FALKLAND ISLANDS SOIL MAP INTERPRETATION GUIDE

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Dear landowner / land manager,

We are very pleased to be able to attach your soil farm maps. The maps were created by the Darwin (DPLUS083) Falklands Soil Mapping Project (April 2018 – October 2020), which was aided by the Darwin Initiative through UK Government funding. The project was led by SAERI in collaboration with the Falkland Islands Government's Department of Agriculture, James Hutton Institute, UK Falkland Islands Trust, UK Centre for Ecology and Hydrology, University of Magallanes and the Natural History Museum.

The soil maps were created using digital soil mapping, which was informed by fieldwork over two summers at 200 survey sites and lab analyses of soil samples from these survey sites. The soil property information refers to the top 20 cm of the soil only. The category thresholds applied to each individual layer were designed as an interpretation guide but are not meant to be defining limits. All maps are produced at a 30 x 30 m pixel resolution.

The map interpretation provided here is based on global standards from more productive agricultural lands; the application and interpretation of Falkland soils can be challenging for some parameters due to the lack of published scientific work in acidic, high organic matter soils, which are characteristics of Falklands soils. This is explained in the relevant sections in this guide. These maps provide a great starting point to quantify the soil resource and have land management applications, although we recognise that further work is required to facilitate interpretation and use of the soil maps, and we hope to address this through future projects. Furthermore, on-going monitoring might be required as soil properties can change with land use over time.

The individual farm maps were based on the current geographic information system (GIS) files for land ownership and internal fencelines. We recognise that this information may be outdated and that internal fenceline information was not available for all farms. If you would like to provide updates for the GIS files and have your farm maps reissued with updated information, please contact us. The Department of Agriculture would also be more than happy to help you with the practical application of this guide, so please do get in touch if you have questions or would like to discuss your maps in more detail.

Lastly, these soil maps are also available for all of the Falkland Islands online through SAERI's webGIS with an enhanced functionality; so please visit SAERI's website (link below) if you would like to explore these further.

Your Soil Mapping Team

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CONTENTS

Soils are a function of the bedrock and past and present climates. Rock building stopped in the Falkland Islands about 250 million years ago, and the Islands were in their present location around 150 million years ago. This means that the Falklands do not have rocks from the most recent geological periods, which usually contain lime-rich rocks. The lack of these lime-rich rocks is critical from a soil composition point of view - there are no basic (alkaline) rocks to counteract the acidity in the soils. Ice sheets in the last glaciation, between 14,000 and 25,000 years ago did not completely cover the Islands. Thus, the mixing of material that occurs during glaciation did not obscure soil parent materials.

The mineral soils of the Falklands have developed by chemical and physical changes from the underlying rocks. What matters is not that the rocks are old or ancient in geological time, but that they are all acid or very acid – as are the related soils. The main difference among the rocks is between the hard, quartz-rich rocks of the mountains lying mainly above 500 m (Port Stanley and Port Stephens formations), and the soft rocks of silt stone, mud stone and tillite which form the lowlands (Fox Bay, Port Philomel, Fitzroy and Lafonia formations). The fine soil material of the latter group contains mainly silt and clay particles, and these have a better mineral nutrient store than the quartzite hard rocks.

The commonly found lowland soil profile has a 30-35 cm surface peaty horizon, overlying a thin bleached horizon (5-10 cm), possibly an iron pan (up to 1-2 cm thick), and all overlying the silty clay, poorly drained, mineral subsoil. In upland areas the common soil profile consists of shallow peat over rocks or over a thin mineral profile. Deep peat – often overlaying greenish-grey – clay is most frequently found in the northern half of East Falkland and some upland areas.

Peat is formed where environmental conditions prevent or greatly slow down the decay of dead plant material. These undecayed plant remains gradually accumulate, with other plants continuing to grow on the surface, which adds to the accumulating organic matter. In the Falklands it is likely that low temperatures and wind driven evapotranspiration restrict the growth of decomposing bacteria; combined with seasonal waterlogging this causes peat to accumulate. Peat and peaty soils are an important carbon sink (ground store of carbon) but climate change predictions for drier conditions with an increased soil moisture deficit in spring could potentially have large knock-on effects for plant growth and soil functions normally associated with peats, such as slow nutrient cycling and carbon sequestration.

In addition to new information on soil type, fertility and peat depth, the Soil Mapping Project will also enable a more accurate assessment of the distribution of peat and the total amount of carbon stored in the soils of the Falklands.

To understand soils more fully, some background knowledge of local geology is helpful (Stone and Aldiss, 2008). An authoritative guide to the origins, general characteristics and agricultural prospects for soils in the Falklands is provided by James Cruickshank (Cruickshank ,2001). In their recent articles in Wool Press (McAdam, McNee and Radic, 2020) some of the team members present background information on the origin of Falkland soils, differences between mineral and peat soils and the soil profile and problems surrounding aluminium content.

pH H_2O
10 g of dried topsoil were mixed with 50 ml of deionised water. After one hour pH was read on a calibrated Mettler Toledo pH meter.

Nitrate-N
Palintest (SOIL.5/N) Photometer method 570 nm (mg/L N). Topsoil is extracted using 1 M ammonium chloride at soil ratio 1:25.

Phosphate
Palintest (SOIL.5/P) Photometer method 640 nm (mg/L P). Topsoil is extracted using 0.5 M sodium bicarbonate at a soil water ratio 1:25.

Potassium
Palintest (SOIL.5/K) Photometer method 520 nm (mg/L K). Topsoil is extracted using a 0.1 M magnesium acetate solution at a soil water ratio 1:25.

Magnesium
Palintest (SOIL.7) Photometer method 520 nm (mg/L Mg). Topsoil is extracted using 1 M potassium chloride at a soil water ratio 1:5.

Calcium
Palintest (SOIL. 11) tablet count method (mg/L Ca). Topsoil is extracted using 1 M potassium chloride at a soil ratio 1:5.

Aluminium
Air dry topsoil was used to test for exchangeable aluminium with the 1 M KCl method.

Bulk Density
A core of a known volume was extracted from the topsoil. Mass of oven-dried soil was divided by the core volume.

Resistance to Penetration
An Eijkelkamp Penetrologger was used to measure soil strength. Cone type: 1.0 cm 260 deg. Penetration speed: 2 cm / second. Five repeat measurements at each location were made and these were averaged for the top 20 cm soil.

Unrubbed Fibre
From a representative sample of fresh topsoil of a moisture content as received two 10 g subsamples are retrieved. One is dried at 105 °C overnight, or to a constant weight, to determine the moisture content. The other sample is placed with 2 g Calgon detergent and 200 ml de-ionised water into a flask, shaken and left to stand overnight. The next morning the flask is shaken by hand thoroughly for 1 minute and then poured over a brass screen of 100 mesh size. The soil is washed on the screen and a 2% HCl solution is added to dissolve any carbonates present in the soil. The screen plus fibrous material over 0.15mm are dried at 105 °C overnight. The dried weight of the fibrous material is weighed. To calculate the results, divide the total dry weight from the first subsample into the weight of fibres over 0.15 mm from the second subsample and multiply by 100. This gives the percent fibre content over 0.15 mm in size.

Organic Matter
A sample (5-10 g) of air-dry topsoil was dried at 105 °C and weighed; this was placed in a furnace at 500 °C for at least 6 hours and re-weighed. Organic matter percentage = (1 – (ash weight/dry soil weight)) * 100.

pH (H_2O)

Soil pH refers to the relative concentration of hydrogen ions (H^+) and hydroxyl ions (OH^-) and is expressed on a scale of 1 (very acid) to 14 (very alkaline). If their concentrations are equal, then the soil's pH is neutral (pH7). In acid soils the hydrogen ions have a greater concentration than the hydroxyl ions (pH < 7); in alkaline soils this is the other way round (pH > 7).

