**Hedgehope Makarewa Catchment Group Project**

**Summary report of landscape data | Southern Cross Produce**

## Executive Summary


Many farmers are actively seeking opportunities to reduce their environmental impact to meet their goals, regulations, consumer and community expectations.

Land and Water Science Ltd (LWS) have undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales. Landscape variability has a significant role in governing the type and severity of water quality outcomes, even when land use is the same. Landscape variability also significantly affects soil greenhouse gas (GHG) production.

Linking the landscape susceptibility and farm system allows farmers to target mitigations and contaminant load reductions to reduce their environmental impact. This report summarises the datasets but does not deliver an integrated plan for mitigating environmental challenges. Instead, this data summary report seeks to *present* the key data and insights that can be used by the landowners and their farm systems specialists/advisors to apply mitigation opportunities to the identified areas.


**Method**

LWS, i. prepared the preliminary landscape data report for the focus property which was supplied to the landowners Southern Cross Produce; ii. met with the landowners on the property; iii. walked the property; iv. sought the landowner's perspective on the environmental challenges they face, and; v. discussed their preferred pathway for mitigating environmental risk.

**The Farm**

The property is located at 406 Rakahouka-Hedgehope Road, Mabel Bush, Southland. The property is ~110 hectares in size, operates as a horticultural cropping and sheep grazing property, and is one of several parcels of land owned by Southern Cross Produce. The property is of low relief and has a mean slope of 3.9° and a range of 1 to 77° (reflecting steep sides of a drainage ditch), and lies between the 54m and 68 m contour Relative to Sea Level (RSL).

Environment Southland designates the property as occurring within the Makarewa Groundwater Management Zone.

**The Catchment**

The property is situated within the Gold Creek sub-catchment, which is located on the south-eastern edge of the Hedgehop-Makarewa Catchment. The Hedgehope-Makarewa catchment is located within the greater Oreti catchment in Southland, New Zealand. It extends from the divide draining the southern side of the Hokonui Hills to the north of Invercargill. The total area of the catchment is approximately 111,940 hectares (ha).

The Gold Creek sub-catchment accounts for 4,639 hectares of land, or 4% of the wider catchment, and is drained by the Gold Creek Stream. This is fed by a diverse network of smaller streams, combining to run in a westly direction through the sub-catchment. At the bottom of the sub-catchment, Gold Creek Stream enters the Makarewa River. The Makarewa River flows in a south-west direction before joining the Ōreti River and discharging to the sea via the New River Estuary at Invercargill.

**Landscape Susceptibility**

The landscape datasets generated for this Southern Cross Produce property have been presented. The landscape package includes a farm-specific model of surface drainage, terrain ruggedness, and high-resolution (3 cm) drone captured photographic images. It is important to emphasise that the susceptibility models do not consider land use nor any existing management practices of physical mitigations (e.g., sediment traps, wetlands) already in place. As such, landscape susceptibility models only identify the inherent or natural susceptibility of the land, they do not indicate that the areas of elevated susceptibility are losing high rates of contaminants.

Within the context of the above paragraph, the main landscape susceptibilities associated with the property are thought to include:

i. Moderate nitrate, nitrite and nitrogen (NNN) susceptibility to loss via the surface water or any subsurface drainage network, noting the underlying aquifer in the north east will naturally remove any leached nitrate. There is also some high susceptibility in the southwestern corner of the property where the underlying aquifer will not remove any leached nitrate;

ii. Some elevated areas of landscape susceptibility to particulate phosphorus (PP) loss that tend to coincide with the imperfectly to poorly drained Dacre soils on the property; and

iii. Elevated Total Kjeldahl Nitrogen (TKN) landscape susceptibility which also coincides with the imperfectly to poorly drained Dacre soils.

Managing runoff to reduce PP, TKN, and a component of likely microbial losses would be beneficial. Nitrate-nitrite-nitrogen is best managed by reducing excess NNN in the soil before and during late autumn and early spring.

## 1. Objective

In the following landscape data report, existing soil and geological datasets and the physiographic classification provided by LandscapeDNA are used to provide a generalised overview of the farm setting before the presentation of a high-resolution and data-driven assessment of landscape susceptibility. Here the objective is to move beyond the low resolution of historic soil and geological maps towards property, paddock, and sub-paddock scale assessment of landscape susceptibility. The aim is to provide landscape knowledge capable of supporting a spatially targeted and highly efficient approach to mitigating soil GHG and water quality-related losses.

## 2. The Farm Landscape

### 2.1 Site description

The property is located at 406 Rakahouka-Hedgehope Road, Mabel Bush, Southland. The property is ~110 hectares in size, operates as a horticultural cropping and sheep grazing property, and is one of several parcels of land owned by Southern Cross Produce. The land is flat with some undulations.

From the LandscapeDNA website ([www.LandscapeDNA.org](http://www.LandscapeDNA.org)), the property straddles the oxidising soil & reducing aquifer, and oxidising soil & aquifer, with minor elements of reducing soil & oxidising aquifer physiographic families (Fig. 1). According to LandscapeDNA, the southernmost extent of the property overlies an ‘oxidising aquifer,’ that is naturally susceptible to nitrate leaching from well drained Waikiwi soils. The northern and eastern portion of the property overlies a reducing aquifer, which will naturally remove leached nitrate. Groundwater data from shallow bores, c. < 6 m below the mean water table, may be used to refine the assignment of aquifer properties.

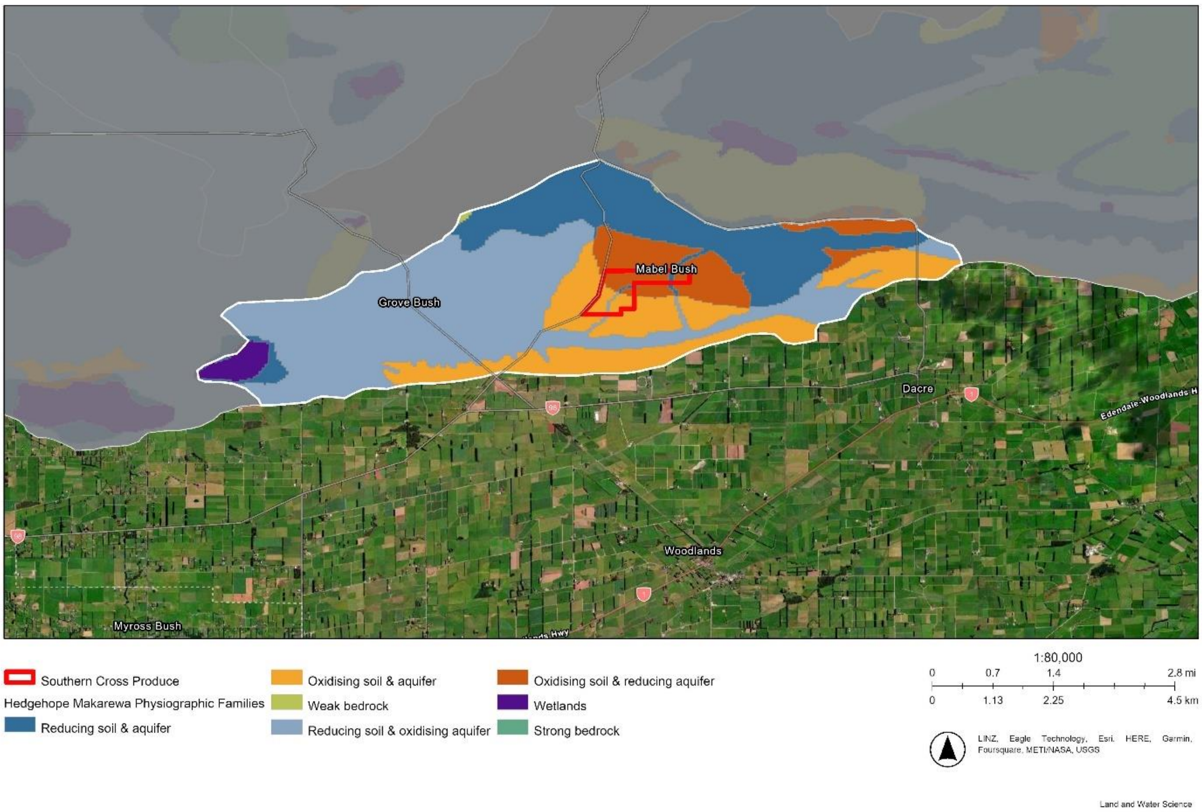


*Figure 1. Case Study property – Southern Cross Produce. Physiographic Families classification.*

LandscapeDNA integrates geology, soil, and topographic variation to identify at a generalised broad level the susceptibility of the landscape to contaminant loss. The geological component identifies that the property straddles two distinct geological units. Across the north-eastern part of the property the main rock type is gravel, with subordinate amounts of sand and lignite. The rock and sediment is described as “quartz gravel with minor quartz sand carbonaceous mudstone and lignite” by the regional geological survey (Q-Map V3). The maximum age estimate of this landform is 4 million years old. Across the south-western part of the property the main sediment is alluvial gravel, with subordinate amounts of sand, clay and silt. They are described as “weathered sandy greywacke (quartz) gravel”. The maximum age estimate of this landform is 349 thousand years old (Pleistocene age) and is therefore a lot younger.

