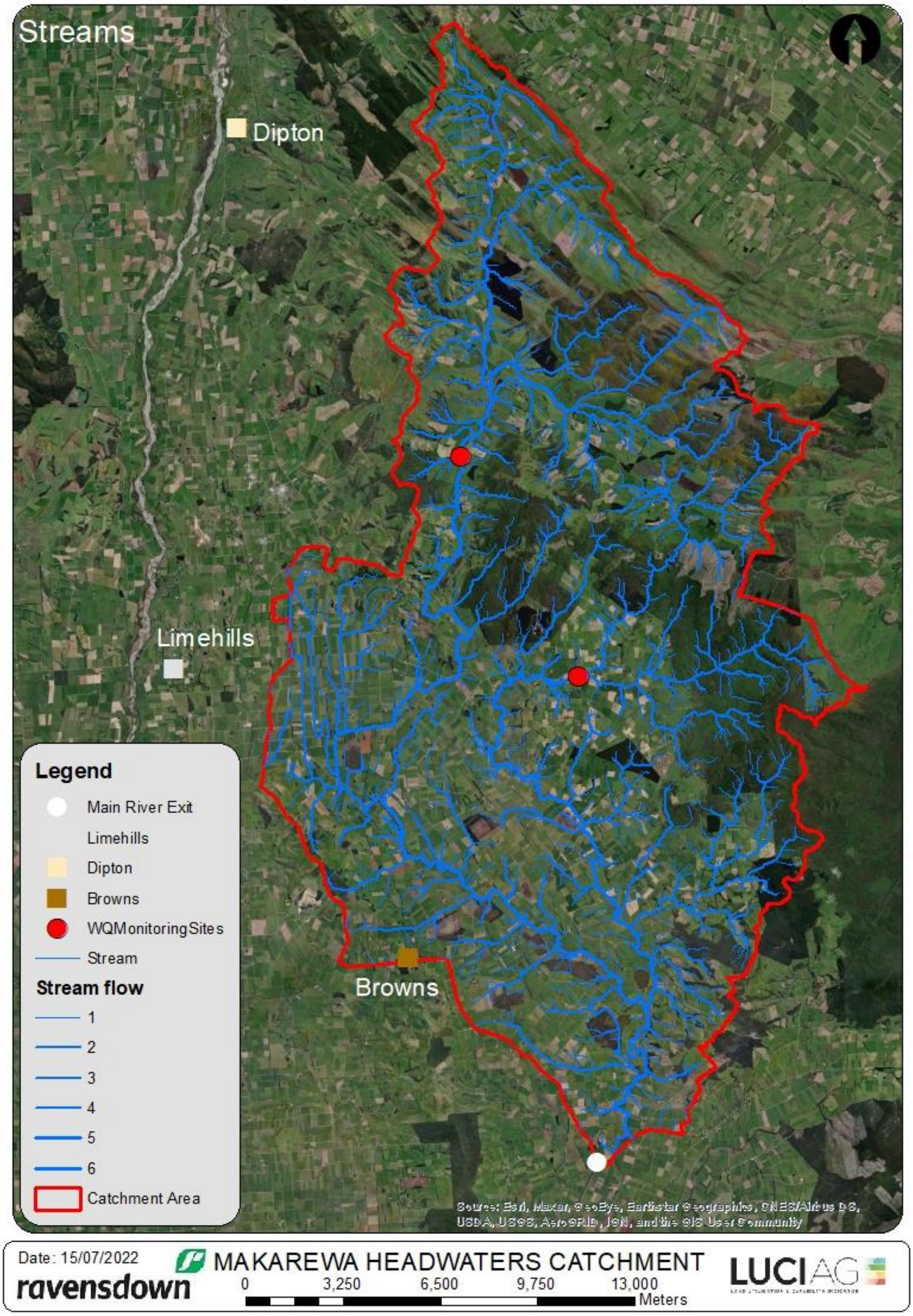

Figure 1. Catchment area, waterways (may include ephemeral streams) and main river exit from the catchment. Please note that waterways are generated by LUCI-Ag based on a digital elevation model (DEM) of topography and combined rainfall. Due to the resolution of the resolution of the DEM waterways may not be in exactly the correct location on the map.

