NEW OFFSET OPTIONS FOR NEW ZEALAND

Motu Note #25

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Storing carbon down
below ground and in the sea
makes a better world.

INTRODUCTION

This report synthesises the current state of scientific knowledge around the issues associated with three innovative carbon reduction or removal options in a New Zealand context: soil carbon; marine carbon and carbon capture and storage. It draws on literature and a series of interviews with key New Zealand researchers.

Soil carbon

Currently, there is strong interest in better understanding of soil carbon as a potential mitigation option. The theoretical potential is enormous as even increases of less than 1% could mitigate current emissions and there are many co-benefits, including better soil fertility, structure and water retention, which in turn collectively could lead to productivity gains. However, there is no single recipe for increasing soil carbon. It is always contingent on soil type, management practice and climate, and the costs of measuring soil carbon can be significant.

Globally, preventing losses and increasing soil carbon has been proposed as a mechanism to capture some of the carbon dioxide already emitted into the atmosphere. In New Zealand, the protection of intact wetlands and restoration of drained peat soils could provide a mechanism for preventing future soil carbon losses.

There is good evidence that biochar represents a very stable form of carbon, but the main challenge to any widespread use in pastoral systems remains cost and the large area that would need to be covered.

Marine carbon

Although technologies for seaweed sequestration are being investigated overseas, in New Zealand, this area of research is in the early stages. To remove carbon from the atmosphere, the algae would need to be either turned into biofuel or stored long-term.

Carbon storage and capture

Carbon capture and storage technologies could buy time while the economy shifts towards more sustainable energy options. Geosequestration involves capturing carbon dioxide at a point source to avoid emissions. In New Zealand, this would require retrofitting old power plants. Another option is the mineralisation of carbon, which is being explored successfully overseas.

We would like to thank Air New Zealand for providing the core funding for this paper;
The Aotearoa Foundation and the Tindall Foundation have also contributed to this stream of work.
Any opinions expressed are those of the author who also remains responsible for any errors and omissions.

SOIL CARBON

Globally, soils are the largest reservoir of carbon in the terrestrial biosphere. There is more carbon bound in soil than in land plants and the atmosphere combined. Even a small increase (less than 1%) in the amount of carbon stored in soil could offset greenhouse gas emissions significantly (NZ Agricultural Greenhouse Gas Research Centre, 2015).

Soil carbon stocks in undisturbed ecosystems are generally in a steady state, with inputs from plants balancing losses through microbial decomposition. The amount of carbon depends on the nature of vegetation, climate and soil type, and it usually changes when land use changes, for example during conversions from forestry to pasture and vice versa (McNeill, Golubiewski, and Barringer 2014) (Schipper et al. submitted).

About 12% of anthropogenic carbon dioxide that has entered the atmosphere globally can be attributed to land use and subsequent soil carbon stock losses. In addition, as the climate warms, rising soil temperatures are expected to enhance carbon fluxes to and from the soil, with potentially increased losses particularly in high latitudes (Crowther et al. 2016).

Therefore, preventing losses of soil carbon is important for climate stability and increasing soil carbon has been proposed as a mechanism to capture some of the carbon dioxide emitted from burning fossil fuels (Golubiewsky et al. 2015).

In New Zealand, with its temperate climate and agricultural practices dominated by permanent pasture with high carbon inputs, soils generally already have relatively high carbon contents. However, soils may not be at their theoretical maximum carbon storage capacity, with the potential to store more (Beare et al. 2014) (Ausseil et al. 2014).

Grazed pasture covers more than half of New Zealand's land area (~15 million hectares) and such grasslands are a key category under the land use, land use change and forestry (LULUCF) section of the New Zealand greenhouse gas inventory. However, the inventory accounts for changes in soil carbon stocks only when land use changes (e.g. when pasture is converted to forestry or vice versa). The effects of various management practices within a particular land use are less well understood (Schipper et al. submitted).

Currently, under Kyoto Protocol accounting, New Zealand soils are reported as a net source of carbon. Grazing land management is a voluntary category but it may become mandatory under any new agreements in the future. There is no mechanism in place at this stage to earn credits from increasing soil carbon within an existing land use.

However, there is strong interest in Europe to better understand soil carbon as a potential mitigation option, because of the theoretical potential and co-benefits, including better soil fertility, structure and water retention, which in turn collectively should lead to productivity gains.