The soil component in LandscapeDNA is derived from Topoclimate South Soil Survey and S-Map. The Topoclimate survey identifies two main soil types across the property (Fig. 2), Waikiwi and Dacre series. The Waikiwi soil series is described as deep, well drained, silt, with low vulnerability of water logging in non-irrigated conditions. The other soil reflected in two narrow channels through the property is Dacre soils, and they are described as deep, poorly drained silt. Generally the Dacre soil series is poorly drained with very high vulnerability of water logging in non-irrigated conditions, and have very high soil water holding capacity. The S-Map portal specifies 'low' confidence in the spatial accuracy of soil siblings across the property. In reality, there is actually a transition from well drained Waikiwi soils to poorly drained Dacre soils. The transition from Waikiwi to Dacre soils is gradual and plays a critical role in determining susceptibility. The high-resolution landscape susceptibility layers generated by LWS have a resolution of 40 x 40 m (0.16 ha) and provide greater resolution over changes in soil properties than is currently provided by S-Map or LandscapeDNA.

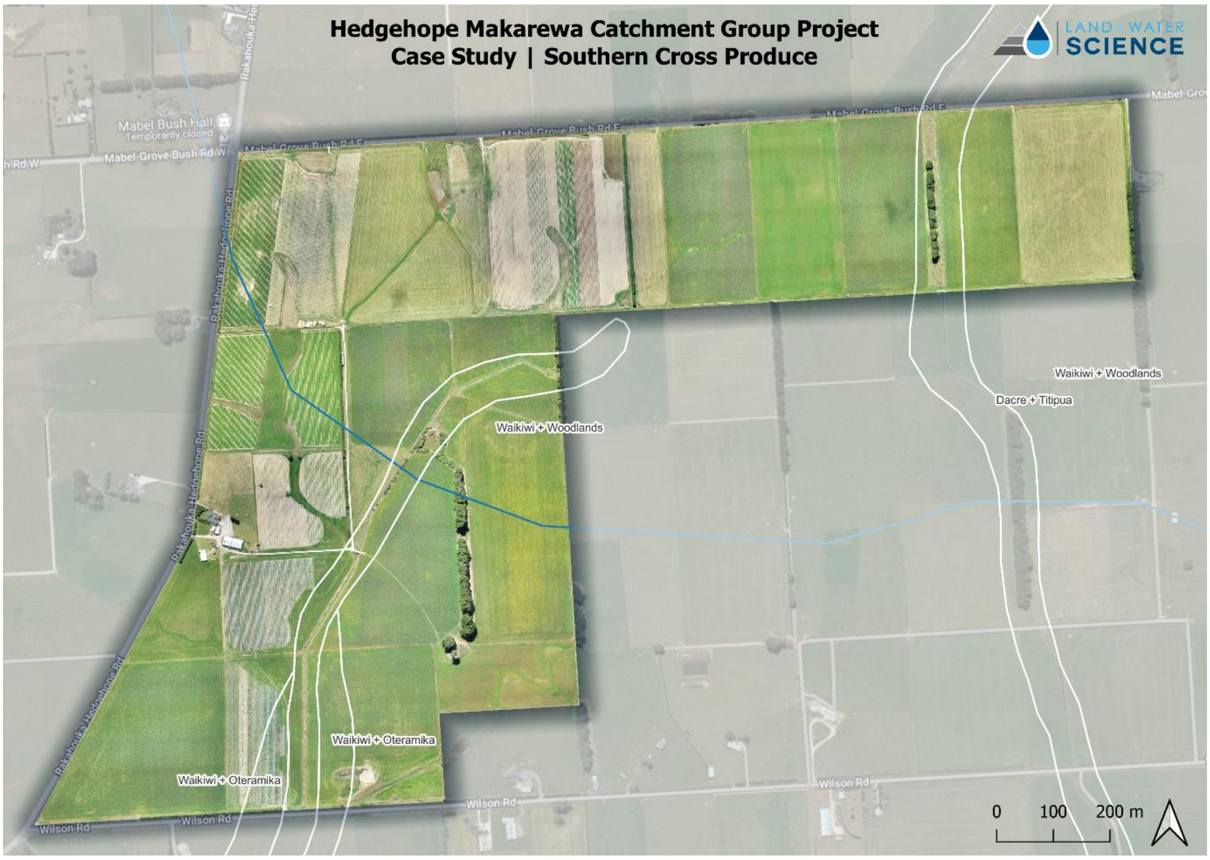


*Figure 2. Case Study property – Southern Cross Produce. The blue lines are from Q-Map denoting the geological units, the white lines and labels are from S-Map denoting the soil siblings. Please note that the soil polygons identified here are a general simplification of a more complex pattern which is subsequently described in the body of this report.*

## 3. New soil map

Although not presented here, a new soil map was developed for the Hedgehope Makarewa Catchment Group as part of the Thriving Southland funded project. The map is available for viewing online in the catchment group's StoryMap application. The soil map was developed as a key step towards a more refined soil resource for the catchment.

## 4. Digital Terrain Model (DTM)

The subject property was surveyed with a drone to develop a high-resolution, Digital Terrain Model (DTM), with a vertical accuracy of 0.02cm. A DTM provides the basis for resolving in high-resolution the topographic variation across the property (Figs. 4). Topography is a dominant control over the movement of water across a property and as such the transport of contaminants from one area to another. The drone derived digital terrain model (DTM) of the property has a mean slope of 3.9° and a range of 1 to 77° (reflecting steep sides of a drainage ditch) and lies between the 54m and 68 m RSL contour (Fig. 4). The low mean slope is consistent with what is a low relief property, although there is clear evidence for strongly incised drainage channels in the elevation model.


*Figure 3. Southern Cross Produce. The photogrammetry survey generates an orthomosaic output at 3cm resolution, producing a Digital Elevation Model of 12cm/pixel, with a vertical geolocation accuracy of 0.02cm.*

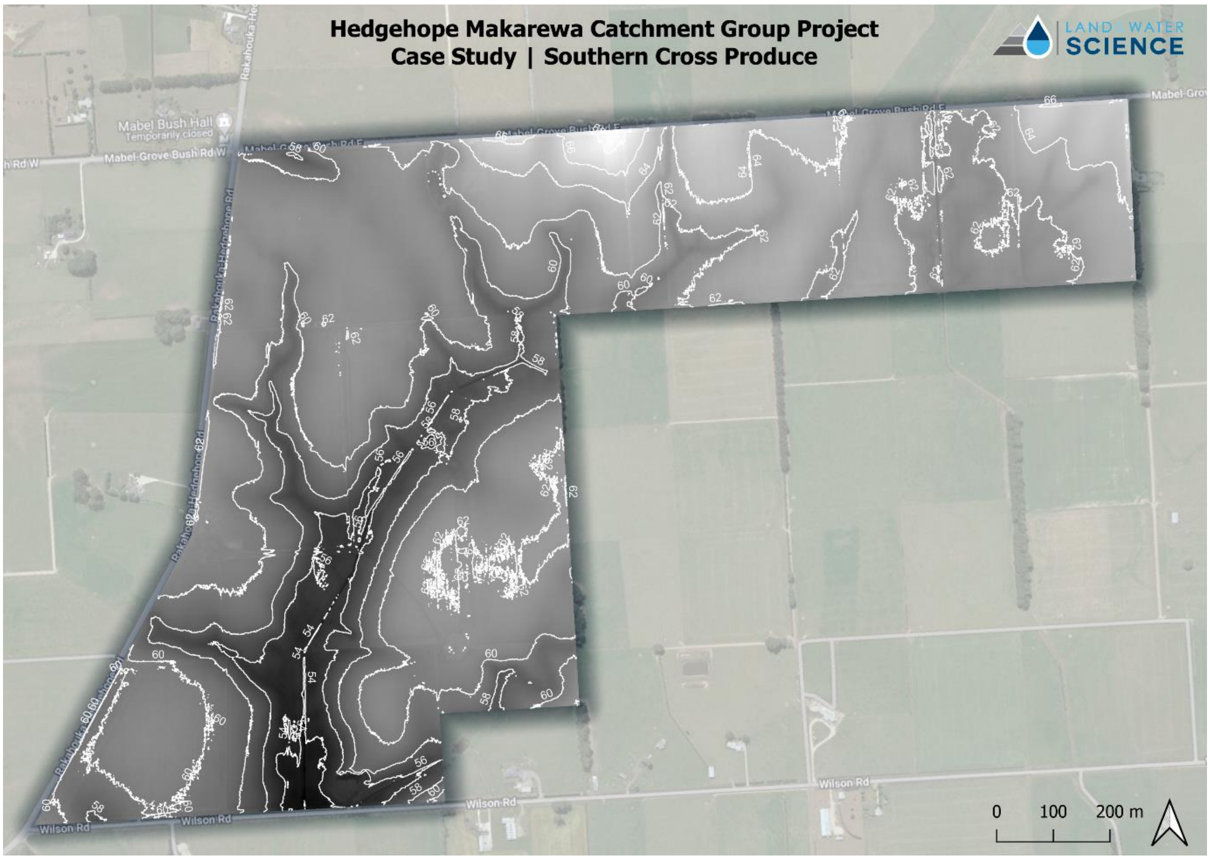


*Figure 4. Case Study property – Southern Cross Produce. Shade model of elevation overlaid with elevation contours (2m) of property in meters relative to sea level. Note the incised channels that are typical of this part of Southland and plays an important role over spatial variation in soil properties and landscape susceptibility.*

Following the survey, the DTM was utilised to build a digital model of the hydrology of the property, which includes the generation of watersheds, a digital drainage network, and nodes or junctions where drainage channels intersect or leave the property. The need to better define the hydrology of the property reflects the role of water in transporting contaminants from one area to another, and at times, off site.