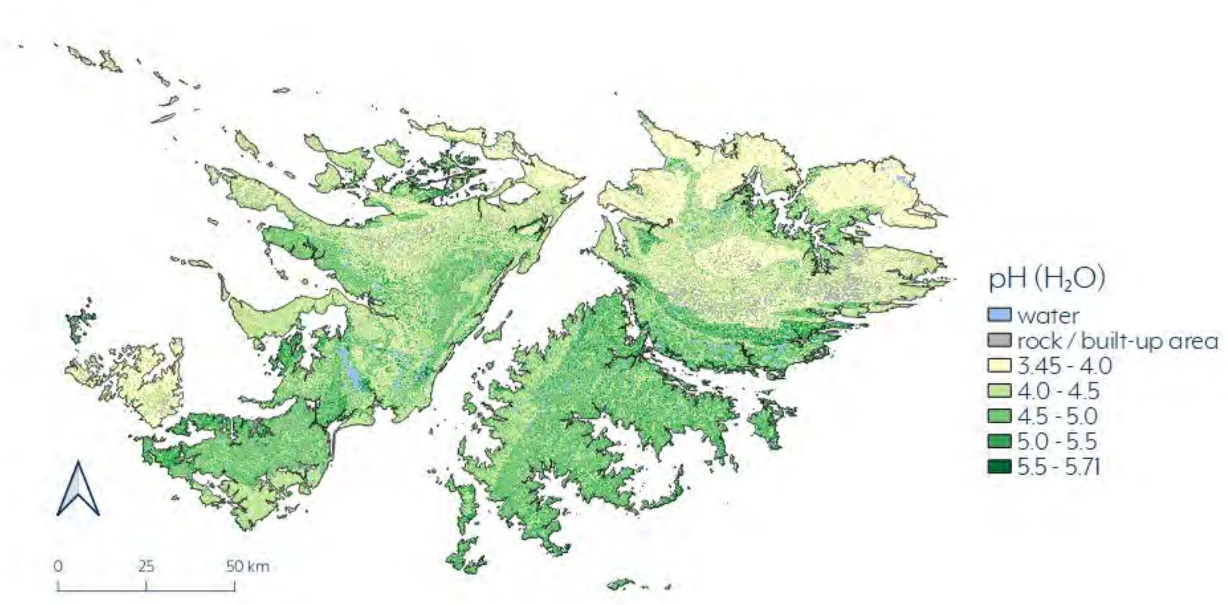
Soil pH can be measured either in water (H_2O) or in calcium chloride ($CaCl_2$); the latter is thought to be more accurate as it reflects what the plants experience in the soil, and is less sensitive to short-term variations, for example due to rainfall. pH measured in calcium chloride is generally lower than measured in water but this is highly dependent on soil type. When referring to a pH value it is important to always state which method was used to measure it.

Soil pH is an indicator of chemical processes in the soil and gives an indication of nutrient availability and toxicities. Macronutrients such as calcium, magnesium, nitrogen, potassium and phosphorous are only found in low amounts in acid soil, whereas other elements such as aluminium, iron and manganese are present at higher concentrations in acid soils. This can lead to toxicity, which can inhibit plant root growth. The level of pH also impacts presence and activity of soil microorganisms, which in turn impacts availability of macronutrients. These processes are discussed in detail for each relevant macronutrient.

The Soil Mapping Project tested pH with both methodologies in order to be able to compare the results as widely as possible. Across the Falkland Islands the mapped pH_{water} ranges from 3.45 to 5.71. The majority of areas are either very strongly or extremely acidic; the aforementioned issues with reduced nutrient availability increased toxicities can therefore be expected in the Falkland Islands.

Table 1 : Relevant pH categories for the Falkland Islands (adapted from Hazleton & Murphy, 2016).

pH_{H2O}	STANDARD INTERPRETATION
3.45 – 4.0	extremely acid
4.0 – 4.5	extremely acid
4.5 – 5.0	very strongly acid
5.0 – 5.5	strongly acid
5.5 – 6.0	moderately acid



NITRATE-N

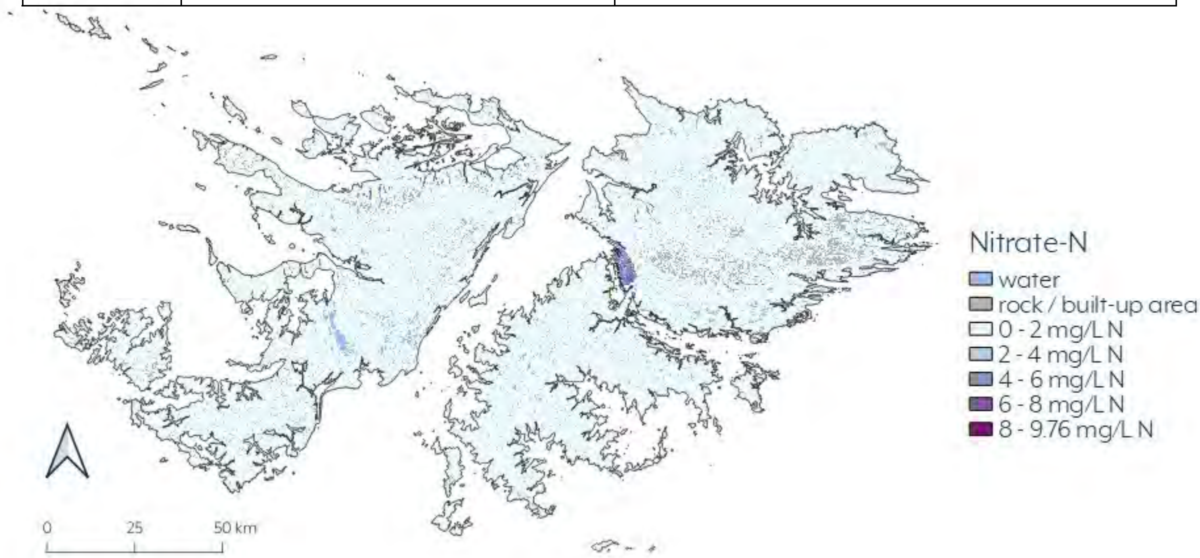
About 99% of all nitrogen is present in the atmosphere. Atmospheric nitrogen is therefore the major source of nitrogen for plants. Atmospheric nitrogen is deposited mainly through rainfall or can be fixed by symbiotic or non-symbiotic organisms. Nitrogen is an essential macronutrient of which plants need a large amount during the growing season. Most of the soil nitrogen is locked away in organic matter. Conversion of organic nitrogen into plant-available form – ammonium and nitrate – occurs through a process of mineralisation. Nitrate is also obtained through the nitrification of ammonium; however, nitrification is inhibited in acid soils by nutrient deficiencies of calcium and magnesium as well as Al toxicity; cold temperatures also inhibit nitrification. Low nitrate contents in grasslands can also occur when vegetation competes with nitrifying bacteria for ammonia.

For the Soil Mapping Project nitrate nitrogen was determined with Palintests and is expressed as mg/L N. Across the Falkland Islands the mapped values range from 0 to 9.76 mg/L N but the majority of values are <1 mg/L N. The measured nitrate levels across the Falkland Islands are low for all crops, based on interpretation for mineral soils in glasshouses; for the organic soils in the Falklands these low values may indicate a gradient of fertility. Furthermore, it is important to bear in mind that nitrate levels in field conditions can be very transient and variable and depend on many factors such as weather conditions. Higher nitrate values (up to 250 mg / L N) were recorded during the soil survey in tussac peat where sea lions were present but these are not reflected on the map.

The comparably low values can be explained by several factors: there is usually an identifiable peak and trough cycle of nitrate availability present in soils, which is dependent on soil temperature, moisture and plant uptake. Atmospheric nitrogen deposition is generally low in the Falklands compared to industrialised areas, decomposition of organic matter will be slow due to generally cold temperatures and nitrification processes are inhibited by high soil acidity (low pH) and cold temperatures. Furthermore, biological nitrogen fixation associated with plants is limited because there are no native legumes in the Falkland Islands and therefore the *Rhizobium* bacteria, essential for atmospheric nitrogen fixation, is not widespread. Apart from *Rhizobia* in introduced legumes, the only known plant-associated terrestrial nitrogen fixation occurs through bacteria which are in a symbiotic relationship with native pig vine *Gunnera magellanica*.

Table 2 : Nitrate-N concentrations given in ranges relevant for Falkland Islands soils (adapted from Bailey, 1993).

INDEX	NITRATE-N mg/L N	STANDARD INTERPRETATION
0	0 – 2	Low 1
0	2 – 4	Low 2
0	4 – 6	Low 3
0	6 – 8	Low 4
0	8 – 10	Low 5



PHOSPHATE

Phosphate in soil comes from minerals called apatites. An additional source of phosphate is organic waste (seabird guano is of particular relevance to the Falklands) and industrial fertilisers. Phosphate is an essential macronutrient, which has many different functions in plants, but most importantly it is required for energy storage.