During the 21st session of the Conference of the Parties (COP21) to the UN Framework Convention on Climate Change, held in Paris in December 2015, the French government launched the '4 per mille Soils for Food Security and Climate' initiative, which calls for a 0.4 percent increase in soil carbon annually (in agricultural soils, notably grasslands and pastures, and forest soils) (unfccc.com 2017).

The initiative consists of a voluntary action plan under the Lima-Paris Action Agenda (LPAA), backed up by a research programme. A survey of soil carbon stock estimates and sequestration potentials from 20 regions (including New Zealand) highlights region-specific efforts for soil carbon sequestration and shows that 0.4 percent or even higher sequestration rates can be accomplished, with the highest rates (up to 1 percent) for soils with low initial carbon stocks (Minasny et al. 2017).

Globally, applied to the top 1m of agricultural soils, the 4 per mille initiative would sequester between 2-3 Gt C per year, which effectively offsets 20–35% of global anthropogenic greenhouse gas emissions. The authors state that soil carbon sequestration would buy time over the next 10 to 20 years while other effective sequestration and low-carbon technologies become viable (Minasny et al. 2017).

Current knowledge of effects of land use and management practices in New Zealand

Changes in soil carbon over time can be measured by re-sampling of soil from the surface or at depth or by monitoring carbon exchange rates between the atmosphere and soils at the soil surface. In addition, statistical methods have been used to develop a model to estimate the total national soil carbon within different land-use and soil types. The Carbon Monitoring System (CMS) model was developed by Landcare Research and has been progressively improved by other researchers (McNeill, Golubiewski, and Barringer 2014).

Scientists have tracked changes in soil carbon during conversions from plantation forests to pasture, and vice versa, and found that new pastures accumulated carbon at a rate of 1.67 t C per hectare per year in the first decade following conversion, and then at lower rates for up to 50 years (Sparling and Schipper 2004).

The relatively rapid accumulation during the first few years can most likely be attributed to changes in vegetation and management that encourage growth of pasture roots that input carbon into soil in previously forested soils, but the exact mechanisms are not well understood.

The high initial sequestration rates level off with time, which means that soil-based options could provide useful mitigation tools for the first half of this century to buy time during the transition to low-carbon technologies. These findings also argue that further increases might be possible if appropriate pasture management systems are discovered and implemented at national scales. Despite the limitations to soil carbon sequestration (e.g. saturation limits), IFOAM argue that there is no other mitigation method that can store a similar amount of carbon at such a low economic cost and with environmental and health co-benefits in the immediate term (IFOAM 2009).

Following conversion from pasture to forestry, soil carbon levels declined by between 6 and 17 tonnes of carbon per hectare. Of course, the additional carbon stored in the tree biomass can offset this lost soil carbon (Schipper et al. submitted).

To assess long-term soil carbon changes under pasture, researchers have re-sampled sites that had been analysed some 30 years previously, originally as part of the soil survey of New Zealand to obtain data on soil properties for the National Soils Database (Schipper et al. 2014).

This study found that for flat land under long-term grazing, certain soil types (allophanic, gley and organic) lose significant amounts of carbon, while for other soil types there was no evidence of change in soil carbon stocks (i.e. they appeared to be at steady state). Less intensely grazed hill country soils, however, show significant and rather substantial gains in carbon content, but the mechanisms behind this gain are not yet understood.

Many thanks to the following people who have contributed their time and expertise to this report:
soil scientists Louis Schipper, at Waikato University, Frank Kelliher, at AgResearch, and Mike Beare, at Landcare Research;
Andy Reisinger, at the NZ Agricultural Greenhouse Gas Research Centre, Wendy Nelson, marine scientist at NIWA,
Susie Wood, marine scientist at the Cawthron Institute, Bob Beth, World Business Academy, Helen Plume and Andrea Brandon,
at the Ministry for the Environment, Brad Field, CSC project leader at GNS Science, and Kelly Hughes, at ATS Environmental.

Ongoing application of phosphorus fertiliser shows no effect on carbon stock, but there is no information on the effects of nitrogen fertiliser. (Schipper et al. submitted) Irrigation resulted in the loss of carbon from soils, (Mudge et al. 2017) and pasture renewal shows a one-off loss of carbon of 1-4 tonnes per hectare (Rutledge et al. 2017).

A report commissioned by the Ministry for Primary Industries identified pressures on New Zealand soil, including intensification through irrigation, the addition of chemicals, poor matching of land use to land type and ongoing effects of past deforestation. All of these can deplete soil carbon stocks (Ministry for the Environment 2016).