Ultimately, water is the vehicle that transports contaminants from land to water. A better understanding of the areas water collects from and drains to is a critical component of effective land management. Furthermore, soil moisture also tends to follow the drainage network, with higher soil moisture and greater incidences of saturation associated with low-lying areas that receive drainage from higher elevation parts of the property. The saturation of the soil with water also controls soil GHG generation (section 5.2).

## 4.1 Hydrological network for Southern Cross Produce

Watersheds (Fig. 5), the drainage lines and associated network (Fig. 6), discharge nodes (Fig. 7), and priority nodes (Fig. 8) were generated for the property. Watersheds encompass the area that collects and drains water to a node. Water drains towards a common collection point, following the lowest lying pathway to a drainage line. Hence the water that flows through a drainage channel during a runoff event is sourced from the entire area within the watershed. Discharge notes identify the location at which water leaves the survey area and priority nodes identify where small drainage channels connect to and feed into larger drainage channels. Each drainage line or 'channel' is ranked (ordered) according to its level of branching. A low order drainage line e.g., order 1, defines the smallest drainage features, whereas a high order drainage network e.g., order 6, defines the largest drainage features, such as broad or incised swales, drainage ditches, and in some instances flowing stream channels. Typically, higher-order drainage lines are more likely to contain water for extended periods, whereas low order drainage lines may only channel water in response to wet conditions and associated surface runoff events.

Critically, the DTM does not detect nor consider any artificial drainage that has been undertaken. Where present, artificial drainage will greatly modify the hydrological properties and behaviour of water movement across or through the landscape. Accordingly, knowledge of artificial drainage is important given its role in water and hence contaminant export. Most typically, artificial drainage follows the topographic drainage, with many low order drainage channels tiled or piped to expedite soil drainage and/or in some settings to prevent a shallow water table from rising and flooding the property.

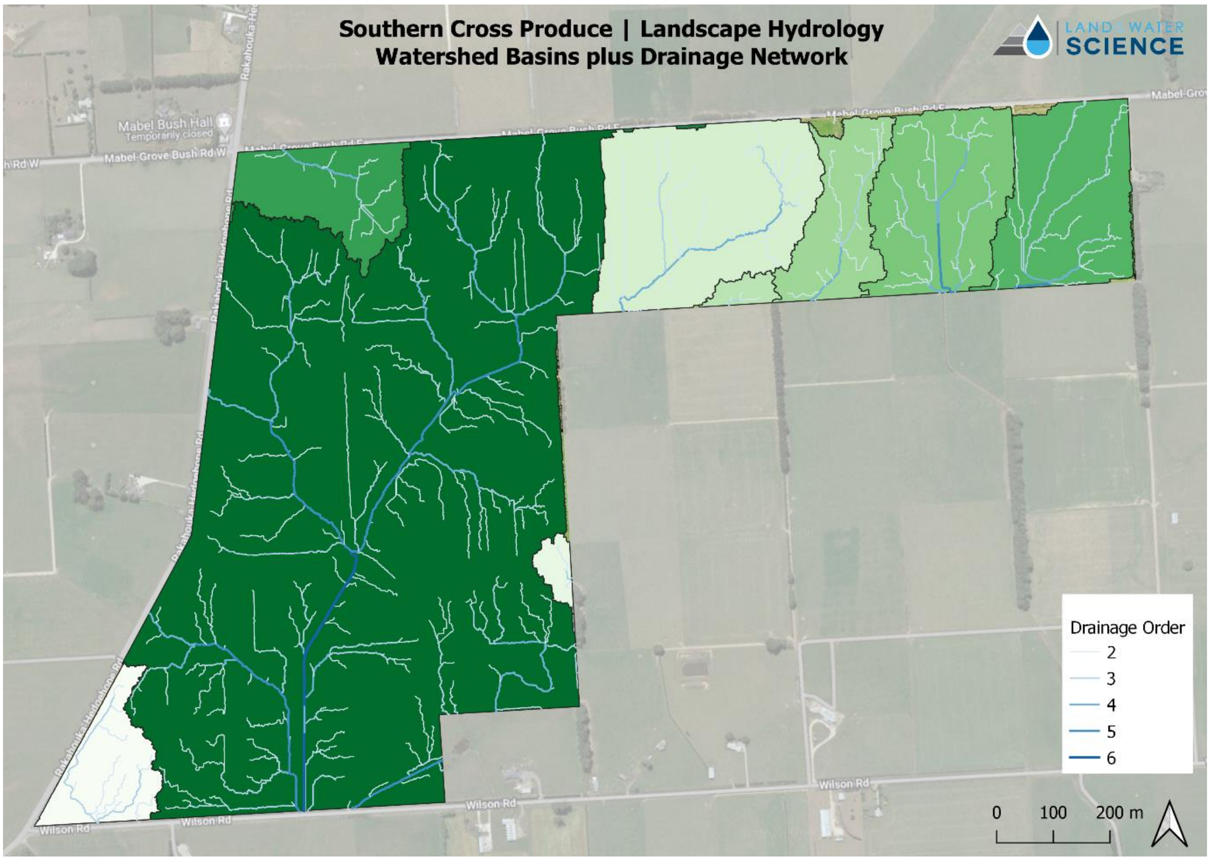


*Figure 5. Southern Cross Produce - landscape hydrology – watershed basins plus drainage order network. These watersheds can be further subdivided for each tributary.*

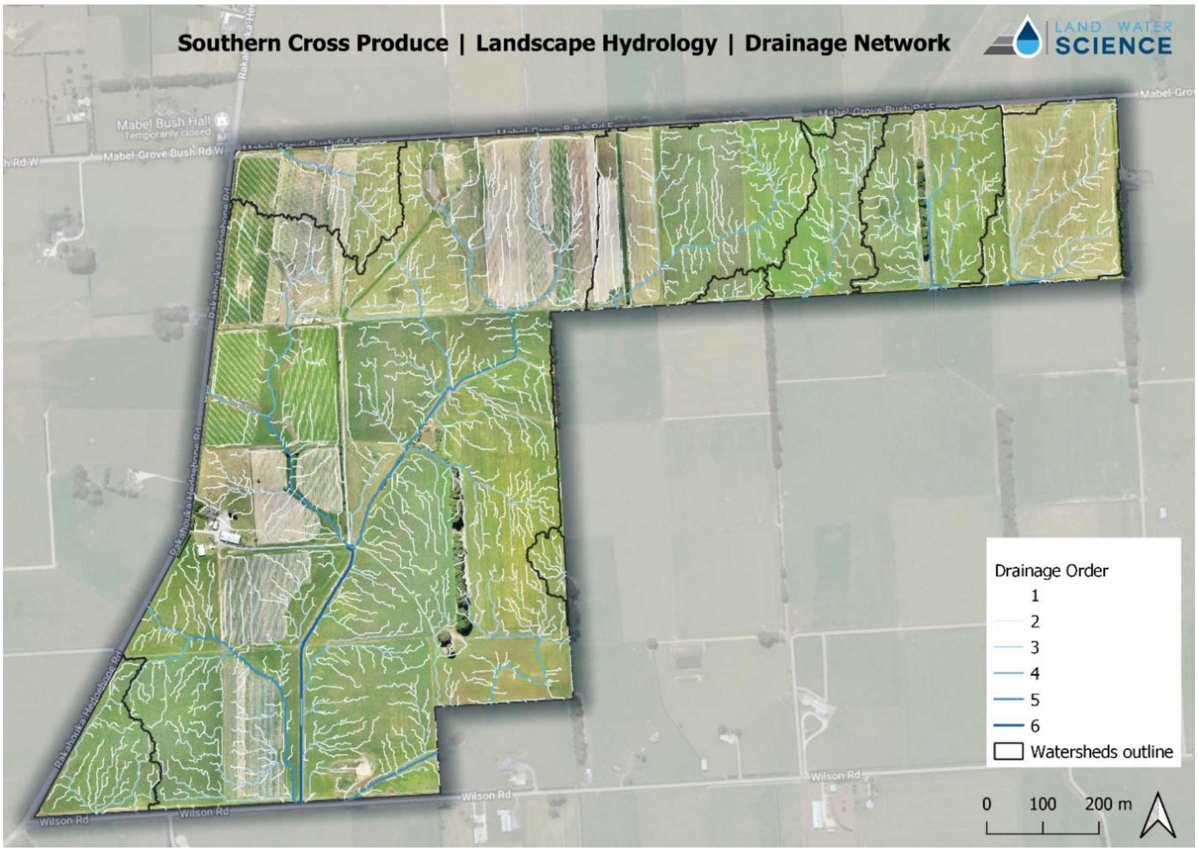


*Figure 6. Southern Cross Produce - landscape hydrology – drainage network. The legend denotes the 'order' of a drainage lines, with low order drainage connecting to generate higher order drainage lines.*