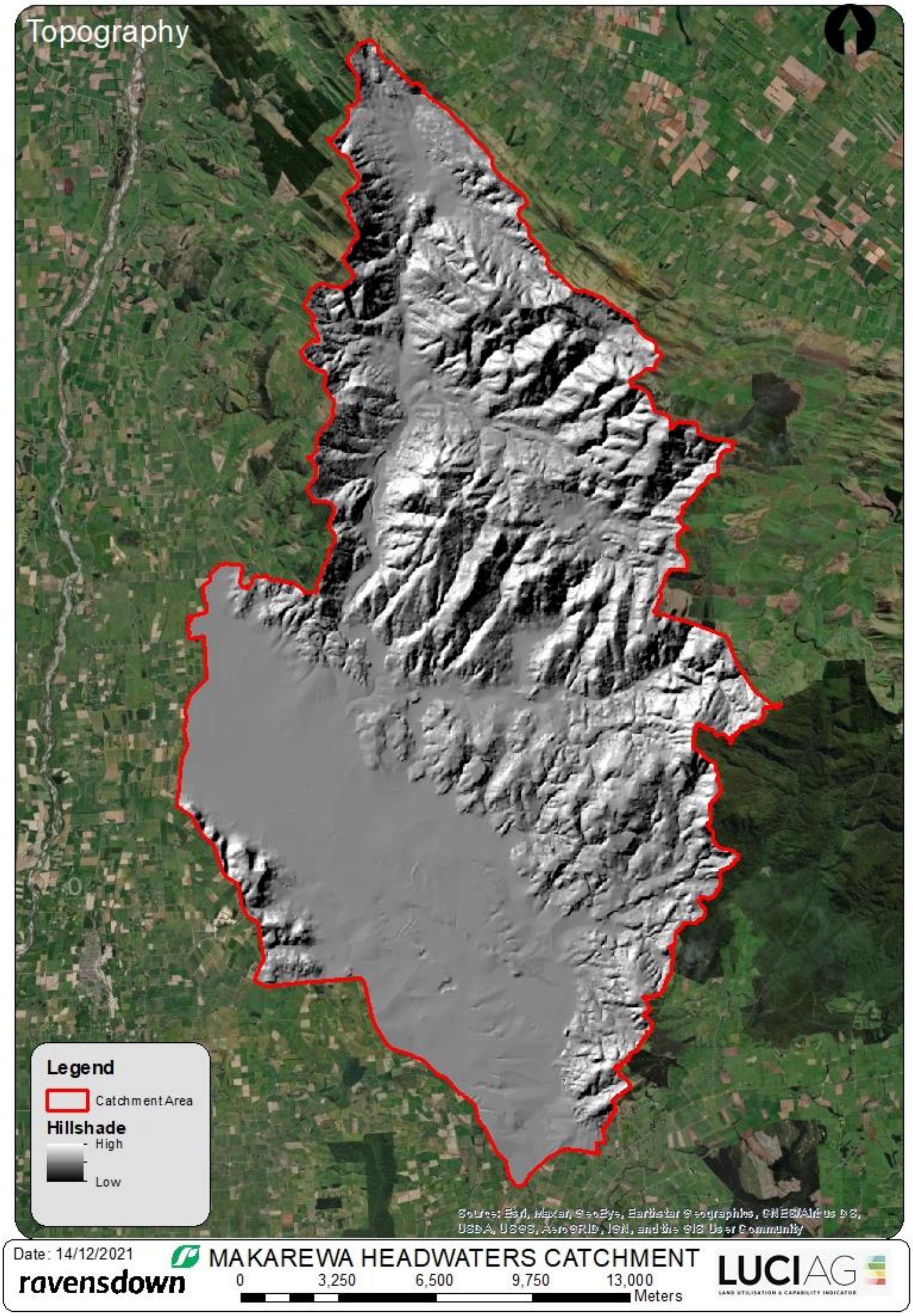

Figure 2. Topography of the Makarewa catchment.