Opportunities and challenges for soil carbon sequestration

What it is	It is possible to increase the carbon stock in soils by adding organic matter, whether derived from increased plant growth and inputs or importation of organic matter such as compost.
Advantages	There are strong co-benefits, including higher soil fertility and water-retention capacity, which can feed-back to enhanced productivity and soil resilience.
Key challenges	Soils lose carbon quickly, but recover it only slowly. There is no single recipe for increasing soil carbon; it is always contingent on soil type, management practice and climate. Costs of measuring soil carbon can be significant. Soil carbon changes are not linear so predictability over longer time frames is difficult.
Current knowledge	Mineral soils differ in their capacity to take up and maintain higher carbon levels, partly depending on their clay content. Phosphorus fertiliser has no effect on carbon stocks. There is no New Zealand-specific information about the effect of nitrogen fertiliser. Irrigation increases carbon loss from pasture. Hill country, which is less intensively grazed than flat-land pasture, is gaining a lot of carbon. However, the mechanisms behind this are unclear at this stage.
Prioritisation	Medium. At this point, few countries (Australia) have a government-approved methodology to account for soil carbon changes. There is a lot of international interest in initiatives that explore soil carbon as a mitigation option.

Managing peat soils in New Zealand

Organic or peaty soils stand out in the national survey for their disproportionate contribution to greenhouse gas emissions. These soils hold large pools of carbon, accumulated over many centuries because the decomposition of plant matter is suppressed in the water-logged, oxygen-free conditions. Apart from storing large amounts of carbon, peat soils in their natural state support a large range of habitats, play an important role in the retention and purification of water and in the mitigation of droughts and floods. When peat soils are drained for agriculture, they become a source of greenhouse gas emissions.

In New Zealand, peat soils cover only a very small proportion (<1%) of managed grasslands, but the loss of carbon persists for many decades or even centuries, as long as the land remains drained. This ongoing loss differs from mineral soils, which usually reach a new steady-state carbon content within a few decades following land-use change (Schipper et al. submitted).

Better management of organic soils has been identified as an effective mitigation option globally (FAO 2014). In New Zealand, the amount of carbon stored in peat soils has been crudely calculated to be equivalent to about an eighth to a fifth of the carbon stored in all vegetation.

Even though peat soils only account for less than 1 per cent of the surface area, their contribution is big because the carbon-rich layers are usually some metres deep (as opposed to about 20cm of top soil in most mineral soils). Already, some of the peat soils in the Hauraki region have subsided below sea level. As they degrade further through time, continued drainage will become more expensive for farmers (Pronger et al. 2014). However, overall, agriculture on peat soil is worth $700m per year to New Zealand.

Opportunities and challenges for climate management of peat soils

What it is	Peat soils cover only about 1% of New Zealand's land area but the amount of carbon they store is equivalent to about a fifth of the carbon in all of the vegetation in New Zealand. In their natural, water-logged state, peat soils store carbon, but they release it when drained. An international review identified better management of organic soils as one of the main options (globally) for decreasing carbon flux into the atmosphere.
Advantages	Peat soils are deep and good sites for long-term storage of carbon. Drained peat soils release 2.9 tonnes of carbon per hectare per year (Campbell et al. 2015).
Key challenges	Agriculture on peat is estimated to be worth $700m per year to New Zealand.
Next steps	Invest in protecting intact wetlands and peatlands and in restoration (reflooding and replanting) of drained peat soils. Some peat soils (e.g. in Hauraki) will become more expensive to farm.
Prioritisation	Low-medium. Within existing policy, it is not possible to earn carbon credits.

Burying carbon

Biochar is a fine-grained charcoal, produced through pyrolysis (heated to 400-500°C under oxygen-limited conditions) from waste biomass. The characteristics of biochar differ depending on the exact techniques used and the source of the biomass material.

When added to soil, biochar is resistant to decomposition and can store carbon for centuries. In addition, co-benefits include better water retention, reduction in the use of mineral fertilisers, prevention of nutrient leaching and an increase in pH.

Researchers at Massey University's Biochar Research Centre are exploring the feasibility and effectiveness of biochar incorporation into New Zealand soils, however the costs of distribution and processing are significant, and small-scale onsite production from local farm biomass could be more effective.

One study investigating the longevity of biochar in New Zealand soils found that it took 35 weeks to offset the carbon dioxide emitted during biochar production, before it began to remove atmospheric carbon dioxide (Herath et al. 2015).