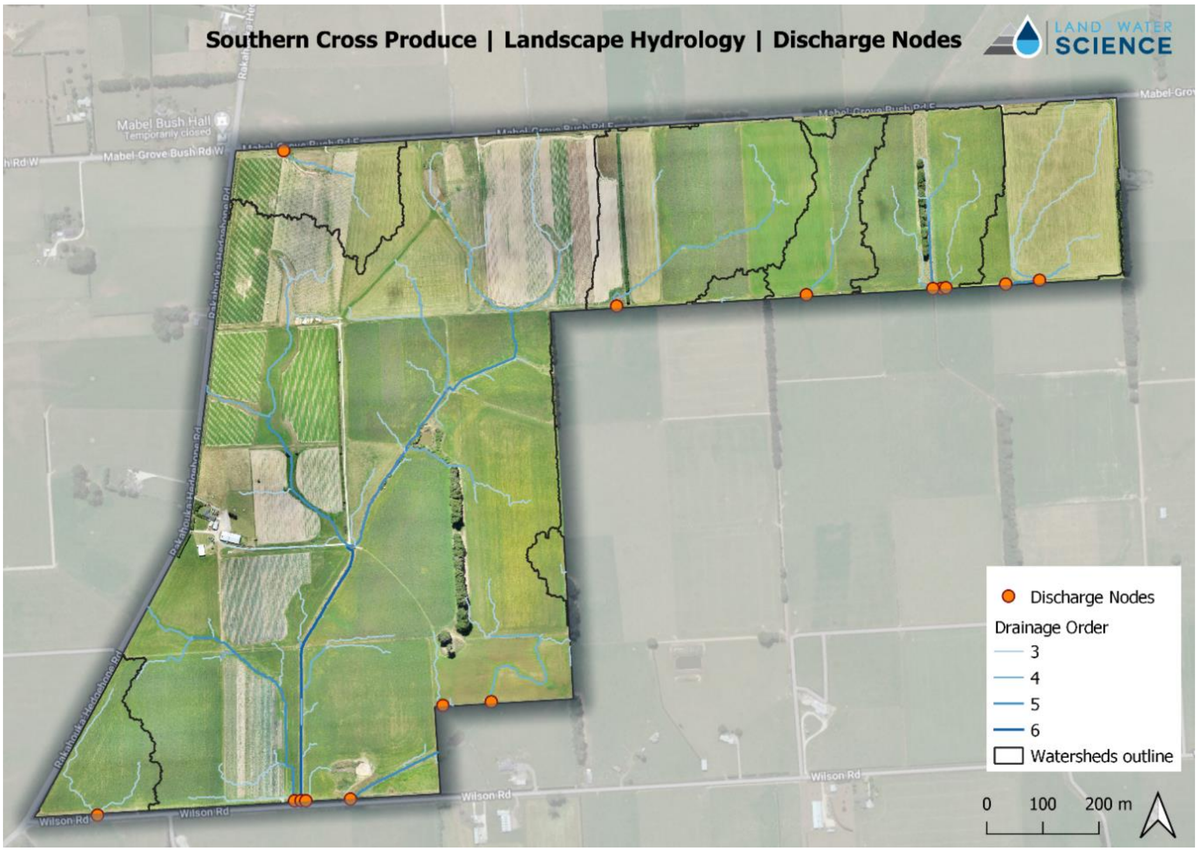


*Figure 7. Southern Cross Produce - landscape hydrology – 'discharge' nodes plus drainage network. Discharge nodes are the points where the water leaves the property.*

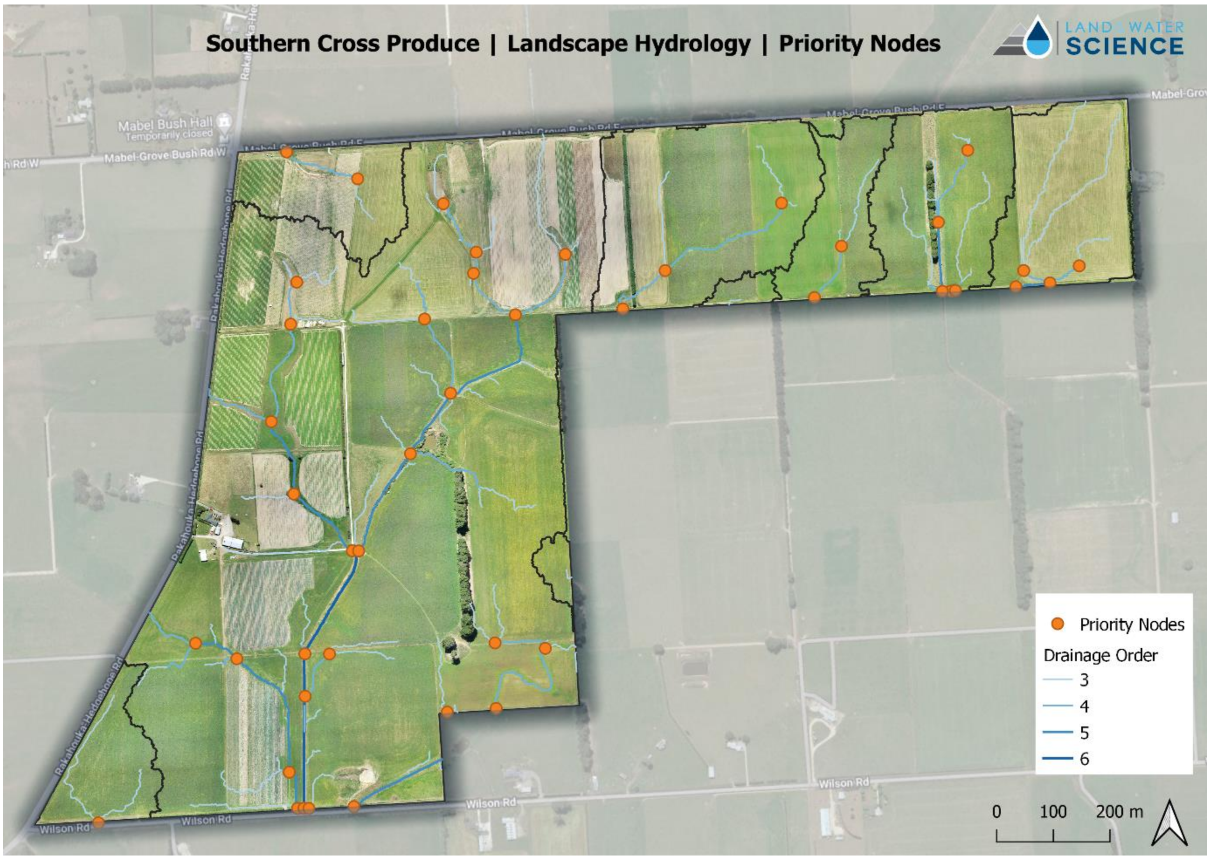


*Figure 8. Southern Cross Produce - landscape hydrology – drainage orders 3 - 6 only (i.e., the major drainage channels within the farm property), plus the related junctions and discharge nodes.*

The spatial context provided with the hydrological mapping creates insights as to the source and movement of water across the property. Again, water is the dominant control over contaminant loss. As such, the hydrological network generated here is seen as a critical starting point for understanding and prioritising possible mitigations to support a more resilient farm system e.g., sediment traps ('Duck Pond), wetland areas etc. It is our recommendation that the hydrological model of the property be used as a spatial framework through which the susceptibility of the farm landscape is viewed and ultimately managed.

## 5. Landscape Susceptibility

The landscape is a significant driver of variability in the type and severity of water quality and soil GHG loss, even when land use is the same. Land & Water Science Ltd (LWS) have generated a new, high-resolution approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales (Figs. 9 - 16).

The mapping provides integrated knowledge on the property-scale landscape factors that control water quality and soil nitrous oxide emissions across Southland. The maps of landscape susceptibility highlight the various contaminants and their forms using a scale of very low, low, medium, and high. As with any model, ground truthing in partnership with rural communities is the best way to ensure that the outputs are relevant.

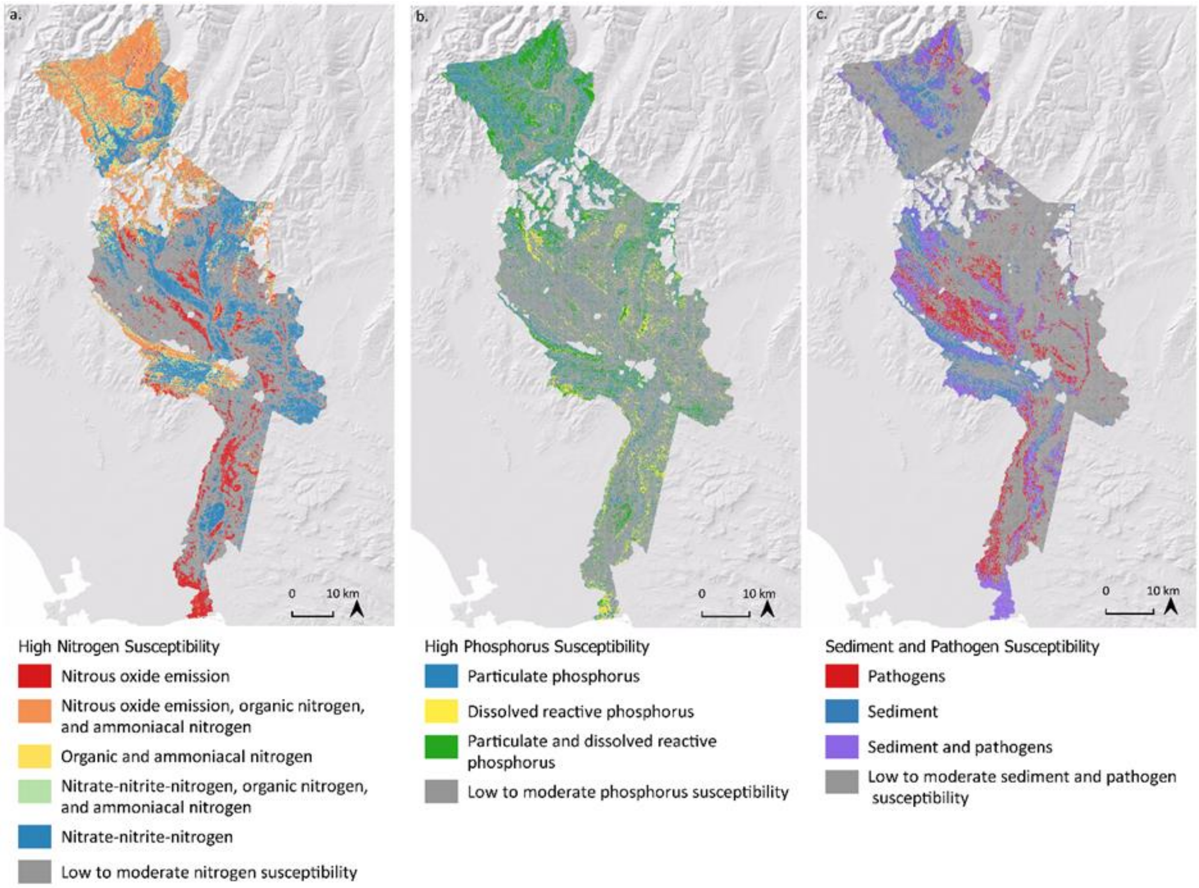


*Figure 9. Example maps of landscape susceptibility (high) for the Mataura Catchment, Southland*