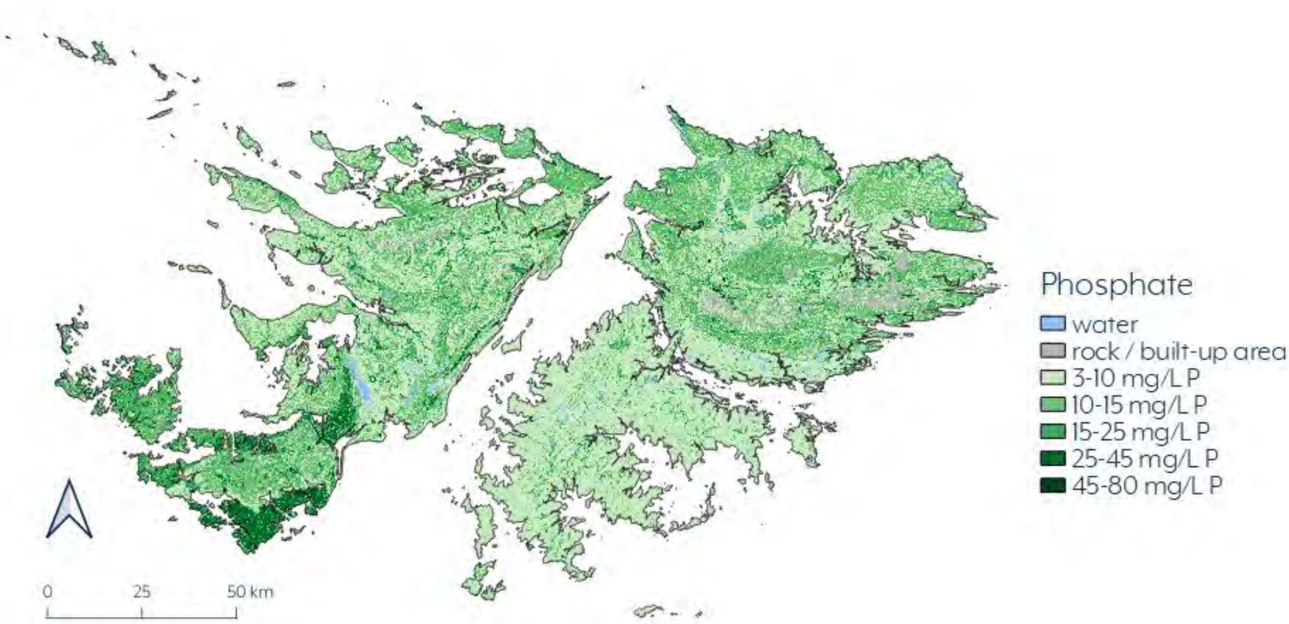
Total phosphate in the soil has a weak relationship with plant-available phosphate. Plant-available phosphate is heavily dependent on pH and concentrations of other elements. When pH is low, plant-available phosphate is often lost through reaction with iron and aluminium compounds. Organic matter, on the other hand, has the potential to offset this to some degree; organic compounds released through decomposition bind with iron and aluminium, thereby preventing them from reacting with phosphate.

For the Soil Mapping Project the total phosphate was determined with Palintests and is expressed as mg/L P. The mapped values across the Falkland Islands range from 3.5 to 79 mg/L P but the majority of phosphate levels are either deficient or low for all crops. Low soil pH and high concentrations of exchangeable aluminium* mean that little of the phosphate present in the soil is actually available to plants. High organic matter in Falkland soils may counteract this effect but it is not known to which degree. A general phosphate deficiency for the Falkland Islands can be assumed.

* It should be noted that extractable aluminium is a better indicator for phosphate retention.

Table 3 : Phosphate concentrations given in ranges relevant for Falkland Islands soils (adapted from Bailey, 1993).

INDEX	PHOSPHATE mg/L P	STANDARD INTERPRETATION
0	0 – 10	deficient for all crops
1	10 – 15	low for all crops
2	15 – 25	adequate for grassland
3	25 – 45	adequate for grassland
4	45 – 80	adequate for most outdoor crops



POTASSIUM

Potassium is found in several primary minerals such as feldspars and micas. Other sources include organic waste and industrial fertilizers. After nitrogen and phosphorous, it is the third major nutrient and an essential element for plant growth.

Potassium is available in four states: mineral (unavailable, 90-98%), fixed (slowly available, 1-10%), exchangeable and soil solution (readily available, 0.1 to 2%.) The release of potassium from the mineral and fixed state to the plant available forms is slow and is heavily dependent on weathering processes. Plant uptake potential also depends on the presence of other cations. In low pH soils, high levels of soluble aluminium can create unfavourable conditions for potassium root uptake. Potassium also competes with calcium and magnesium for plant uptake: the higher the concentrations of calcium and magnesium, the lower the potassium uptake and vice versa. Excessive soil potassium (>1500 mg/L K) can lead to elevated levels in forage crops and may be detrimental to animal health.

For the Soil Mapping Project, the exchangeable potassium was determined with Palintests and is expressed as mg/L K. The mapped values across the Falkland Islands range from 43 to 866 mg/L K but the majority are less than 200 mg/L K. Potassium values are generally low but are adequate for grazing pastures in most areas. When assessing potassium in localised areas, levels of aluminium, magnesium and calcium should also be assessed.

Table 4: Potassium concentrations given in ranges relevant for Falkland Islands soils (adapted from Bailey, 1993).

INDEX	POTASSIUM mg/L K	STANDARD INTERPRETATION
0	0-60	deficient for all crops
1	60-120	low for all crops
2	120-240	adequate for grazing
3	240-400	adequate for silage
4	400-600	adequate for most glasshouse crops
5	600-900	adequate for potatoes

MAGNESIUM

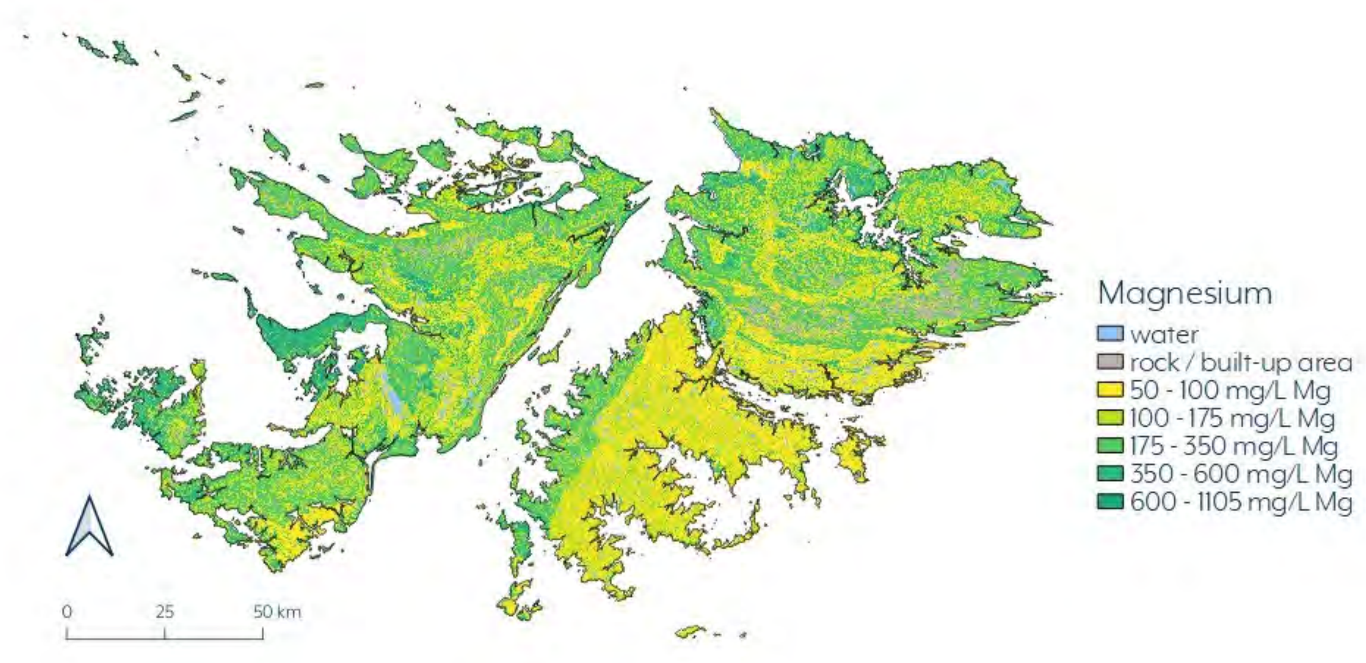
Magnesium is the eighth most abundant element in the earth's crust and is found in minerals such as dolomite and serpentine but also in certain types of clay. In its mineral form, magnesium is only slowly available to plants; weathering processes release magnesium into exchangeable form and into soil solution, both of which are readily available to plants. Magnesium is an essential macronutrient in plants and critical for photosynthesis. Deficiencies are rarely seen in plants but tend to become apparent first in livestock. Magnesium is essential for animal nutrition and low levels in forage crops may lead to hypomagnesaemia.