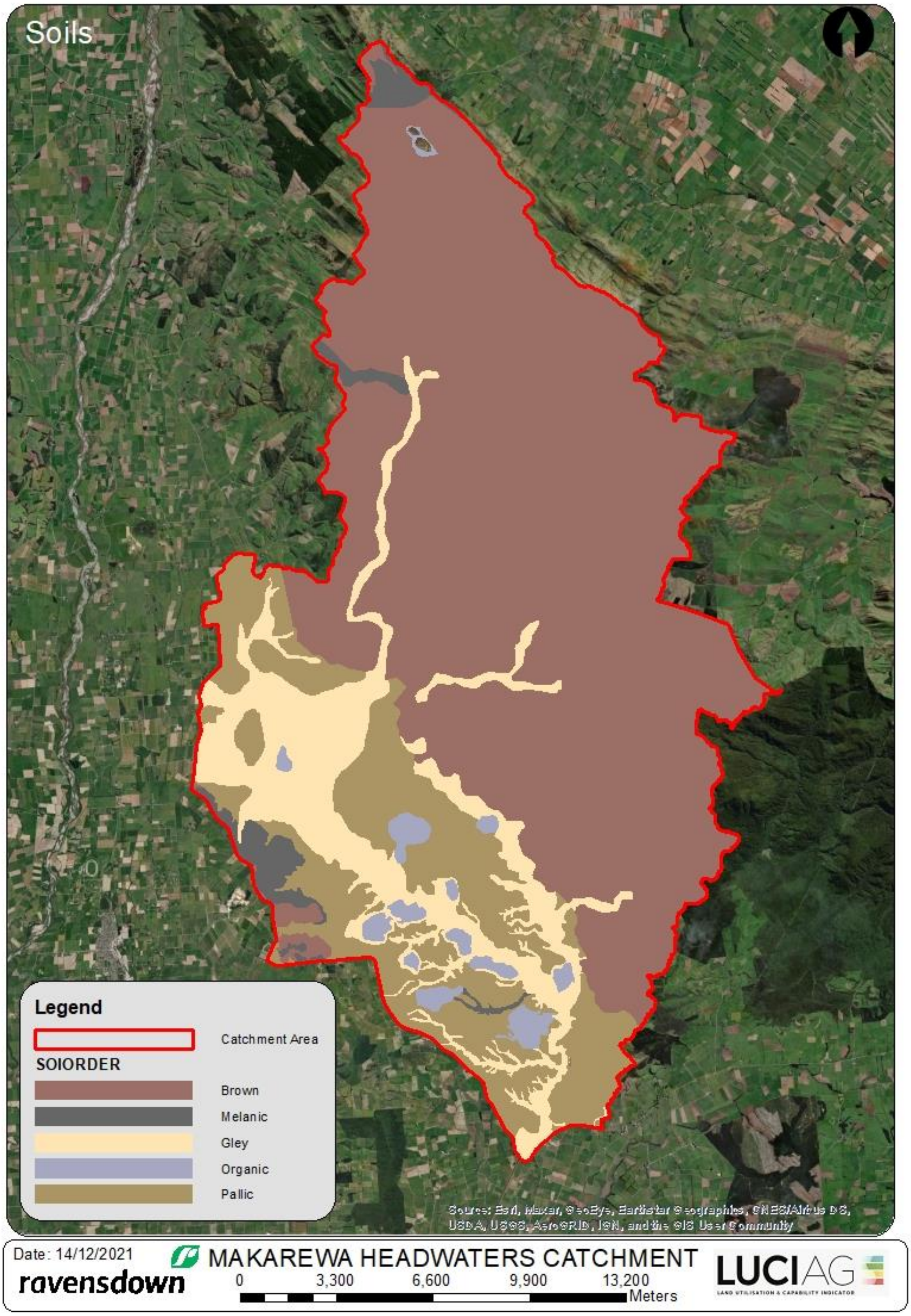

Figure 3. Soil orders present in the catchment

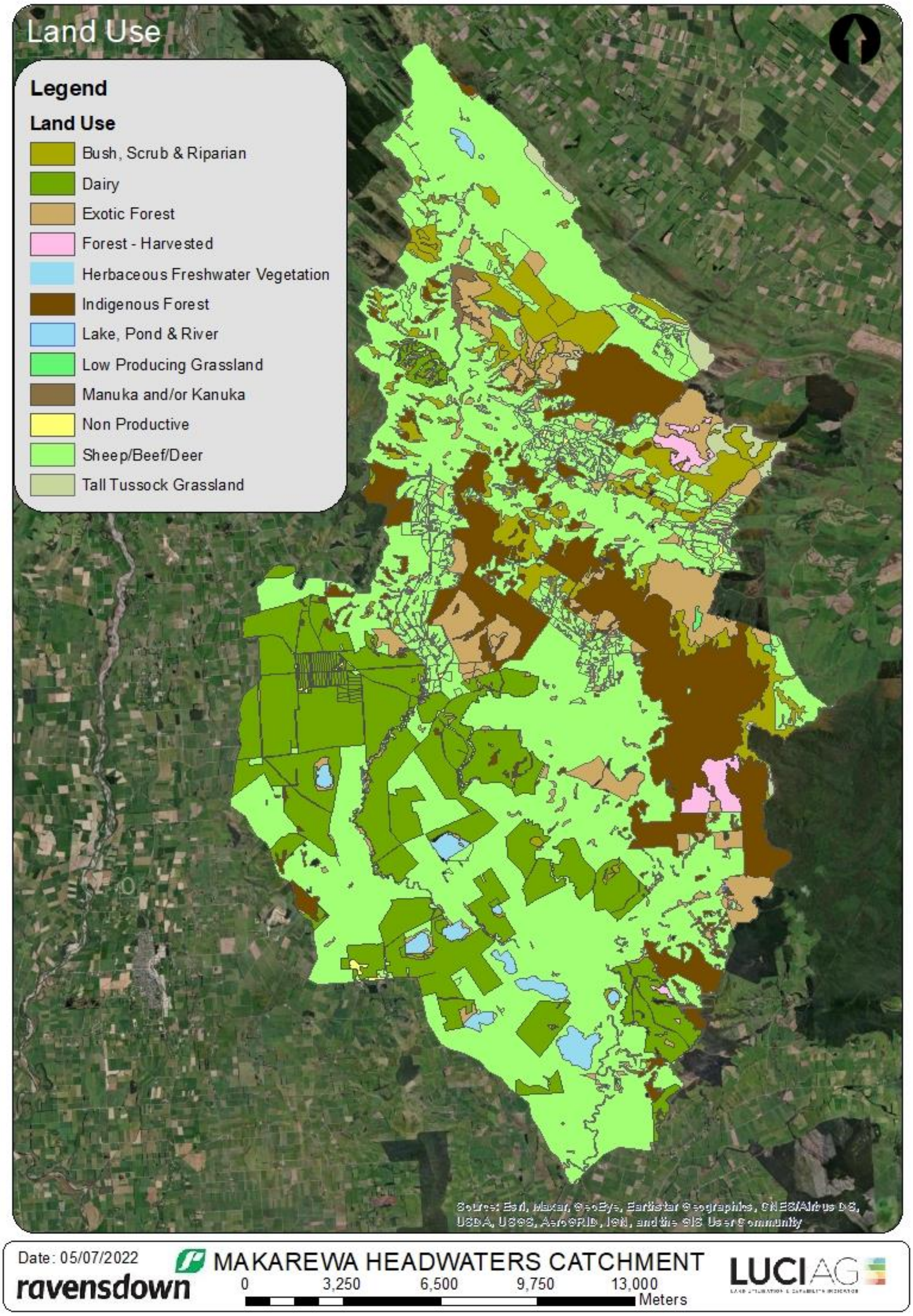

Figure 4. Predicted land management within the Makarewa catchment. Predictions based off using farm reports, aerial photos and the following databases: Land Information New Zealand – NZ Property titles, Manaaki Whenua – Land Cover DataBase, and Manaaki Whenua – Land-use intensity.

Water Quality Within the Catchment

Two water quality monitoring sites are located within the catchment (Figure 1)– one on the Otapiri Stream and the other on the Makarewa River. Table 1 shows the 5 year median for total nitrogen and total phosphorus for each of the two monitoring sites (LAWA 2012). The LAWA website also indicates that the total nitrogen trend is very likely degrading at both sites. At the Makarewa River site total phosphorus is also likely degrading, while at the Otapiri Stream site the trend for total phosphorus is indeterminate. At both sites suspended sediment is also poor, but the trend is likely improving.

Table 1 – Instream 5 year median for Total Nitrogen and Total Phosphorus at water quality monitoring sites within the Makarewa Headwaters Catchment (LAWA, 29 Nov 2021)

Monitoring Site	Total Nitrogen (mg TN/L)	Total Phosphorus (mg TP/L)
Otapiri Stream at Otapiri Gorge	0.91	0.036
Makarewa River at Lora Gorge Rd	1.11	0.032

Feral Animals

There is concern, that feral deer and pigs residing in forested areas contribute to decreased water quality within the catchment. Anecdotal evidence from one farmer within the upper catchment indicates that hunters are culling up to 170 feral deer and 170 feral pigs from forested areas on their property annually. Other farmers within the catchment report frequent incursions of deer on to their property to eat feed and wallow in streams and waterways. To date, media reporting around feral animals, such as deer and pigs, has focussed on the substantial damage they can do to native forest and their economic impacts to farming via feed reduction, damage to crops and orchards, damage to pasture and soil through rooting and wallowing etc (Grzelewski 2007; Latham & Warburton 2014; Gibson 2021).

Water quality (N, P and soil) impacts of specific feral animals in New Zealand has not been well quantified. Indeed, the fact that the animals are feral and free roaming, makes these impacts difficult to attribute to specific species. However, given the known impacts they have on soil damage through rooting and wallowing, and based on anecdotal evidence of species densities, it is likely that some impacts to water quality must accrue. In addition, the impact of domesticated deer on water quality is well understood (McDowell 2007; McDowell 2008; McDowell and Wilcock 2008).

LUCI-Ag models N and P losses from forest and scrub areas based on a thorough review of published data for New Zealand (Trodahl 2018). The impact of feral animals on N and P losses is not specifically addressed in these studies, but is implicitly included. These studies indicate that N and P losses from forest and scrub areas are consistently lower than losses from agricultural areas (Trodahl 2018). So within most catchments agricultural land is likely to be a greater contributor to decreases in water quality than forest and scrub areas containing feral animals. However, it is also clear that feral animals, such as pigs and deer, can have a devastating environmental and economic impact. Further study into the specifics of these impacts could be beneficial and further assistance to farmers to control feral animals on their land would benefit landowners and their farmed and natural environments.