Before reading any further, it is important to emphasise:

A. that the susceptibility models presented below do not take into account land use nor any existing management practices or physical mitigations (e.g., sediment traps, wetlands) that are already in place, and;

B. when reviewing the maps please note they are *not* identifying actual losses, rather they seek to identify the natural susceptibility of the landscape to inform land users of the risks and opportunities associated with their landscape.

## 5.1 Landscape Susceptibility to Erosion

To assess the susceptibility of the property to erosion the drainage network derived from the drone survey was overlaid with an earlier classification of the susceptibility of the landscape to erosion and sediment loss (Fig. 10). The erosion susceptibility layer is based on the integration of several datasets, not limited to airborne radiometrics and a regional scale digital terrain model. Within the erosion susceptibility classification, red areas are identified as having a naturally elevated susceptibility to erosion and are mainly associated with hill and high country areas that have erodible geologies. For the subject property, this classification reflects moderately low to low susceptibility.

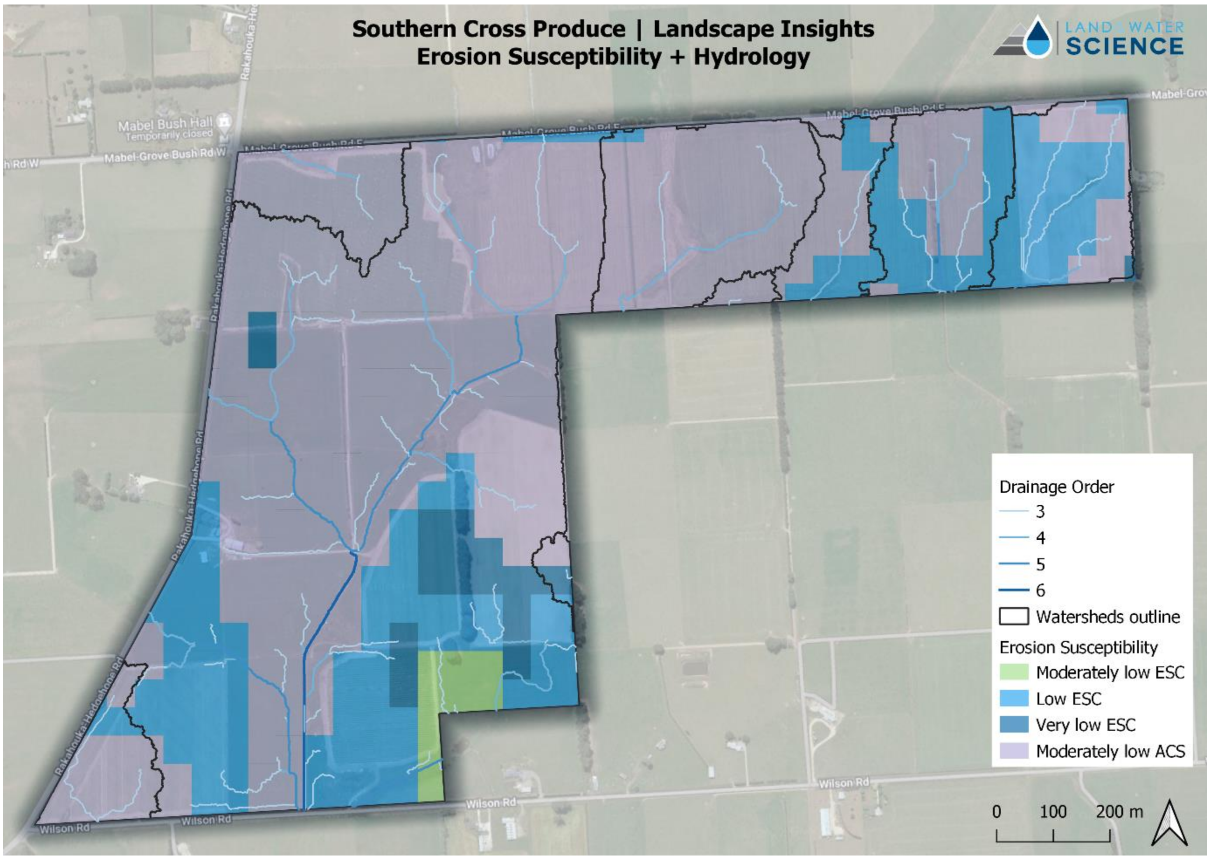

*Figure 10. Southern Cross Produce. Terrain Ruggedness Index showing the areas of the property which has the roughest terrain.*

Two different types of erosion susceptibility are identified. The lowest lying and flattest areas are associated with a mauve colour and a ‘Moderately low ACS.’ Where ACS defines the ‘activity status’ of the low-lying area in terms of its susceptibility to sediment mobilisation in response to runoff. The ‘moderately low ACS’ for the majority of the property is likely a feature of the low relief and the relatively large area of well drained Waikiwi Soils.

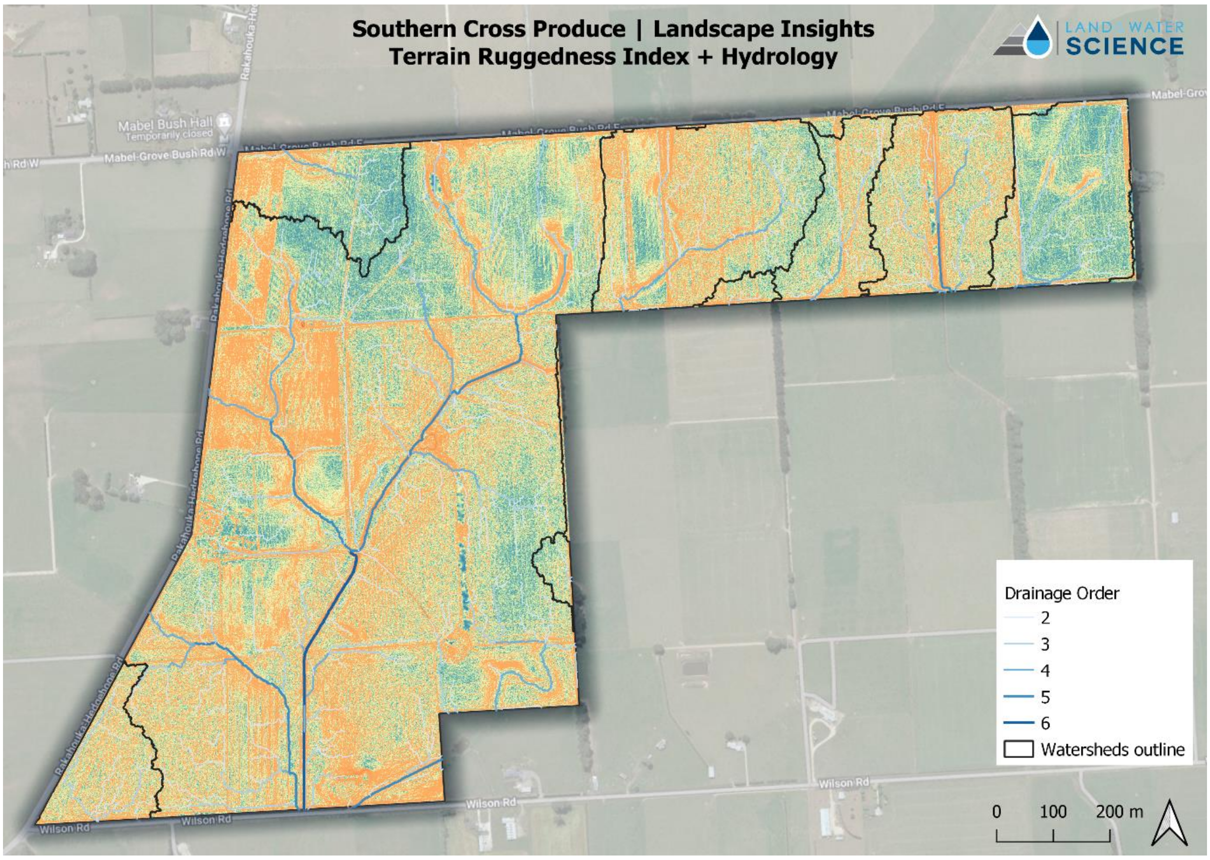


*Figure 11. Southern Cross Produce - landscape hydrology overlaid with Erosion Susceptibility, developed by Land and Water Science (2020).*

The drone survey also enabled a new, higher resolution (0.7 x 0.7 m with a vertical resolution of 0.02 cm) model of terrain ruggedness to be defined for the property (Fig. 12). The Terrain Ruggedness Index (TRI) presented here is a new output that provides much finer scale resolution over the ruggedness of the landscape. The TRI has been widely used nationally and internationally to support identifying areas of active erosion. The new TRI layer can be utilised to identify sub-paddock scale erosional features such as slips, slumps, soil creep (terracettes), and erosional features that are generated in response to ephemeral runoff. The TRI map, when used in combination with the digital drainage network and landscape susceptibility models, could be used to narrow down ('hone in') the areas of highest susceptibility for prioritisation. The utility of the TRI as a tool for sub-paddock scale identification of erosion will be provided as part of the farm visit.