In acidic soil, magnesium uptake is reduced due to high levels of exchangeable aluminium. Magnesium also competes with calcium, ammonium and potassium for plant uptake; high natural occurrence of any of these may limit magnesium uptake and application levels between these nutrients should be balanced.

For the Soil Mapping Project magnesium levels were tested with Palintests and are expressed in mg/L Mg. The mapped values across the Falkland Islands range from 50 to 1104 mg/L Mg; the majority of values range from 50 to 300 mg/L Mg. An adequate level for grassland and forage crops can be assumed for most of the Falkland Islands but levels of aluminium, potassium and calcium should be cross-checked for localised areas.

Table 5: Magnesium concentrations given in ranges relevant for Falkland Islands soils (adapted from Bailey, 1993).

INDEX	MAGNESIUM mg/L Mg	STANDARD INTERPRETATION
2	0 – 100	adequate for grassland and cereals
3	100 – 175	adequate for most outdoor crops
4 & 5	175 – 350	adequate for most glasshouse crops
6	350 – 600	adequate for tomatoes
7	600 – 1105	excessive



CALCIUM

Calcium is the fifth most abundant element in the earth's crust (3.5%) and is found in minerals such as feldspar, calcite, dolomite and apatite. Calcium is an essential macronutrient for plant growth and cannot be moved within the plant from old to new leaves; plants therefore need a continuous supply throughout the growing season. Plant uptake capacity of calcium, however, is limited because it can only be absorbed by young root tips. Cruickshank (2001) concludes that Falkland Islands soils are massively deficient in calcium (and phosphate) and that all soil improvement projects depend on raising and maintaining the levels of these two elements.

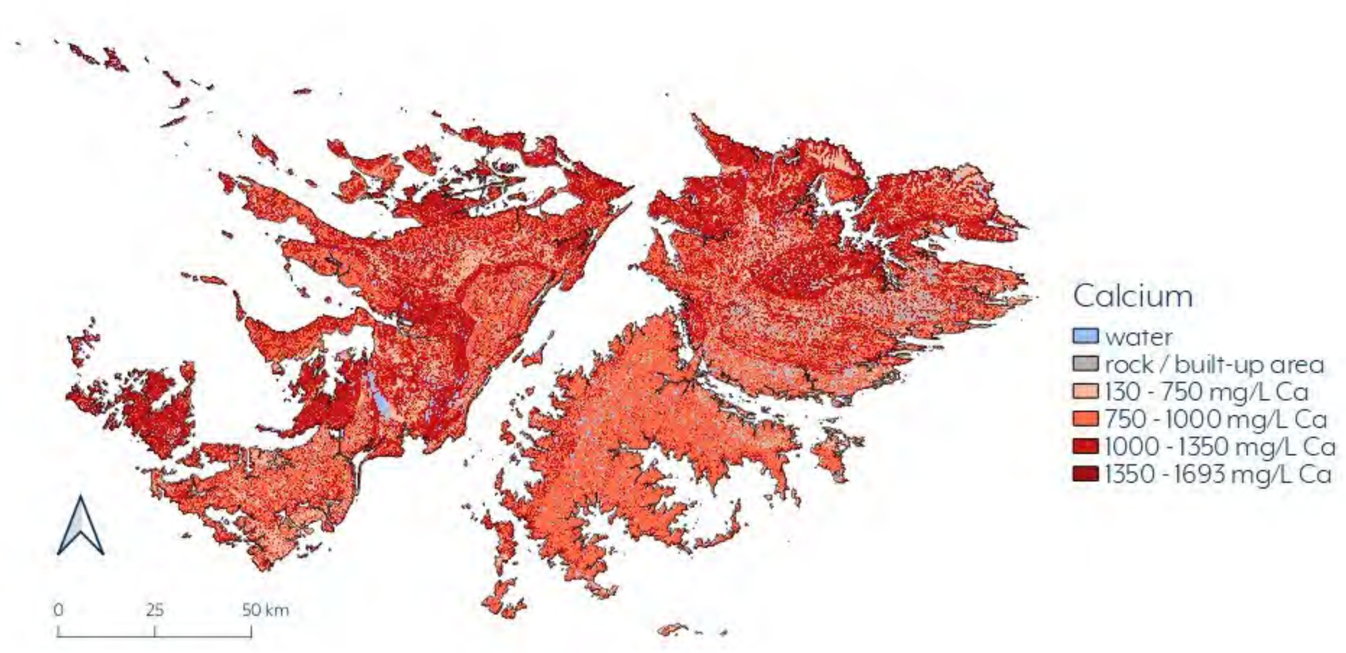
Calcium competes with other elements such as magnesium, manganese and aluminium for uptake and is also depressed by ammonium, but application of nitrate increases uptake. The amount of available calcium decreases as soil acidity increases.

The availability of calcium in soil is highly dependent on weathering processes. Additionally to the mineral form, calcium also occurs in exchangeable form and in soil solution. Calcium is added to the soil with liming materials. The Falklands are at a considerable agricultural disadvantage in having no lime-based rocks. The only naturally occurring sources of calcium are deposits of calcified seaweed around the coast.

For the Soil Mapping Project calcium levels were tested with Palintests and are expressed in mg/L Ca. The mapped values across the Falkland Islands range from 130 to 1693 mg/L Ca and are quite evenly distributed; the majority of values range from 800 to 1200 mg/L Ca. Low to medium values can be assumed for most of the Falkland Islands due to low soil pH but levels of aluminium, potassium and magnesium should also be compared for localised areas.

Table 6: Calcium concentrations given in ranges relevant for Falkland Islands soils (adapted from Marx et al., 1996).

CALCIUM mg/L Ca	STANDARD INTERPRETATION
0 – 750	Very Low
750 – 1000	Low
1000 – 1350	Medium 1
1350 – 1700	Medium 2



ALUMINIUM

Aluminium is the most abundant metal in the earth's crust (ca. 8% by mass). Weathering processes of rocks make aluminium naturally present in all soils. It is not an essential nutrient but its concentrations in the soil become important when the soil pHwater is below 5.5; at this pH level high aluminium concentrations cause plant toxicity, which is mainly evident as stunted root growth, and thereby impacts plant growth and yield.