Baseline Scenario

Nitrogen

Figure 5 shows the likely pattern of N lost via leaching and overland flow at each point over the catchment as modelled by LUCI-Ag. The model links N load to:

- Fertiliser N inputs
- Effluent N inputs
- Stocking rates
- Rainfall
- Irrigation
- Soil variables, particularly those related to drainage

N load only includes what is generated at that point as a result of these variables and it does not include N received at that point from up-hill sources. Please also note that N load in Figure 5 is categorised from high to low based on the catchment data only and does not relate to either average or expected regional or national loss values.

Highest N load areas within the catchment were generated from dairy farms, particularly the dairy farms on the free draining Brown soils (compared with the poorly draining Gley soils). The less intense sheep/beef/deer farms generated lower N loads than the dairy farms, while the lowest N loads were generated under native or exotic forestry.

Figure 6 shows N load generated at a point in the landscape plus that contributed to that point from up-hill sources. This is called 'accumulated N load'. Areas of very high accumulated N load identify pathways where water and nutrients converge in the landscape on the way to waterways. Pathways of highest accumulation are often associated with channels, gullies and/or wetter areas within paddocks and these are good targets for mitigation. Although the majority of N from productive land is lost via leaching rather than over land flow, in hill country areas leached N tends to move laterally with shallow soil throughflow into local wet areas, gullies and waterways.

Mitigations to address N loss via LUCI-Ag include:

- Changes in fertiliser N rates
- Changes to effluent N rates
- Changes to stocking rates
- Fencing or fencing and planting additional waterways or wetter gully areas connected to waterways
- Fencing or fencing and planting other areas of high N loss risk areas

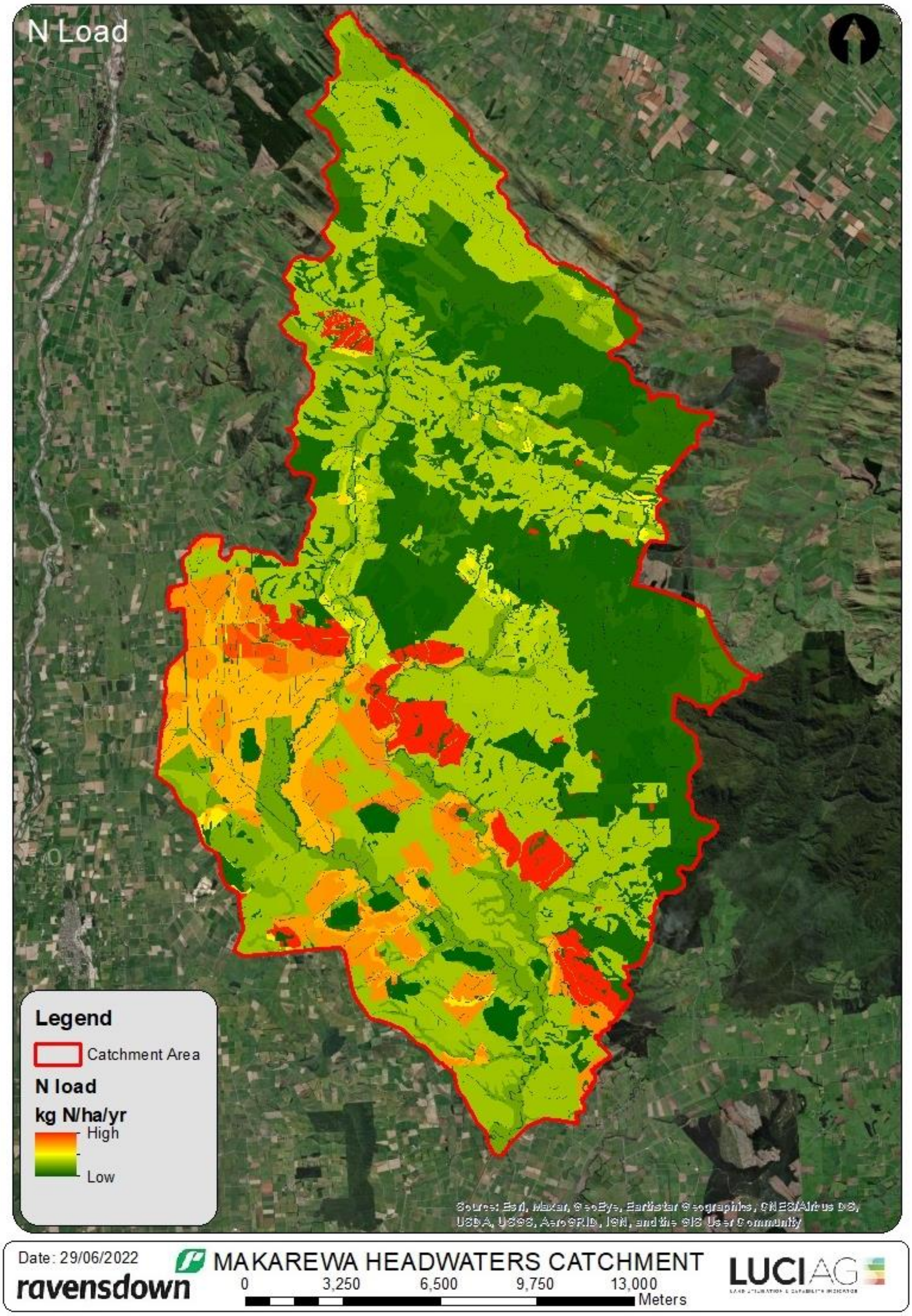

Figure 5. Nitrogen load in the Makarewa catchment as modelled by LUCI-Ag. NOTE: N load is categorised from high to low based on the catchment data only and is not related to either average or expected regional or national loss values.