The TRI output identifies the steep drainage channels throughout the property as having the greatest susceptibility to erosion and sediment loss. Where high TRI coincides with poorly drained and slowly permeable soils, the risk of erosion and runoff is elevated. During a high-intensity rainfall event, e.g., a thunderstorm, runoff may result in these soils being incised, and the eroded soil carried to the drainage network.

Overall, the susceptibility of the landscape to mass wasting and erosion is considered moderately low. The main control over sediment loss is runoff. The runoff of water across the land can down cut or degrade soils, with the eroded soil material transported as sediment. The role of runoff in transporting sediment is an important feature of the susceptibility of this property and is discussed below.

## 5.2 Landscape susceptibility to soil zone nitrous oxide loss

When a soil becomes saturated with water, even for a short period of time, it may generate nitrous oxide. Nitrous oxide is a potent soil GHG with a warming potential of c. 273 times that of carbon dioxide[1]. It is produced from soils that saturate easily, either due to a slowly permeable topsoil or imperfect to poor drainage. However, if the soil lacks nitrate then very little nitrous oxide will be produced. Urine patches, from livestock are often a key source of urea that is rapidly converted to nitrate under the right conditions.

In brief, the mass of nitrous oxide produced is a factor of the surplus of nitrate in the soil, soil temperature, and the duration of saturation of the soil. Low volumes of nitrous oxide are generated when soil temperatures are low, soil nitrate concentrations are low, and the topsoil is not saturated. High volumes of nitrous oxide are generated when soil temperatures are elevated, soil nitrate concentrations high, and topsoil becomes saturated.

The transition from well drained Waikiwi soils through to > moderately well > imperfect > to poorly drained Dacre soils also controls the susceptibility of the landscape to soil nitrous oxide generation. Specifically, susceptibility to soil nitrous oxide ($N_2O$) emissions increases across the transition from well drained Waikiwi soils to poorly drained Poroa soils. Accordingly, susceptibility is elevated in the vicinity of Dacre soils due to poor drainage, lower lying aspect, and the low permeability of these soils. Although Waikiwi soils have a lower susceptibility to nitrous oxide generation, periodic saturation of the topsoil may still occur in these fine textured soils. Current research has identified an environmentally friendly product for reducing soil nitrous oxide emissions from agricultural soils.

In summary, the susceptibility of Southern Cross Produce to soil zone nitrous oxide is strongly dependent on the soil drainage gradient, which is controlled by topography. Minimising excess soil nitrate prior to the autumn when soil moisture increases may help reduce nitrous oxide emissions. Work trialling this nitrous oxide inhibitor is ongoing, but should be available on the market within the next 24 months.

[1] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

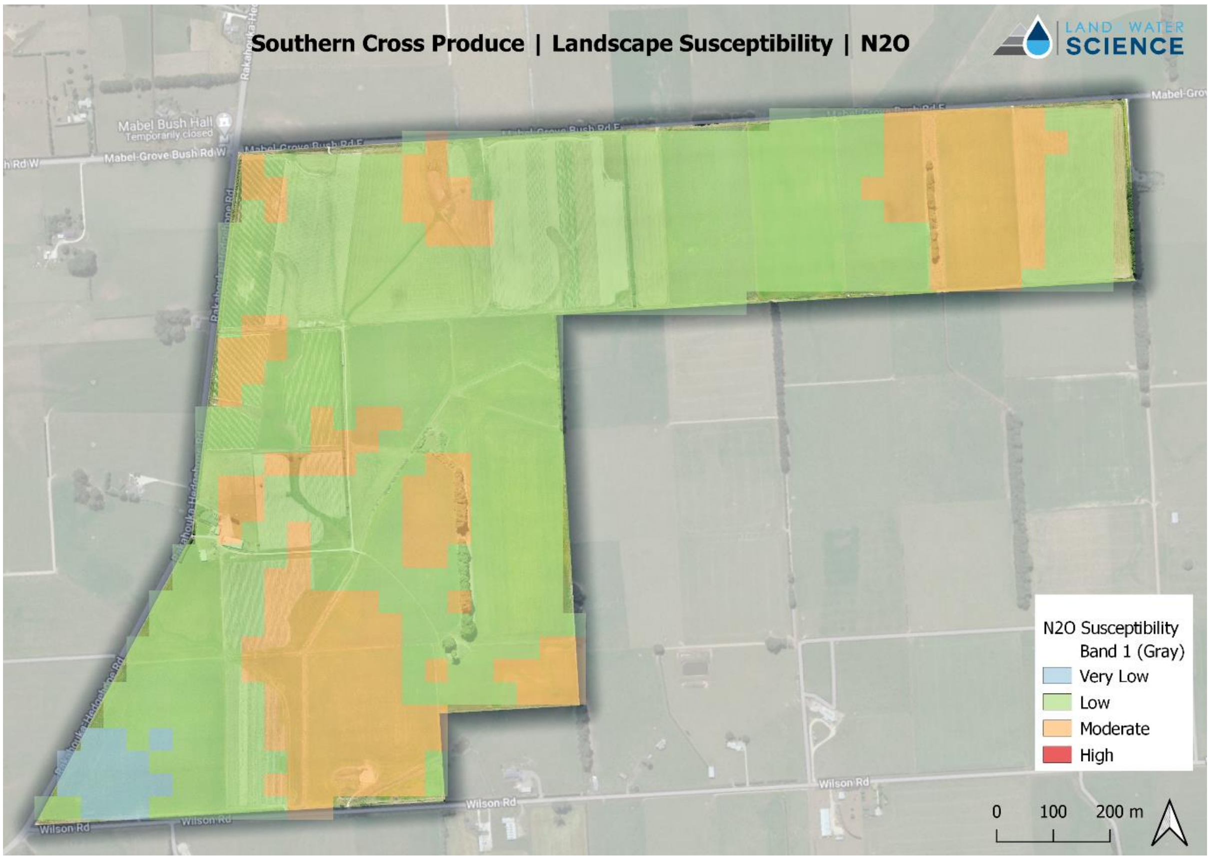


*Figure 12. Southern Cross Produce - landscape susceptibility to soil $N_2O$ (Nitrous Oxide) emission.*

## 5.3 Landscape susceptibility to nitrate-nitrite-nitrogen (NNN) loss

Nitrate and nitrite nitrogen (NNN) is highly soluble and is easily transported through the soil if not used by plants and microorganisms. NNN that moves below the root zone is at risk of being lost via lateral subsurface flow (including via mole-pipe drainage) and via vertical leaching to the underlying water table. Unlike organic or ammoniacal forms of nitrogen, NNN is not typically mobilised in surface runoff. Rather, it is 'rinsed' or leached from the soil and travels to the drainage network via subsurface flowpaths.

NNN leaching losses are often greatest where soils are permeable, well drained and deep. Typically, flatter land with well drained soils generate a greater proportion of NNN, which may be lost below the root zone during periods of soil water drainage - drainage usually occurs during the cooler months of the year. However, artificially drained soils and well drained hill country soils may also lose appreciable concentrations of NNN if intensively farmed.

The susceptibility of the Southern Cross Produce property to NNN loss varies with soil type and elevation (Fig. 13). Specifically, the highest susceptibilities to NNN loss are associated with well drained Waikiwi soils that occupy the higher relief areas of the property. As the elevation decreases and proximity to a drainage channel (swale) increases, the susceptibility to NNN decreases. This reflects the important role of topography over the drainage characteristics of soils. Specifically, soils that occupy higher elevation or steeper parts of the property are more likely to be well drained. Soils that occupy low lying areas, especially those soils adjacent to a drainage channel, are more likely to be imperfectly to poorly drained.