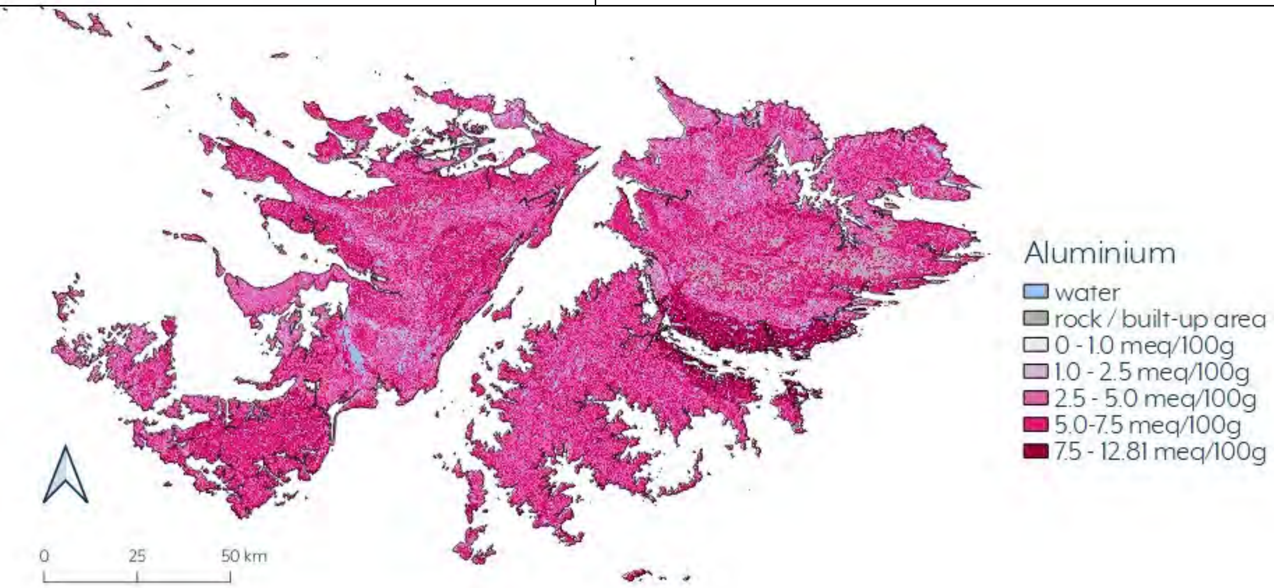
The level of aluminium concentrations is typically measured in three forms: total, extractable and exchangeable. For the Soil Mapping Project all samples were sent to a lab at the Agri Food & Biosciences Institute in Northern Ireland and tested for exchangeable aluminium (1M KCl method), which is the best indicator in relation to plant toxicity. The values are expressed as meq/100g. The mapped values across the Falkland Islands are quite evenly distributed between 0 and 12.81 meq/100g.

Aluminium concentrations are generally very high in Falkland Islands soils due to the underlying geology. The aforementioned aluminium toxicity combined with low pH may be a problem in many areas. For mineral soils aluminium values > 2.5 meq/100g (values typically found in Falkland soils) are considered toxic for plants; however, high organic matter has the potential to alleviate this effect through organic compounds binding with the available aluminium. The extent to which this is occurring in the Falklands is unclear and to interpret the high aluminium values recorded, and the potential effect on plant growth, further work is required. The table below refers to mineral soil only.

In addition, any practice which releases more aluminium into the soil profile is likely to be detrimental to plant growth. For example, erosion to the clay horizon may exacerbate high soil aluminium values. When loss of peat cover exposes the mineral layer, it is easily dried and dispersed by wind, which may increase aluminium soil levels in nearby areas. Legumes like clover and, to a lesser extent, lotus are particularly affected by exchangeable aluminium in the soil.

Table 7: Aluminium concentrations given in ranges relevant for Falkland Islands soils (adapted from Hargrove & Thomas 1981, Edmeades et al 1983, Edmeades et al. 1991, Campillo 1994, Bernier 2000 and Hill Laboratories Technical Note).

1 M KCl EXCHANGEABLE ALUMINIUM (meq/100g)	STANDARD INTERPRETATION FOR MINERAL SOILS
0 – 1.0	Evidence of dry matter decrease in lucerne, ryegrass and white clover
1.0 – 2.5	Evidence of dry matter decrease in *Lotus*
2.5 – 5	Dry matter decrease for most of plants
5 – 7.5	Dry matter decrease for most of plants
7.5 – 12.81	Dry matter decrease for most of plants



BULK DENSITY

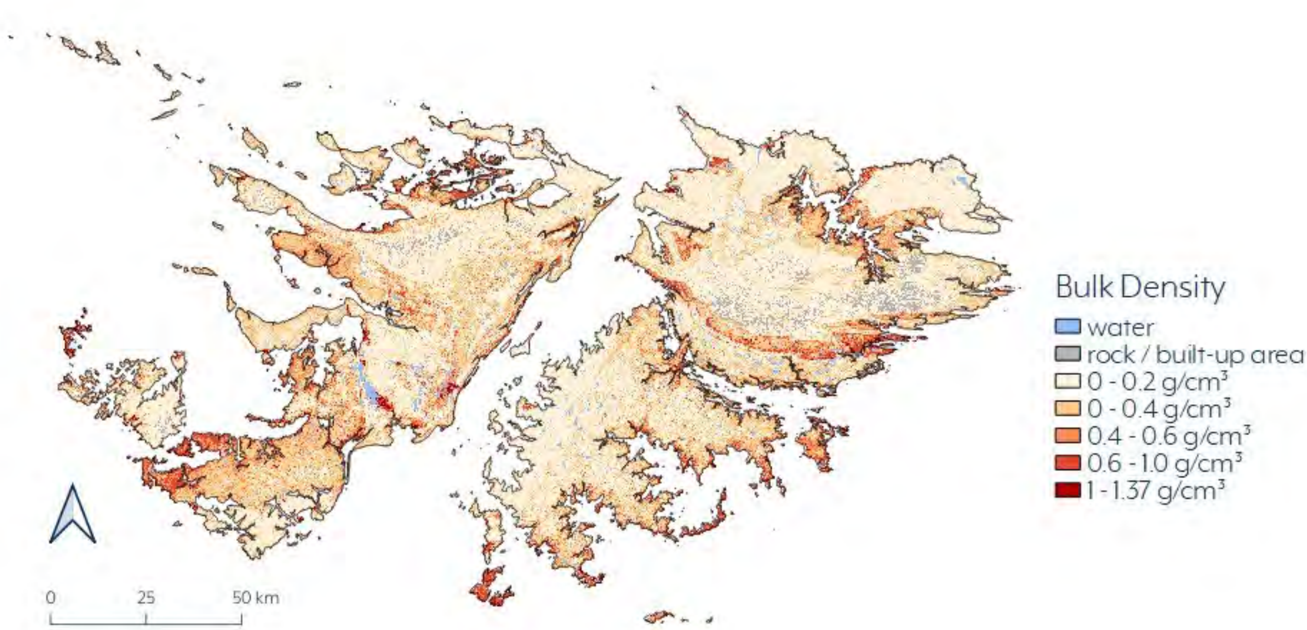
The bulk density of a soil gives an indication of compaction and affects water and air movements, the level of water retention capability and the root growth potential. It is a measurement of the mass of dry soil to the total volume of the soil. It takes into account the amount of porosity present in the soil and the density of the solid material. A higher bulk density value indicates higher compaction and less porosity.

In peat soils the bulk density is always very low (<1.0 g/cm^3) because of the high organic matter content; soils with higher bulk density contain more clay and sand. Undecomposed peats have the lowest bulk density; as decomposition increases, organic particle size decreases which leads to smaller pores and thereby increasing bulk density. In peat soils bulk density combined with fibre content can give a good indication on the state of decomposition and thereby also the nutrient availability.

For the Soil Mapping Project bulk density was assessed with standard methodology: a core of known volume was taken and oven-dried weight was divided by the core volume; the bulk density is given in g/cm^3. The mapped values across the Falkland Islands range from 0.014 to 1.368 g/cm^3; however, the majority of the values are very low and <0.5 g/cm^3. Wherever a peaty topsoil is present a low bulk density can be assumed for this horizon. Compared to other peatlands globally, however, the Falkland Islands have a generally higher bulk density.

Table 8: Bulk density levels given in ranges relevant for Falkland Islands soils (adapted from Hazelton & Murphy 2006).