Opportunities and challenges for burying carbon

What it is	Organic matter carbonised under controlled conditions and stored in the soil as a means of preventing carbon dioxide from escaping into the atmosphere.
Advantages	There is good evidence that biochar represents a very stable form of carbon.
Key challenges	The main challenge to any widespread use in pastoral systems remains cost and the large area that would be needed to be covered.
Next steps	Supporting/promoting research.
Prioritisation	Low.

MARINE CARBON

Globally, there is strong interest in the potential of marine and coastal plants as a sink for anthropogenic carbon emissions. Marine primary producers (algae, seagrass meadows, salt marshes and mangroves) contribute at least 50% of the world's carbon fixation and may account for as much as 71% of all carbon storage.

The Blue Carbon Initiative is a global programme with a focus on the restoration and conservation of coastal and marine ecosystems to safeguard ecosystem services such as coastal protection from storms, nursery grounds for fish and sequestration and storage of carbon. The programme's current focus is on coastal ecosystems, which cover less than 20 percent of the total ocean area but account for about half of the total carbon sequestered in ocean sediments ("The Blue Carbon Initiative" 2017).

Active farming of seaweeds is under consideration as a possible mitigation technology. Seaweed aquaculture beds cover extensive coastal areas, particularly in the Asia-Pacific region, and their use in potential carbon dioxide mitigation efforts has been proposed with commercial seaweed production in a number of Asian countries and is at a nascent stage in Australia and New Zealand (Sondak et al. 2016).

Of the several thousand known seaweeds globally, only about 220 are used commercially and many are harvested from their natural habitats as the technology for their cultivation has not been developed yet. About 100 have been tested in field farms but only about a dozen are cultivated, mostly for food, fodder and fertiliser, but in some cases as a potential biofuel (Chung et al. 2011).

A project in Korea has been developed to monitor seaweed sequestration options. The Coastal CO_2 Removal Belt (CCRB) consists of both natural and human-made plant communities in the coastal region of southern Korea. This pilot seaweed farm can draw down about 10 tonnes of carbon dioxide per hectare per year (Chung 2013).

As seaweed aquaculture is expanding, the industry is developing policy to manage potential impacts, including stocks that are highly susceptible to disease caused by a reliance on a highly limited genetic stock, the displacement and reduction of wild native stocks through competition and the unintentional introduction of 'hitch-hiker' species, including pathogens (Cottier-Cook 2016).

Another issue of concern is the release of reactive halogen species, known to influence atmospheric chemistry, from macroalgae (Laturnus, Svensson, and Wiencke 2010).

In New Zealand, seaweed aquaculture is only in its early research stage.

Opportunities and challenges for seaweed farming

What it is	Kelps and seaweeds are the marine analogues of trees on land. They take carbon dioxide out of the atmosphere through photosynthesis, and along with other aquatic plants contribute more than 50 percent of the earth's atmospheric oxygen.
Advantages	Farming of the introduced edible seaweed undaria has been permitted in Marlborough, Wellington and Canterbury.
Key challenges	Seaweed farming for harvest does not remove carbon from the atmosphere. To achieve that, the algae would need to be either turned into biofuel or stored long-term. To encourage algae to grow where they don't naturally do so requires adding trace nutrients, which interferes with other ecosystem functions.
Next steps	Fund and promote research.
Prioritisation	Low. High costs, only at research stage in New Zealand.

CARBON CAPTURE AND STORAGE

Carbon capture and storage technologies could buy time while the economy shifts towards more sustainable energy options, and they would reduce emissions from industries that have no choice.

Carbon capture involves capturing carbon dioxide at a power plant or an industrial site. The gas is compressed, transported and pumped into a suitable subsurface geological formation where it can be stored. This process avoids emissions but does not normally strip carbon dioxide from the atmosphere. Removing carbon dioxide from the atmosphere itself requires that the emissions are from biofuels, as biofuels get their carbon from the modern atmosphere.

GNS Science was commissioned by the New Zealand government and by the Cooperative Research Centre for Greenhouse Gas Technologies (in Australia) to analyse the storage potential in New Zealand. The reports concluded that New Zealand has more than enough capacity to store all present and future point source emissions ("Research / Carbon Capture and Storage / Energy & Resources / Our Science / Home - GNS Science" 2017).