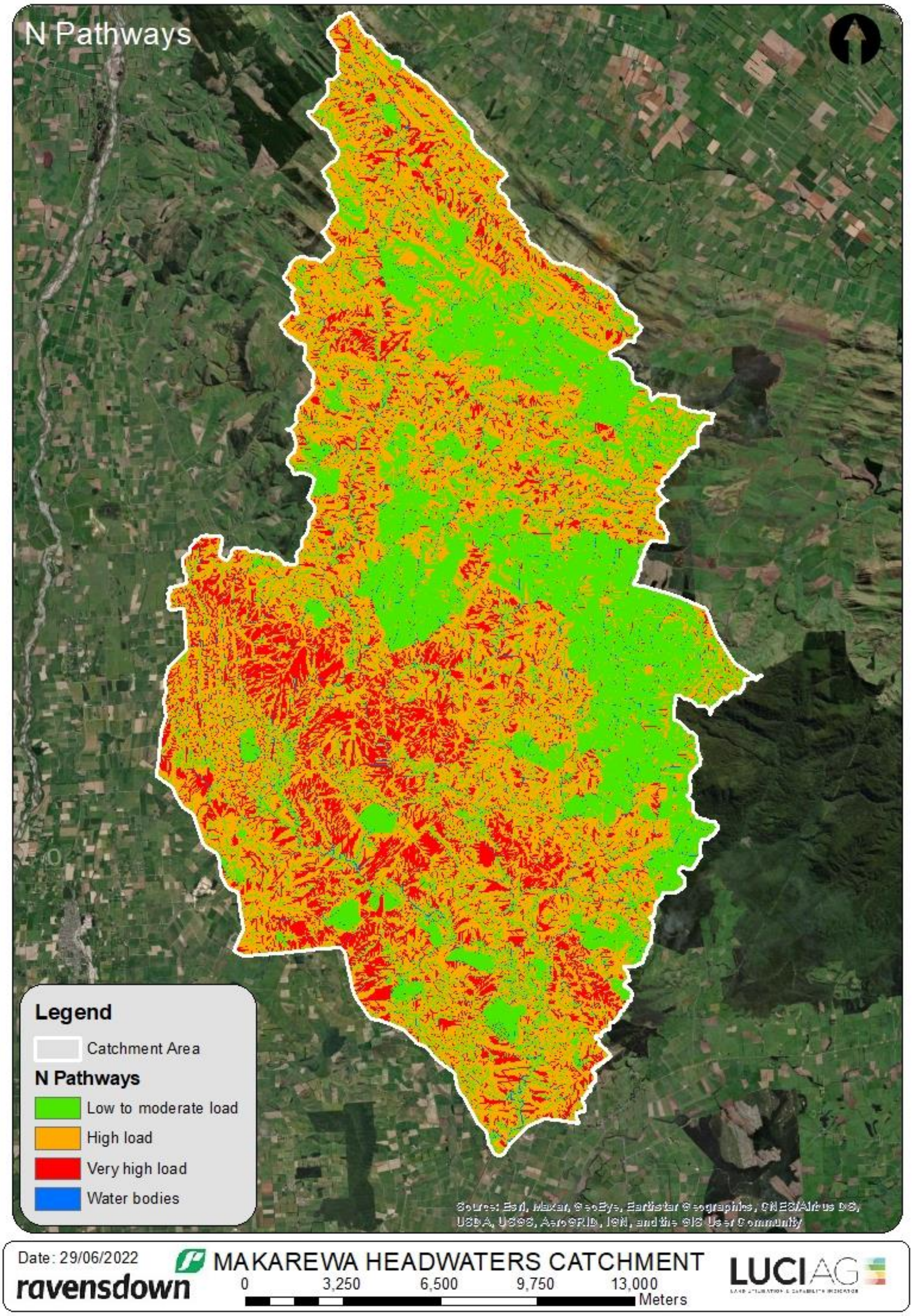

Figure 6. Pathways of accumulated nitrogen load in the Makarewa catchment as modelled in LUCI-Ag. Without LIDAR elevation data, pathways in flat areas are inaccurate.

Phosphorus

Figure 7 shows the likely pattern of P lost via overland flow and leaching at each point over the catchment as modelled by LUCI-Ag. The model links P load to:

- Fertiliser P inputs
- Effluent P inputs
- Rainfall
- Irrigation
- Slope
- Soil variables, P retention and Olsen P

P load only includes what is generated at that point as a result of these variables and it does not include P received at that point from up-hill sources. Higher P loads can be expected on steeper slopes and cultivated areas because P tends to move attached to sediment. Please also note that P load in Figure 7 is categorised from high to low based on the farm data only and does not relate to either average or expected regional or national loss values

The high P load areas within the catchment were highlighted to be:

-Farmed land (Dairy & Sheep/Beef/Deer) on sloping topography.

-The intensity of the farm system also impacted the P load; with sloping Dairy land losing more P than the sloping Sheep/Beef/Deer land.

-On the sloping farmed land, soil order also had a significant effect; Pallic or other slow draining soils had higher P loads than the better draining Brown soils.

-The highest P load areas were on farmed sloping Dairy land underlain by Pallic or other slow draining soils.

-Gley soils on slopes also accounted for a couple of minor hotspots. However, as Gley soils rarely form on hill slopes, this is likely an S-Map error.

Figure 8 shows P load generated at a point in the landscape plus that contributed to that point from up-hill sources. This is called 'accumulated P load'. Areas of very high accumulated P load identify pathways where water and nutrients converge in the landscape on the way to waterways. Pathways of highest accumulation are often associated with channels, gullies and/or wetter areas within paddocks and these are good targets for mitigation.

Mitigations to address P loss via LUCI-Ag include:

- Changes in fertiliser P rates and/or form
- Changes to effluent P rates
- Changes to Olsen P
- Fencing or fencing and planting additional waterways or wetter gully areas connected to waterways
- Fencing or fencing and planting other areas of high P loss risk araeas
- Wetlands/buffer zones