BULK DENSITY (g/cm^3)	STANDARD INTERPRETATION
0 – 0.2	Very low
0.2 – 0.4	Very low
0.4 – 0.6	Very low
0.6 – 1.0	Very low
1.0 – 1.3	Low
1.3 – 1.6	Moderate
> 1.6	High and very high



RESISTANCE TO PENETRATION

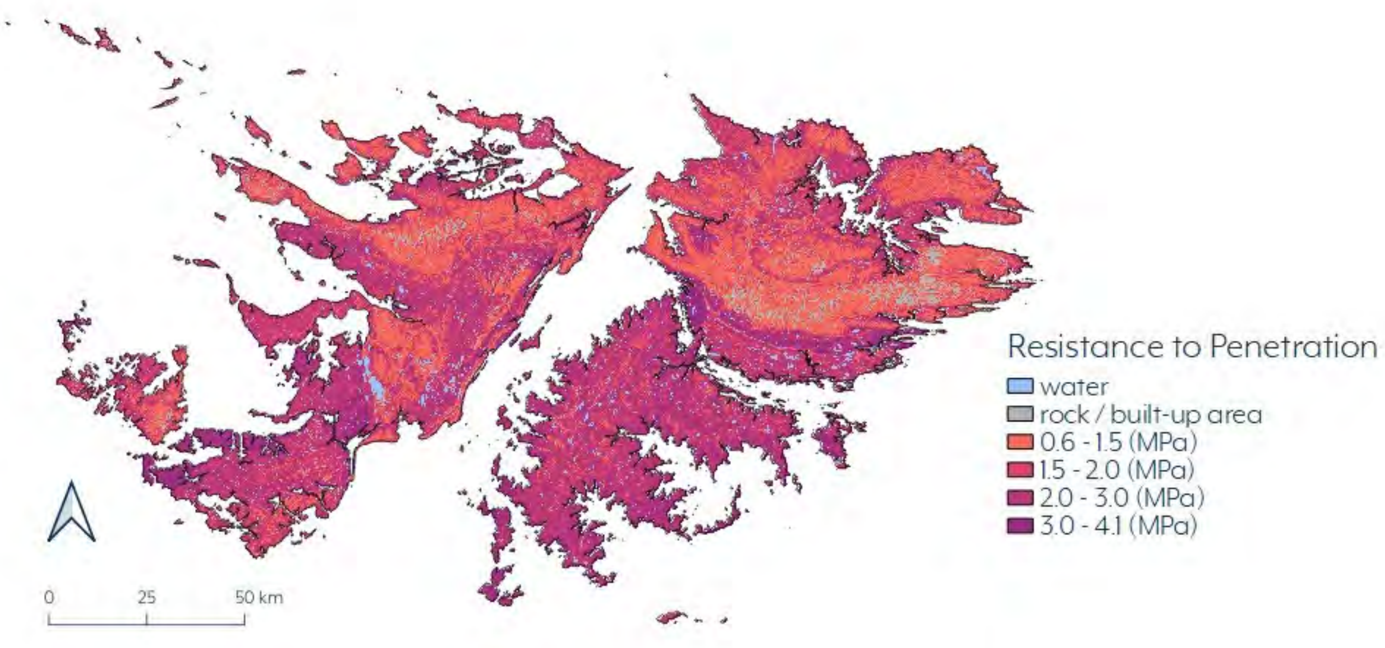
Resistance to penetration gives an indication on soil strength and thereby on the resistance roots growing into the soil will face. Higher resistance to penetration also indicates that the soil is more resistant to poaching by livestock. Peaty topsoil with high resistance is consequently less prone to erosion induced by poaching compared to soil with lower resistance.

Soil strength comes from a combination of cohesive strength (bonding of particles) and internal friction (particle surface sliding over one another). Wet clay soils have good cohesion but low friction, whereas dry sandy soils have no cohesion but high internal friction. Soil strength can be measured with a penetrometer or penetrologger. The device measures the force that is required to push a blunt point into the soil; this is expressed as resistance to penetration in kiloPascals (kPa) or megaPascals (Mpa). Resistance to penetration is highly dependent on soil water content and higher resistance is measured when soils are drier.

For the Soil Mapping Project an Eijkelkamp penetrologger was used to measure resistance and an average for the top 20 cm was created, which was then mapped. The mapped values across the Falkland Islands range from 0.64 to 4.06 MPa and are quite evenly spread across the scale. These values are relatively high considering that most topsoils are peaty and overall bulk density is low. This was most likely due to root mass present in the topsoil, which could create a resistance for the penetrologger as it moves into the soil. At the same time, Falkland peats are also relatively dry which increases their resistance. In Falkland soils lower resistance can be expected in wet organic topsoil with low fibre content; higher resistance indicates either abundant root material combined with low soil moisture or a transition into the mineral subsoil at < 20cm.

Table 9: Resistance to penetration levels given in ranges relevant for the Falkland Islands soils (adapted from Hazelton & Murphy, 2006).

PENETRATION RESISTANCE (MPa)	DEGREE OF CONSOLIDATION
0 – 1.5	medium
1.5 – 2.0	dense
2.0 – 3.0	very dense
3.0 – 4.1	extremely dense



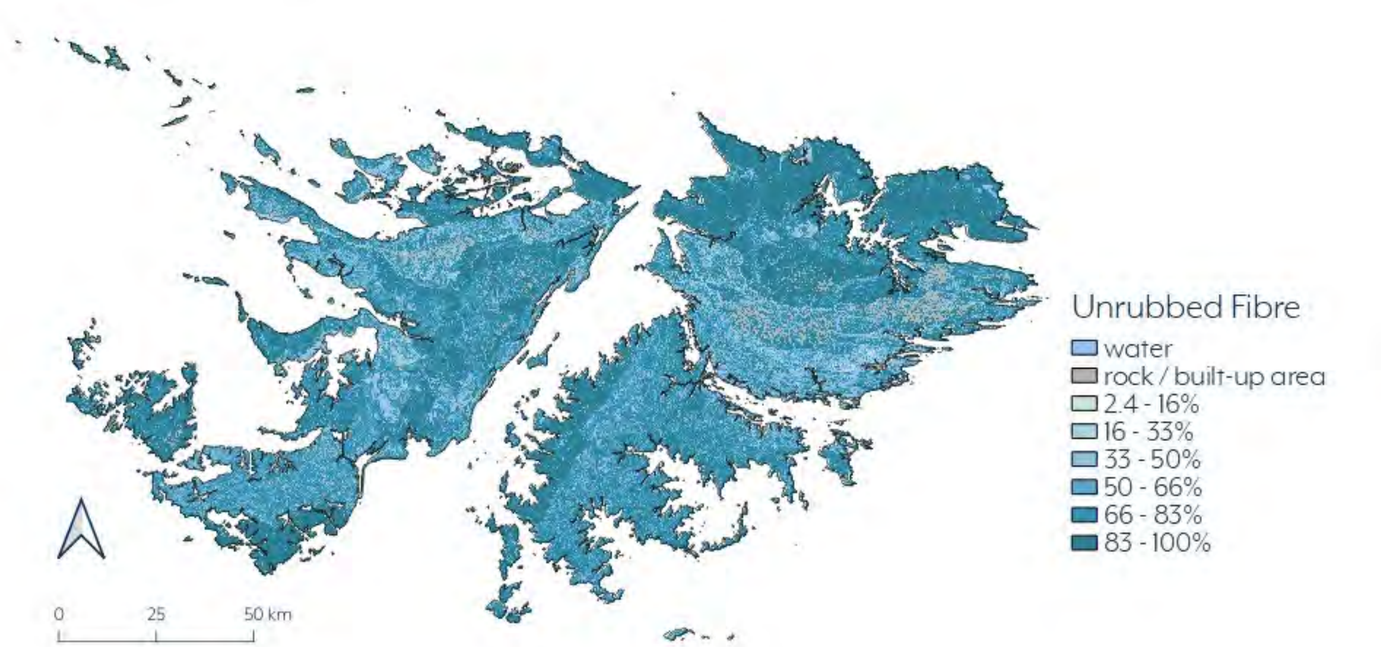
UNRUBBED FIBRE

Fibre content in organic soils gives an indication on the degree of decomposition and determines bulk density, water retention and hydraulic conductivity. High fibre content implicates low degree of decomposition, low bulk density, low water retention and rapid water movement. As decomposition increases and fibre content decreases, the bulk density increases, water retention becomes higher and water movement slows down. Fibre content is also used to categorize organic soils. A fibre content of 2/3 or more in volume before rubbing is considered fibric, i.e. fibrous and at an early stage of decomposition; a soil with a fibre content between 1/3 and 2/3 in volume is considered to be hemic, i.e. intermediate stage of decomposition; a fibre content of less than 1/3 in volume makes a sapric soil, i.e. highly decomposed (FAO, 1988).

Fibre particles either below 0.1 mm or 0.15 mm in size are considered to be amorphous and not fibre; for the Soil Mapping Project we applied the threshold of 0.15 mm. The fibre content was determined by weight rather than volume, the division into fibric, hemic and sapric is therefore only approximate. The mapped values across the Falkland Islands range from 2.4% to 100%; however, fibric topsoil generally prevail in many areas.