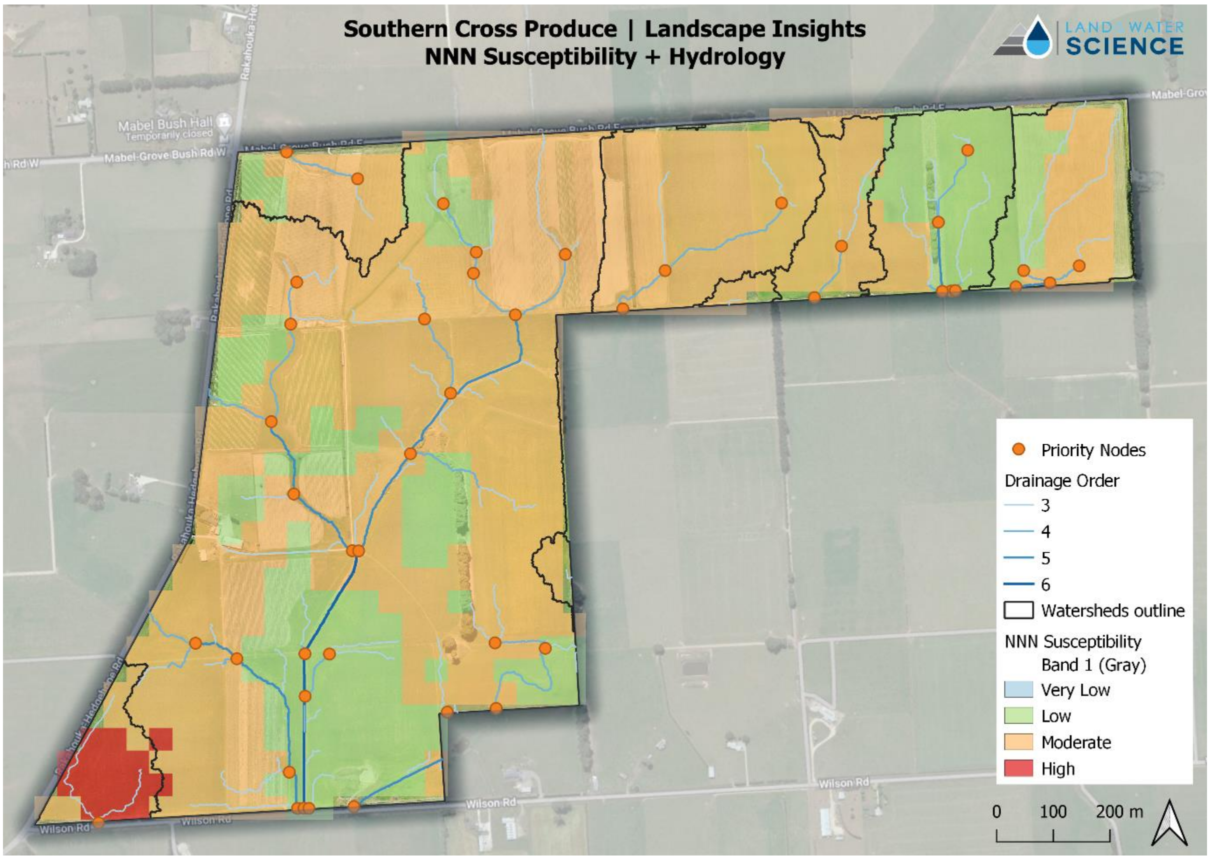


*Figure 13. Southern Cross Produce - landscape susceptibility to NNN (Nitrate-Nitrite Nitrogen) contaminants, overlaid with the hydrology content.*

The transition from well drained Waikiwi soils through to > moderately well > imperfect > to poorly drained Dacre soils is typical of this area of Southland and reflects the strong influence of topographic variation on soil drainage. The NNN susceptibility map supports this pattern of control with the highest susceptibility to NNN loss associated with elevated parts of the property where well drained Waikiwi soils predominate, and the lowest susceptibilities associated with low lying Dacre soils. Nitrate leached from well drained Waikiwi Soils may: i. migrate laterally towards the drainage network, typically as part of a shallow subsurface flow, and/or; ii. percolate vertically to depth, leaching to the underlying water table. Typically, where a soil is very well drained and elevated, a greater proportion of NNN will percolate vertically to the underlying water table, whereas a poorly drained soil, especially one that has been artificially drained, is more likely to discharge NNN via lateral flow to the surface water network.

The lowest susceptibility to NNN loss occurs in the areas defined as Dacre soils, where the soils are inferred to be poorly drained. These soils may actively remove NNN, converting it to nitrous oxide. However, as mentioned above, an important factor when considering the landscapes susceptibility to contaminant loss is the presence or otherwise of artificial drainage. Drainage of formerly imperfectly to poorly drained soils commonly favours NNN loss[2]. However, as to whether or not excess NNN loss is occurring across the areas with elevated susceptibility will be strongly controlled by land use intensity. Accordingly, it is important to emphasise that the susceptibility models do not take into account land use nor any existing management practices that designed to limit NNN loss. As such,

[2] https://www.massey.ac.nz/~flrc/workshops/14/Manuscripts/Paper_Cameron_2014.pdf

landscape susceptibility models only identify the inherent or natural susceptibility of the land, they do not indicate that the areas of elevated susceptibility are in fact losing high rates of contaminants.

In summary, the landscape settings suggest that NNN loss is likely an important management consideration for Southern Cross Produce on this property. Minimising the concentration of nitrate held in the soil prior to the autumn is one possible way to reduce the amount of NNN lost via leaching to the underlying aquifer or via subsurface artificial drainage.

## 5.4 Landscape susceptibility to Particulate Phosphorus (PP) loss

Particulate phosphorus (PP) refers to phosphorus that is attached to sediment that is mobilised in response to runoff. This includes organic and inorganic phosphorus from natural rock weathering, erosion of soil (stream or drainage channel erosion), animal manures, and fertiliser. Soils with high Olsen-P values can produce large quantities of PP if eroded. As with sediment, PP is transport by water across the land to the drainage network. The abundance of P in a soil is a factor of the P content of the geology the soil is formed in, the P that has been added by animals, the addition of inorganic fertiliser, and the breakdown of organic matter. As noted for NNN, it is important to emphasise that the susceptibility models do not take into account land use nor current environmental mitigations that are already in place. As such, they only highlight the inherent or natural susceptibility of the land.

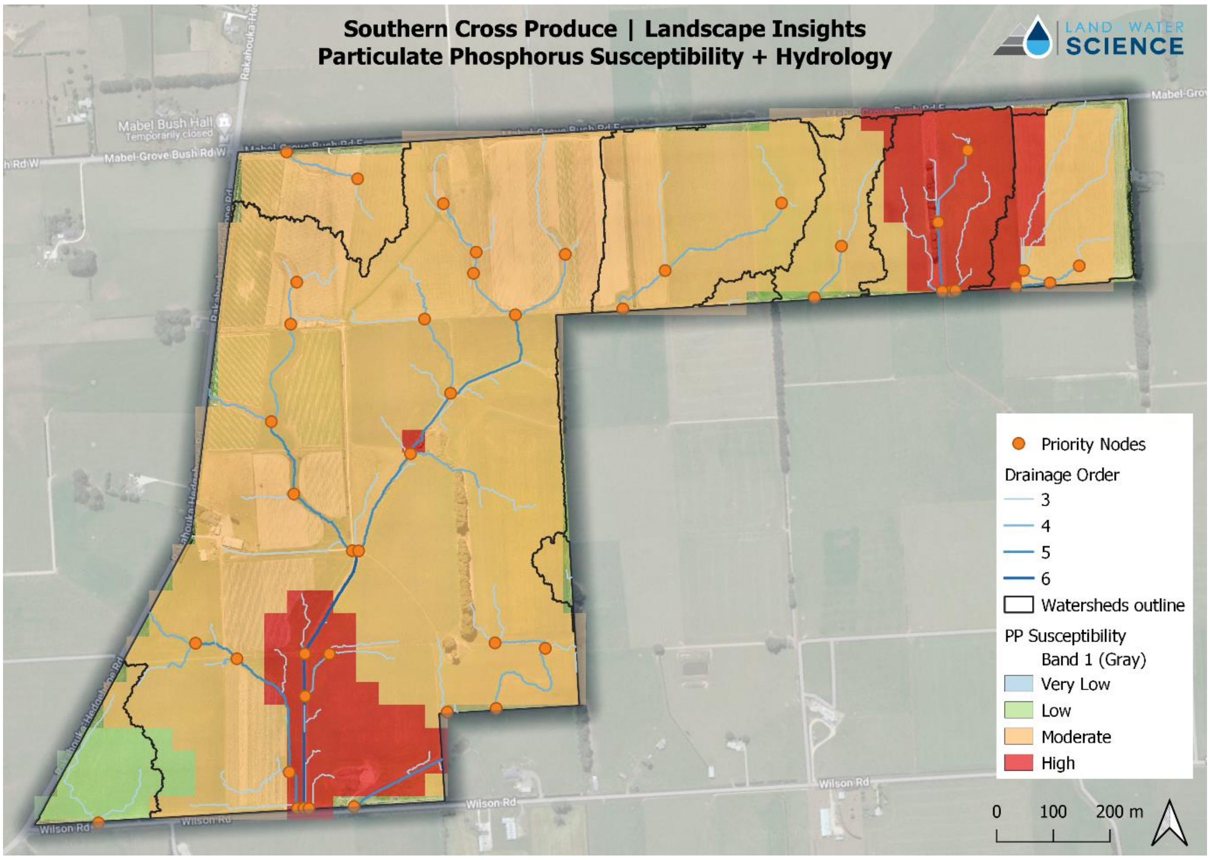


*Figure 14. Southern Cross Produce - landscape susceptibility to PP (Particulate Phosphorus) contaminants, overlaid with the hydrology content.*

The PP susceptibility map for Southern Cross Produce indicates a transition from low susceptibility across well drained Waikiwi soils to higher susceptibilities across low lying areas that are associated with poorly drained Dacre soils. This pattern of susceptibility is consistent the transition from well drained (Waikiwi) through to > moderately well > imperfect > to poorly drained Dacre soils (Fig. 14). An elevated landscape susceptibility to PP loss across lower lying areas is unsurprising given the fine texture, poor drainage, and low permeability of Dacre soils which favour runoff. In summary, the landscape settings suggest that PP susceptibility is something to be mindful of. Managing Olsen-P levels so they do not exceed recommended values is one way of limiting the concentration of P in runoff.