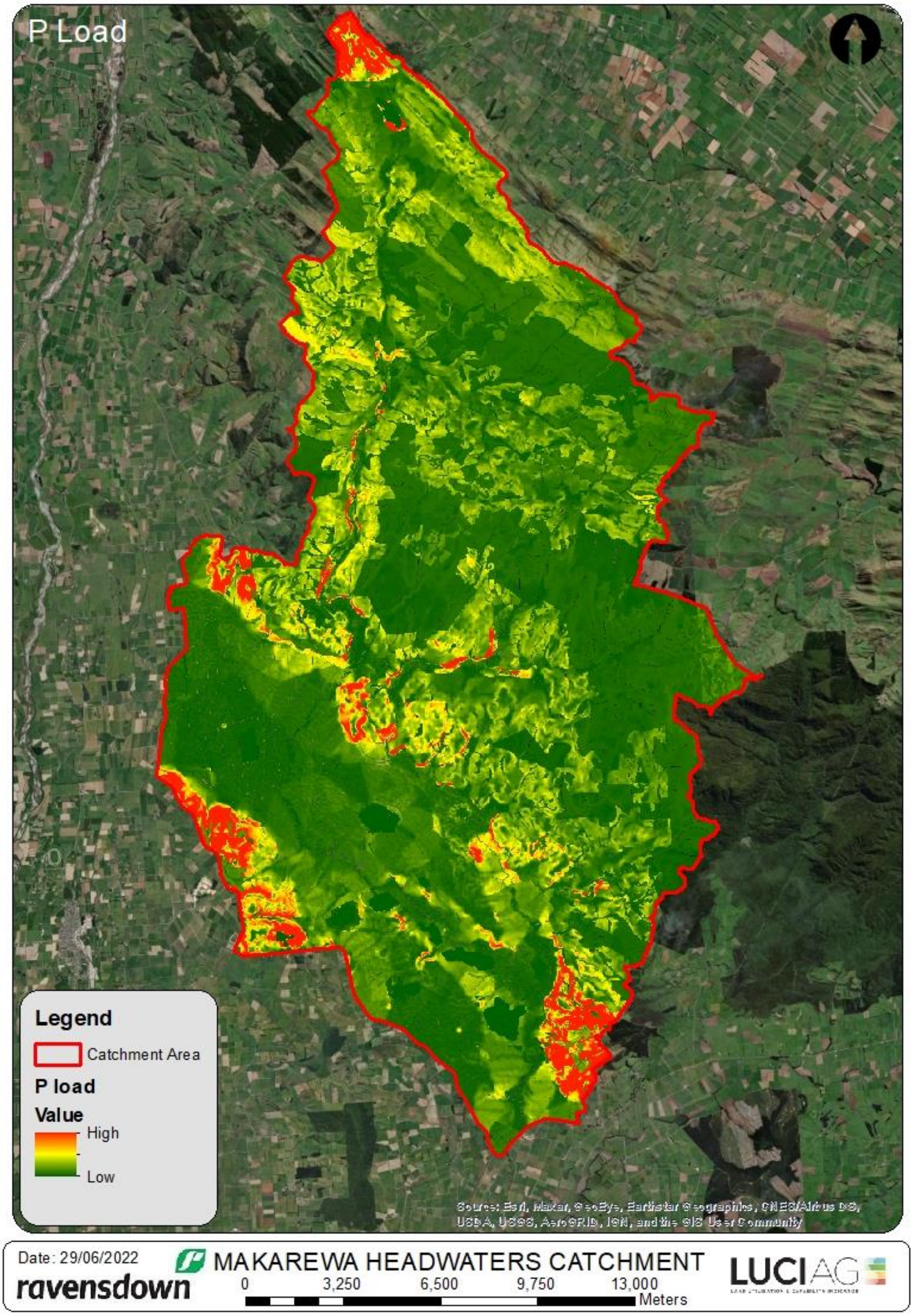

Figure 7. Phosphorus load in the Makarewa catchment as modelled in LUCI-Ag. NOTE: P load is categorised from high to low based on the catchment data only and is not related to either average or expected regional or national loss values

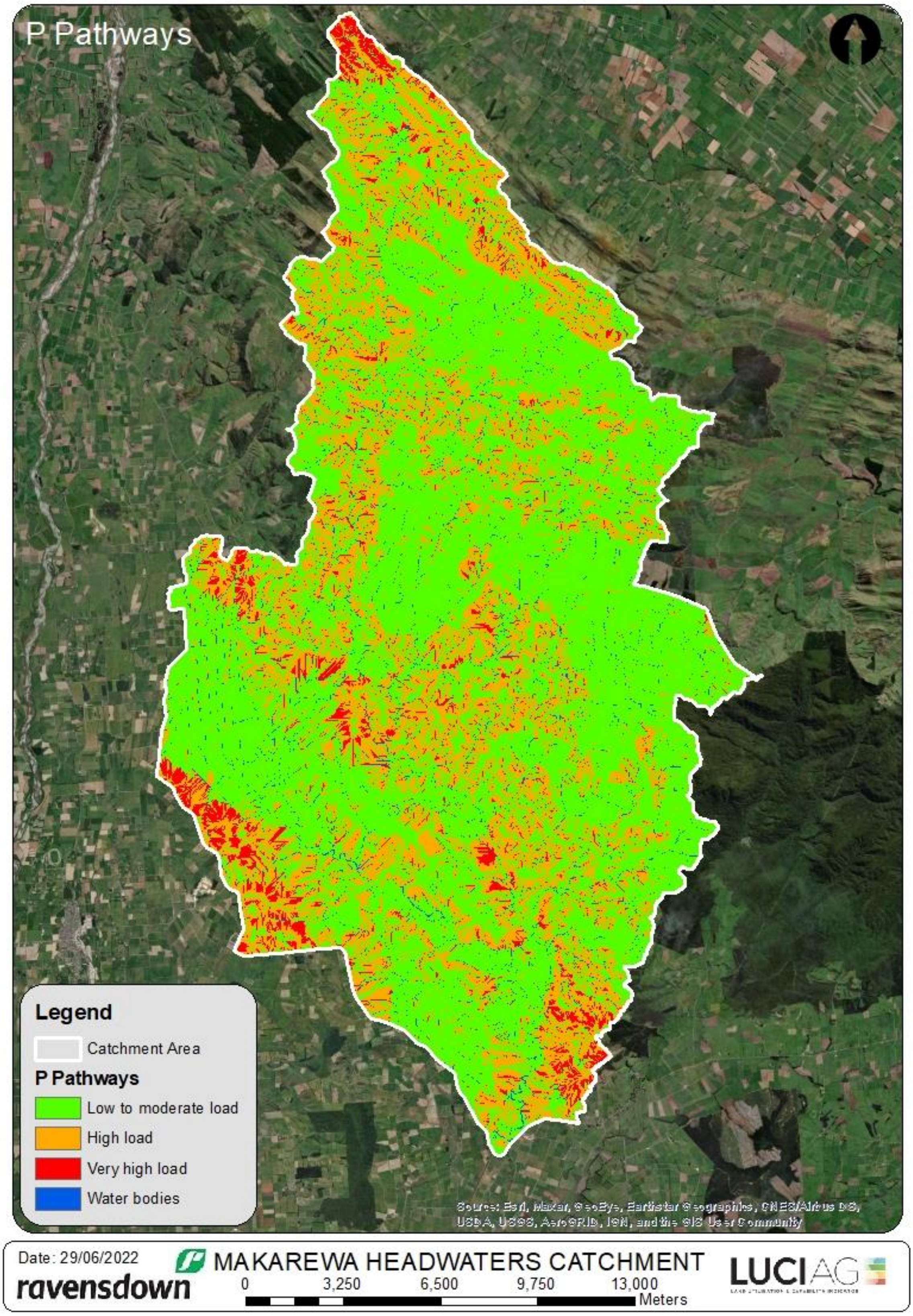

Figure 8. Pathways of accumulated phosphorus load in the Makarewa catchment as modelled in LUCI-Ag. Without LIDAR elevation data, pathways in flat areas are inaccurate.