Table 10: Unrubbed fibre percentage given in ranges relevant for Falkland Islands soils; degree of decomposition is based on FAO (1988).

PERCENTAGE	DEGREE OF DECOMPOSITION
0 – 16%	Sapric (most highly decomposed, identifiable fibre makes up less than one third)
16 – 33%	Sapric (most highly decomposed, identifiable fibre makes up less than one third)
33 – 50%	Hemic (intermediate stage of decomposition)
50 – 66%	Hemic (intermediate stage of decomposition)
66 – 83%	Fibric (fibrous, early stage of decomposition, identifiable fibre makes up at least two thirds of the organic matter)
83 – 100%	Fibric (fibrous, early stage of decomposition, identifiable fibre makes up at least two thirds of the organic matter)



ORGANIC MATTER

Organic matter (OM) comprises the living and non-living organic material in the soil; it is the bank for nutrients in agriculture, which are slowly released by decomposition. The breakdown of OM and its interactions with other soil elements means it has large impacts on soil physical and chemical properties. In mineral soils the OM content is generally very low but small differences of just one percent of OM content or less can make a large difference in soil quality. Application of OM to mineral soils can raise pH and increase availability of some macronutrients through alleviating iron and aluminium toxicity. OM content in the soil also defines the soil class for peat soils as outlined in the table below.

The vast majority of topsoils in the Falkland Islands have an OM content > 20% and approximately 80% of the land surface area has a peat topsoil (i.e. OM >50%). In high OM soils, acid products are released through microbial consumption of OM material which in the Falkland Islands cannot be neutralised because of the underlying geology and low level of alkaline properties. This results in low soil pH, which consequently causes issues with high aluminium levels and low availability of macronutrients as discussed before. At the same time, organic compounds can alleviate aluminium toxicity, but further research is required to which extent this is happening in the Falklands. Organic matter can be sustained by crop residue and moisture retention, avoidance of burning, reducing erosion and keeping cultivation to a minimum.

Table 11: Organic matter percentage given in ranges relevant for Falkland Islands soils (adapted from Natural England 2008 and Huang et al. 2009).

PERCENTAGE OM	SOIL TYPE
0 – 6%	Mineral soil
6 – 20%	Organic mineral soil
20 – 35%	Organic soil
35 – 50%	Highly organic soil
50 – 70%	Peat
70 – 85%	Peat
85 – 100%	Peat

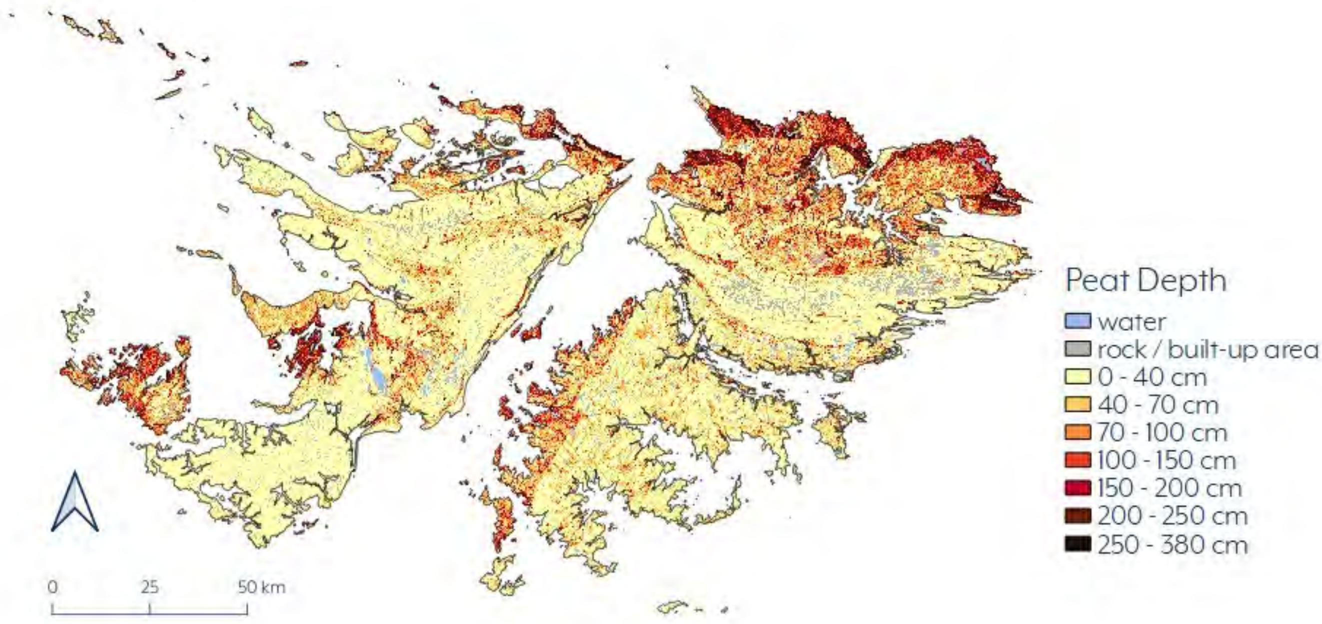
PEAT DEPTH

Knowing soil peat depth is important for several reasons. Peatlands play an important role in the carbon cycle because they store a vast amount of carbon. Globally, they make up only 3% of the world's land area but store 30% of the terrestrial carbon. Vegetation matter containing carbon absorbed from the atmosphere is slowly accumulated as peat when waterlogging and cold temperatures prevent decomposition. In its natural wet state peat, can store this carbon indefinitely. When dried out, oxygen and warmer temperatures start decomposition processes that release the carbon back into the atmosphere, where it may exacerbate climate change. The deeper the peat, the more carbon is stored. Hence, peat depth is important for quantifying the total amount of carbon stored on the Falkland Islands and this map will help set a baseline against which we can measure trends in carbon storage.

Peat depth is also important for the soil classification, e.g. soils with ≥ 40 cm depth are classified as Histosols (= peat soils). Peat depth can also tell you whether plants are connected to the mineral subsoil, which then may have implications for nutrient availability and soil pH. Peat depth also relates to the plant available water holding capacity. Soils with deeper peat depth also have the potential to absorb and store large amounts of water, thereby making soil moisture available to plants on a long-term basis.

For the Soil Mapping Project the peat definition was based on soil horizons with an organic matter content > 20%; this refers to peat, loamy peat, sandy peat, peaty loam and peaty sand. Additionally to the general soil survey points, a further 257 points were included for peat depth to increase the sample size.

Of all of the land surface area in the Falkland Islands, 37.8% of areas have peat deeper than 40 cm, of which the majority (>60%) is in the depth range of 40 to 100 cm. The deep peat areas (100+ cm) are concentrated in the northern half of East Falkland. This large percentage of peat areas ≥ 40 cm means that the Falkland Islands are in the global top ten list of countries with highest peatland proportion!