## 5.5 Landscape susceptibility to Dissolved Reactive Phosphorus (DRP) loss

Excess P, both as DRP and PP, is a key nutrient for plants and algae, with high concentrations leading to weed growth and algae blooms in waterways. Dissolved reactive phosphorus (DRP) refers to the phosphorus compounds that are dissolved in water as opposed to those that are attached to sediment i.e., PP. Typically, DRP is characterised by very small molecules that are strongly held by most soil and geological materials. As DRP binds strongly to soil and geological materials it will become PP if the soil is eroded or fine sediment is lost via the subsurface artificial drainage network.

The DRP susceptibility map for Southern Cross Produce indicates low landscape susceptibility (Fig. 15). The landscape settings suggest that DRP susceptibility is unlikely to be important for this property.

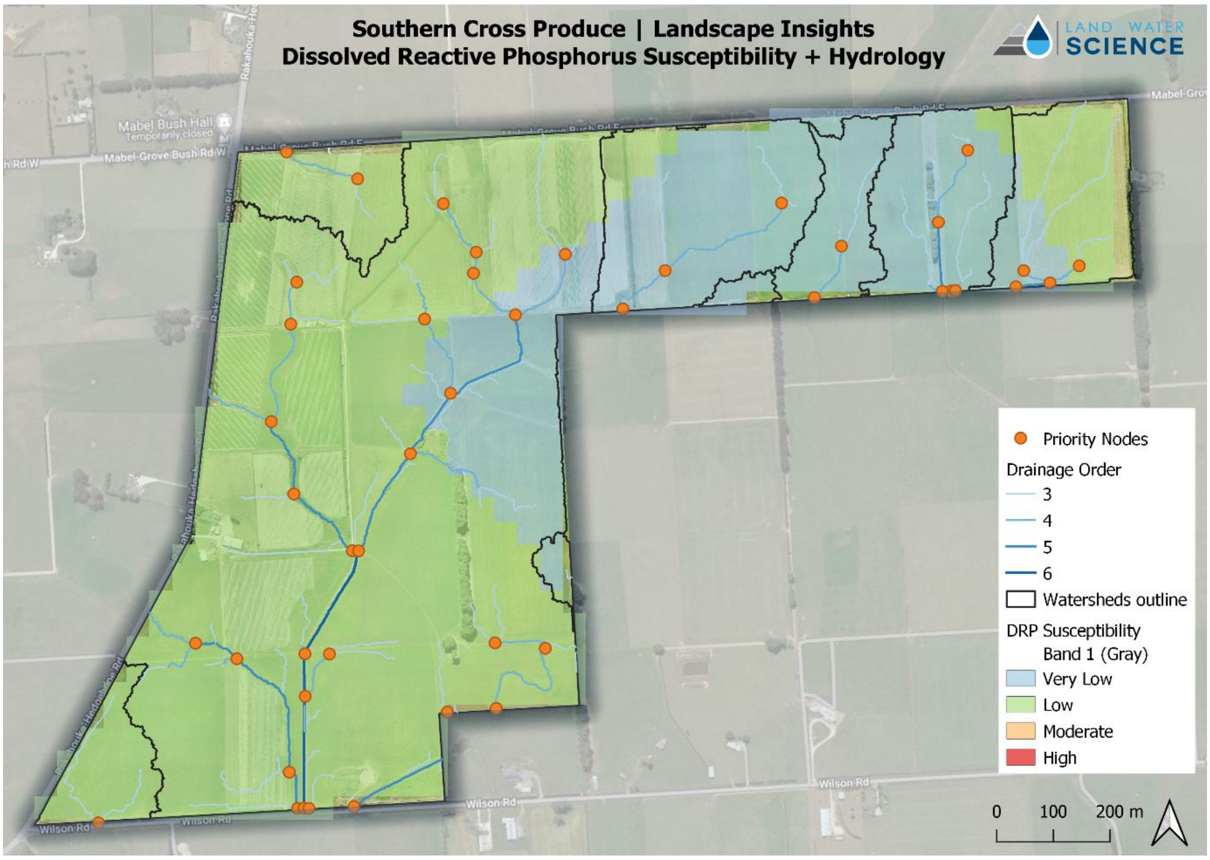


*Figure 15. Southern Cross Produce - landscape susceptibility to DRP (Dissolved reactive phosphorus) contaminants, overlaid with the hydrology content.*

## 5.6 Landscape Organic and Ammoniacal Nitrogen (TKN) Susceptibility

Total Kjeldahl Nitrogen (TKN) is a measure of organic and ammoniacal N. Organic and ammoniacal nitrogen are derived from the breakdown of organic matter, soil organic matter, manure, and animal urine. Organic nitrogen is mineralised to ammoniacal N, ammoniacal N is oxidised to nitrite and ultimately nitrate. The loss of excessive TKN from land e.g., from a recently cultivated paddock, is therefore an important factor controlling stream health. However, it is important to note that all natural systems generate TKN, with TKN loss occurring from natural state landscapes and farmed land. The main difference between natural state and any developed landscapes are the magnitude of losses.

Commonly, natural TKN losses are elevated for soils that are imperfectly to poorly drained or prone to saturation for extended periods of the year. The TKN susceptibility map for Southern Cross Produce indicates a transition from low susceptibility across well drained Waikiwi soils to higher susceptibilities across low lying areas that are associated with poorly drained Dacre soils. In summary, the landscape settings suggest that TKN susceptibility is something to be mindful of.

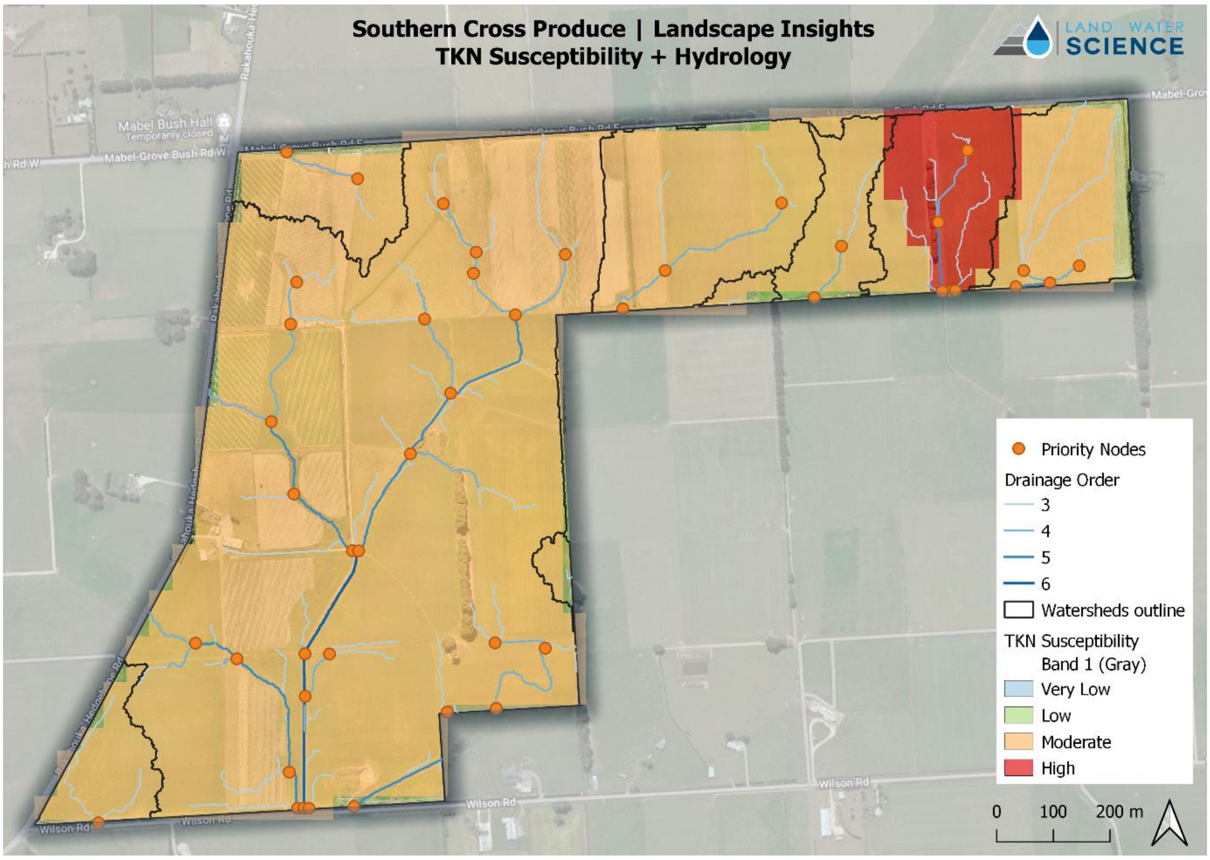


*Figure 16. Southern Cross Produce - landscape susceptibility to TKN (total Kjeldahl nitrogen – being organic and ammoniacal nitrogen) contaminants, overlaid with the hydrology content.*

## 6. Next steps

This report introduces the landscape datasets and insights available for this Southern Cross Produce property and provides an assessment of the susceptibility of the farm's landscape. We hope that the datasets presented here provide some helpful insights that can be used to support aligning the land use with the landscape variability through input from specialist land use experts, and feedback from other growers during the planned field day.