The volume of carbon dioxide readily available for storage is currently small; to capture large amounts would require retrofitting old power plants. However, the availability of sufficient storage pore-space in a region doesn't mean it would be viable to use it. Detailed assessments of sites would be required to check for active seismic faults and other issues such as old, corrodible infrastructure from old oil wells.

Various other technologies, e.g., injecting carbon dioxide into basalt to mineralise it, are being assessed (Kanakiya 2017).

New Zealand could also explore the use of small-scale mineral capture, where the carbon dioxide is mixed with crushed basalt in a surface operation, possibly using renewable energy to speed up the reaction. This could suit small point-source emitters where the cost of setting up underground carbon dioxide storage would be too high.

Alternative solutions would be to combine emissions from small sources at a hub, then pipe the larger volume to an underground storage site, or to find industrial uses for captured carbon dioxide. Each solution could provide a viable way of reducing emissions if applied in different regions of New Zealand, particularly if aligned with biofuels.

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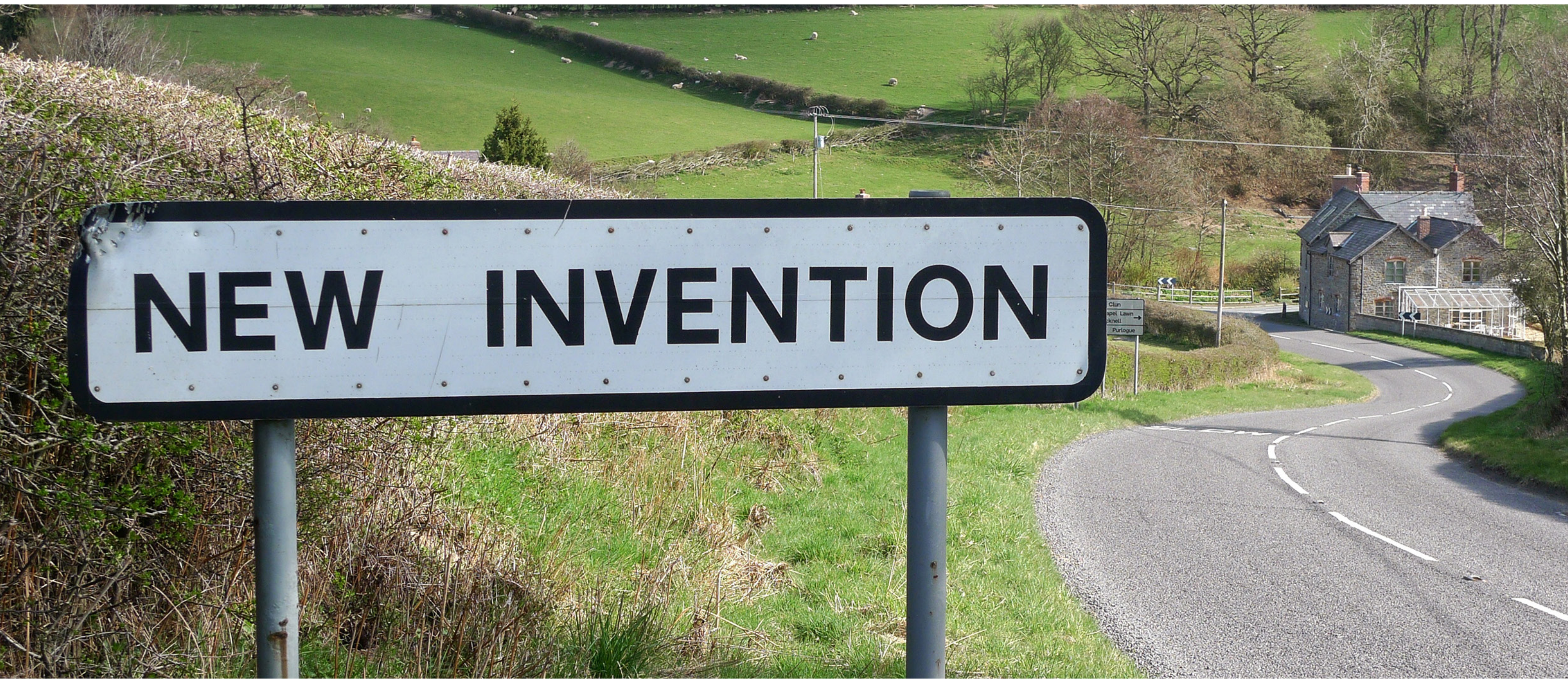

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