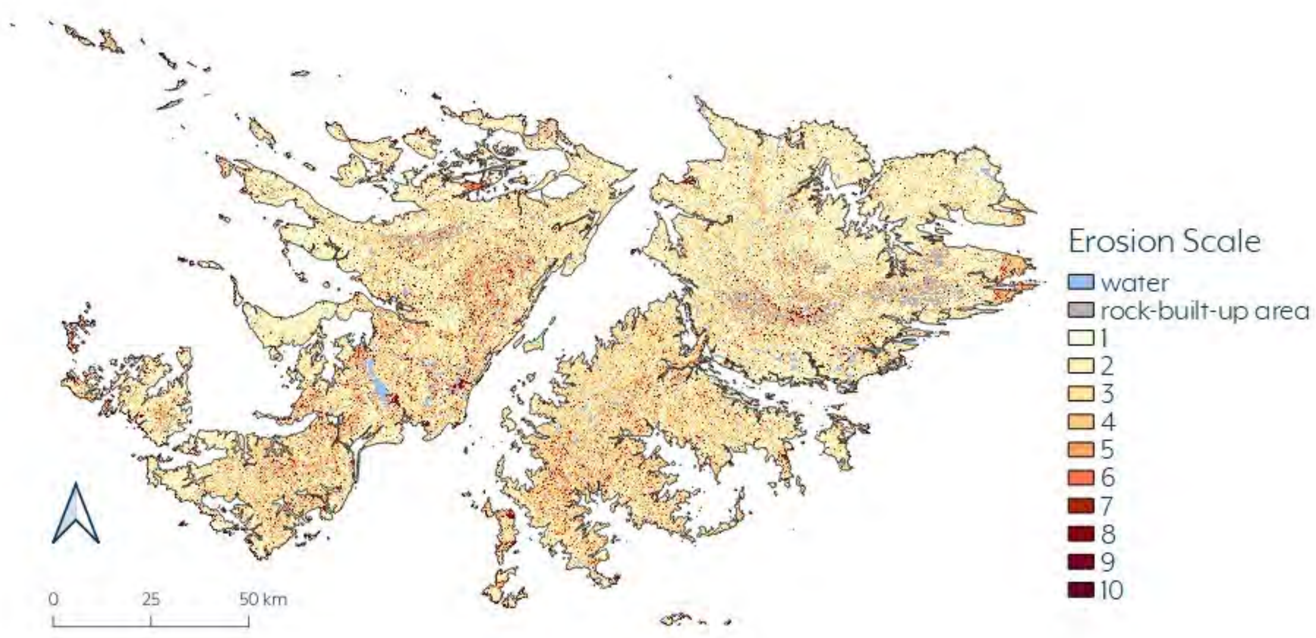


EROSION

The map for erosion extent was produced by selecting 177 points across the Falklands and scoring them on a scale of 0 (=no erosion) to 10 (=full erosion) based on erosion logging during the fieldwork and satellite imagery interpretation. A model containing satellite imagery, topography and habitat was developed to extrapolate this information across the Falkland Islands. The scored erosion refers to erosion down to the mineral / clay horizon; full erosion means that the clay horizon is fully visible. Erosion of deep peat areas and peat banks is not included in this map. It is very difficult to map the occurrence of deep peat banks and their erosion mainly occurs vertically which is difficult to identify at a 30 x 30 pixel resolution.

The erosion map also contains values on the scale of 0 to 10. To interpret the map, it can be assumed that any value at score 7 or higher represents full or almost full erosion for that pixel. Values less than 7 indicate that only a proportion of that pixel is eroded, the lower the value, the lower the proportion of erosion. Although this is a highly accurate map, some errors do exist. Dense tussac *Poa flabellata* as present on many offshore islands, has a similar colour reflection to clay erosion patches; these are therefore misinterpreted. Areas such as sandy beaches, large expanses of sandy soil (e.g. those north of Fox Bay), and rotavated areas may not be what we consider eroded areas in the strictest sense, but on the map they are classed as such because of their lack of vegetation and colour reflection of the bare soil.

About 2.3% of the Falkland Island's land surface area has a pixel value of 7 or higher, or in other words can be considered fully eroded. However, this estimation includes fully vegetated tussac islands but excludes smaller patches of erosion.



EROSION RISK

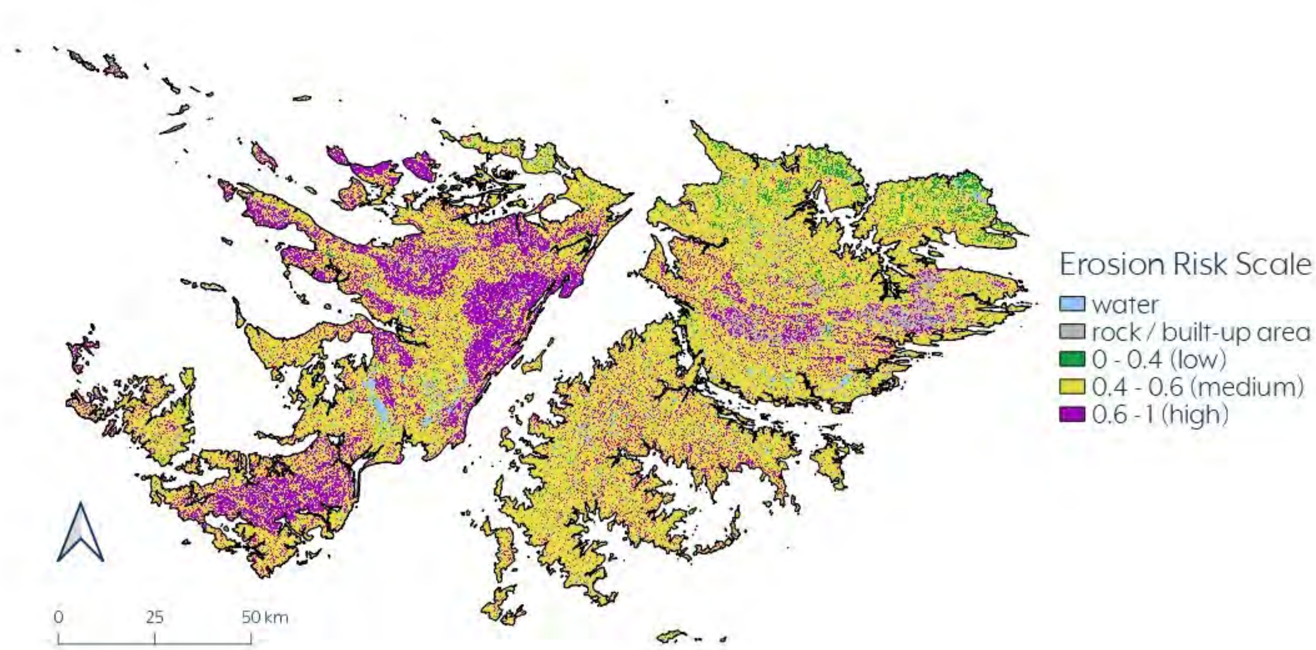
The erosion risk map was produced by overlaying maps for soil erodibility (derived from soil class), land cover protection (=vegetation), slope and flow accumulation (derived from a digital elevation model), and rainfall. The properties in each of these layers were scored to indicate their potential contribution to erosion risk. The erosion risk map represents a combination of all of these on a score ranging from 0 to 1. As you would expect, erosion risk is high in mountainous areas with steep slopes and shallow soil. Wherever a stream or streambed is present, the erosion risk is also high because the flow of water can wash away soil during heavy rainfall.

There is one further component in erosion risk modelling that is not included here because this information is currently not available for the entire Falkland Islands: land use. Stocking rates, when high, can increase erosion risk but can also mitigate the risk when low. Any evaluation of erosion risk on a farm-basis should take land use into account as well.

Approximately 22% of the Falkland Islands are at high risk of erosion; only very few areas can be considered at low risk to erosion.

Table 12: Erosion risk extent in the Falkland Islands based on the erosion risk map produced as part of the Soil Mapping Project.

LAYER CATEGORY	PERCENTAGE OF LAND SURFACE AREA
Inland water	2.4 %
Rock / built-up area	3.2 %
Low erosion risk	3.4%
Medium erosion risk	69.0 %
High erosion risk	22.0 %



GLOSSARY

Carbon sequestration
Long-term removal of carbon-dioxide from the atmosphere and stored in terrestrial or aquatic systems.

Cation
A positively charged ion.

Flow accumulation
The flow path of water is determined by topography. The flow accumulation is determined by the flow path accumulated at each point in the landscape. The higher the flow accumulation values, the more focused the flow and the higher the likelihood that the area will form a run-off.

Hydraulic conductivity
A property of soils (and vascular plants and rocks) that describes the ease with which water can move through pore spaces or fractures.

Hypomagnesaemia
Abnormally low levels of magnesium in blood.

Iron pan
A dense rock-like layer of soil that contains a lot of iron .

Macronutrient
A chemical element required in large amounts for plant growth: nitrogen, phosphorous, potassium, calcium, magnesium, sulphur.

Nitrification
The process of transformation of ammonium to first nitrite and then to nitrate.

Pixel
A minute area from which an image is composed. Each pixel on the soil maps represents a 30 x 30 m area. Each pixel has a particular value and colour associated with it.

Rhizobium bacteria
Bacteria that fix nitrogen and are present in plant root nodules. They live in a symbiotic relationship with legumes and exchange the fixed nitrogen for carbon.

Soil moisture deficit
The difference between the amount of water that is actually in the soil and the amount that the soil can hold.

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