Soil Loss

Figure 9 shows the likely pattern of soil loss over the catchment from sheet and rill erosion. LUCI-Ag links soil loss to rainfall erosivity, soil erodibility, slope length and steepness, and land cover. It should be noted that soil loss on the map is categorised from high to low based on the farm data only and is not related to either average or expected regional or national loss.

- Areas of highest loss are associated with harvested forest on steeper topography.

The main method of mitigation modelling in LUCI-Ag relates to changes in land cover on productive land. This includes retirement of areas of high soil loss and the development of buffers downhill of areas of high soil loss. Buffers can have the capacity to intercept and filter water carrying soil particulates. Because P often moves attached to soil particles, it is likely that the mitigations mentioned for P above will also help to reduce soil loss.

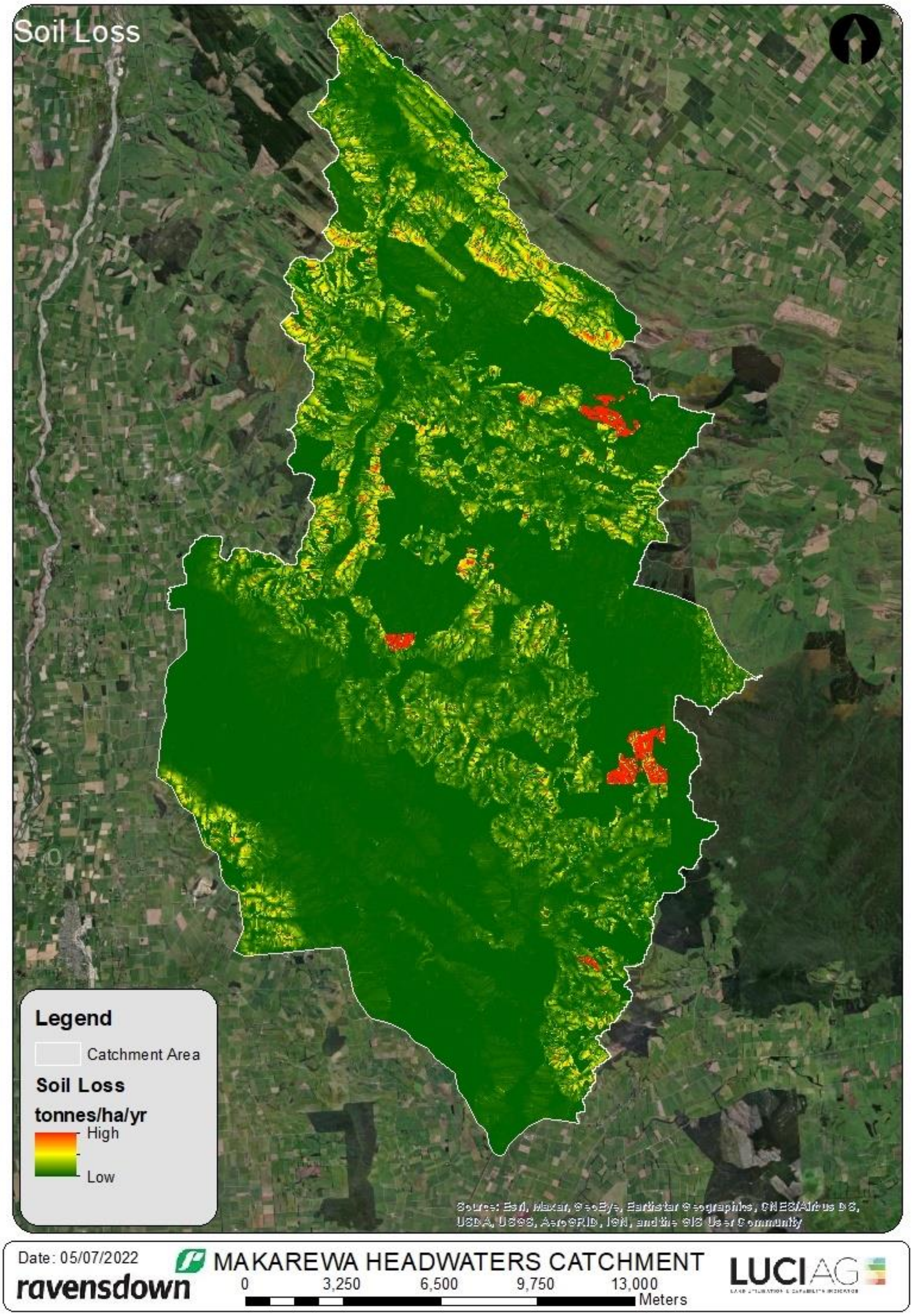

Figure 9. Predicted soil loss in the Makarewa catchment as modelled in LUCI-Ag. NOTE: Soil loss is catergorised from high to low based on the catchment data only and is not related to either average or expected regional or national loss values.

Mitigations & Scenarios

Potential mitigations for hot spot areas

Phosphorus loss hot spot: *Farmed sloping Dairy land underlain by Pallic or other slow draining soils*
Phosphorus (P) is lost predominantly via over land flow, therefore, mitigating soil run off from farm and maintaining an Olsen P in the optimal range are the main goals for reducing P losses.

What farms can do to effectively reduce P loss:
-Soil Olsen P maintained at optimum range
-Apply P fertilisers at right place, right time, right rate and right product
-Avoiding/minimising bare soil, particularly on slopes, where possible
-Have good soil structure, improving soil drainage and infiltration rate
-Avoiding/minimising soil damage/pugging/compaction during cool/wet periods of the year
-Improved winter forage grazing management (discussed below)

Once the P has been lost from the paddock, there are potential methods of trapping the lost P, such as:
-Fencing/riparian planting off waterways
-Wetlands have shown significant promise in recent experiments run by DairyNZ and NIWA (Tanner *et al*, 2021). For example, a wetland 1% the size of the catchment area on average reduced total P in water by 25%.
-Sediment traps

Nitrogen loss hot spot: *Dairy farms on the free draining Brown soils*
Nitrogen (N) losses from farm are predominately via nitrate leaching, through the soil profile. The hot spot areas within paddocks are urine patches, where urine is deposited at high rates.

What farms can do to effectively reduce N loss
-More cool season active cultivars/species (e.g. Italian ryegrass) can significantly reduce N losses (Talbot *et al*, 2021), as the plants are up taking N that may otherwise be leached.
-Feeding lower N supplements, such as fodder beet and whole crop cereal silage, can significantly reduce stock urine-N concentration, compared with higher N supplements e.g. pasture silage (Talbot *et al,* 2020)
-Efficient use of supplements/feed/N fertiliser through feed budgeting
-Apply N fertilisers at right place, right time, right rate and right product
-Avoiding/minimising soil damage/pugging/compaction during cool/wet periods of the year
-Minimising cultivation (e.g. minimum till or direct drill) and bares soil, where possible
-Time spent grazing off pasture (e.g. feed pads) particularly in poor conditions, however, there is a limiting cost of infrastructure
-Improved winter forage grazing management (discussed below)

Once the N has been lost from the paddock, there are potential methods of trapping the lost N, such as:
-Wetlands have shown significant promise in recent experiments run by DairyNZ and NIWA (Tanner

et al, 2021). For example, a wetland 1% the size of the catchment area on average reduced total N in water by 20%, in cool zones.

Soil loss hot spot: *Recently cleared forestry land*
Trees are good at reducing soil erosion while growing, as they bind soil and reduce the impact of rain drops on soil. However, when trees are cleared and bare ground is exposed on steep slopes, the risk of soil erosion is high.

What can forestry land do to effectively reduce soil loss
-Get plants/cover growing on bare ground as soon as possible after harvesting
-Using effective buffer zones and sediment traps when harvesting. There should be a minimum 10 m buffer zone to any significant natural area, property boundary, or significant river freshwater body or a 5 m buffer for smaller water bodies. More information on this regulation is found in Section 14 – Resource Management (NES-PF) Regulations 2017.
-Avoid harvesting around periods of intense rainfall

Fencing scenario

It has been shown through individual LUCI-Ag farm reports, that the fencing the farmers have completed, has resulted in a significant reduction in N & P losses. In the individual farm reports, it is shown that the fencing work already done on farms resulted in reductions in N and P losses by 5-28% and 4-70%, respectively. This highlights the significant impact current fencing off waterways has already had on water quality. This is consistent with McDowell *et al* (2019) which attributes the reduction in national average waterway P concentration to on farm actions (such as fencing).

A current catchment scenario was run with an assumed current state of fencing of waterways (the model assumed all dairy land was fenced off, 50% of the flat land dry stock was fenced off and 25% of the dry stock on hill country was fenced off - approximately 350 km of fencing). A further scenario was run, where all streams were fenced off in flat and rolling sheep and beef land and hill country sheep and beef land remained as is, to see what further gains could be made. An additional 220 km of fencing was modelled. In the increased fencing scenario, there is another 1% reduction in P to be gained through additional fencing for the main river exit P concentration. This reduction is relatively low due to the dilution from other parts of the catchment. However, there was significant reductions in in-stream P concentrations for waterways within the catchment. Through increasing fencing, modelling showed over 50% of waterways saw reduced P concentrations, with over 20% of waterways showing a reduced P concentration of over 10%. Modelling also showed over 33% of waterways saw reduced N concentrations, with over 13% of waterways showing a reduced N concentration of over 10%.

There are also other additional benefits of fencing/riparian planting including biodiversity gain and providing shade to waterways which reduces water temperature and excessive plant growth.

This shows the significant improvement in waterway N and P concentration made by farmers already through fencing and it shows that significant improvement can be made for many waterways within the catchment through further fencing work.

Intensifying flats while retiring higher slope land

A catchment scenario was run where 990 ha of low slope land (>24 m away from any stream) which was classed as gorse/broom/manuka/kanuka/matagouri/fernland/scrub land, was intensified to sheep and beef land. To offset the N & P losses from this intensification, steeper land (>15 degrees in dairy pasture and all steep land (> 25 degrees) in sheep and beef pasture, and less productive easy hill (>15 degrees) in sheep and beef country) was retired to forestry. This intensification of flatter land and retiring of steeper land resulted in a 9% reduction in instream P concentration (Table 2).

Table 1. Likely percent reductions in N and P loads from intensifying better land and retiring steeper/unproductive land.

Mitigation Options	Estimated Reduction in instream N concentration at Main River Exit (%)	Estimated Reduction in instream P concentration at Main River Exit (%)
Intensifying flatter land and retiring steeper land	<1%	9%

Within the individual farm reports, scenarios were run where the flats of the farm were intensified and areas around streams were retired and planted into trees. These individual farm reports show that retiring of land around streams could offset the P losses associated with intensification of better land.

Intensive winter grazing regulation

Intensive winter grazing (IWG) has received scrutiny from the public and government legislation has subsequently been introduced. To avoid having to apply for resource consent for IWG a list of permitted activity criteria must be meet. The new National Environmental Standard for Freshwater (NESF) have a list of permitted activity. The proposed Southland Water and Land Plan will also involve IWG.

To reduce environmental losses from IWG, the following mitigations are available:

-Avoid sloped land, steeper slopes increase run off risk
-Replanting the paddock as soon as practically possible, catch crops (e.g. Oats or Italian ryegrass) have been shown to reduce losses from winter grazing (Malcolm *et al*, 2018; Malcolm *et al,* 2021)– or potentially under sowing in pasture species with forage crops. Having ground cover increases plant N and P plant uptake and physically holds the soil together, reducing N, P and sediment losses
-Avoid planting (leave in pasture) and grazing of critical source areas
-Avoid grazing close to waterways/drainage
-Graze paddocks strategically e.g. graze slope downwards, allowing the rest of the crop to acts as a buffer zone for longer
-Place supplementary feed and troughs in areas away from critical source areas, waterways, ponding

areas
-Back fencing can reduce stock movement and soil damage
-Reducing mob size
-Selecting appropriate paddocks to winter graze and having a winter grazing plan
-Minimising cultivation (minimum tillage and direct drill) when establishing the crop, where possible

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