A Case for Including Deep-Water Marine Permaculture in Agricultural Emissions Pricing Negotiations

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Summary

To mitigate agricultural emissions, marine permaculture arrays (MPAs) offer a 'double benefit' approach to emissions reduction. Marine permaculture is the practice of farming kelp and seaweed offshore in large submerged arrays, which have the potential to permanently sequester substantial amounts of carbon within New Zealand's exclusive economic zone. Dissolved and particulate organic carbon (DOC and POC) shed from MPAs is locked up in seafloor sediments at depths over 1000m, forming a near permanent carbon sink. Alongside this, seaweeds can be processed into highly effective, carbon positive fertilisers, which are in demand from the agriculture industry who are significant consumers of industrial products.

Recently MFE, MPI and MBIE have begun helping farmers to develop a system to price farm-level agricultural emissions, in a way that is separate from the government's fall back measure to introduce agricultural emissions at the processor level to the Emissions Trading Scheme (ETS) with 95% free allocation. This essay proposes including MPAs as a method of emissions unit generation within a farm-level emissions pricing system, in a similar way to how carbon forestry generates ETS units. Including marine permaculture into a farm-level system would effectively subsidise a useful fertiliser product which could, in turn, reduce on farm emissions.

Abbreviations & terminology

MPA - Marine Permaculture Array. A deepwater lightweight latticed structure used to grow kelp/seaweed.
ETS - Emissions Trading Scheme. A legislative system which New Zealand uses to price carbon dioxide emissions.
ZCA - Zero Carbon Act. Recent legislation setting carbon dioxide and methane reduction targets.
Macrocystis pyrifera* / *M. pyrifera - Giant kelp. A fast growing kelp species plentiful in New Zealand and across the Southern/Pacific Ocean.
Pinus radiata* / *P. radiata - A pine species frequently planted in New Zealand forestry operations.[8]
Asparagopsis armata* / *A. armata - A red seaweed species Cawthron Institute is researching for biogenic methane reduction purposes.
CDR - Carbon Dioxide Removal.
DOC - Dissolved Organic Carbon. Detritus dissolved in the ocean from kelp.
POC - Particulate Organic Carbon. Small pieces of detritus from kelp which remain undissolved in the ocean.
NPP - Net Primary Production. The net carbon gain of plants over a time period.
MFE - Ministry for the Environment.
MPI - Ministry for Primary Industries.
MBIE - Ministry of Business, Innovation and Employment.
GDP - Gross Domestic Product. A measure of the monetary value of a country's output over a time period.
CO_2e - Equivalent carbon dioxide emissions. The global warming potential of greenhouse gasses, measured as equivalent carbon dioxide emissions.
The photic zone - The uppermost zone of the ocean which receives enough sunlight to allow photosynthesis.
The biological pump - The biologically driven carbon cycle within the ocean which sequesters atmospheric carbon to the ocean's interior/seafloor sediments.

Introduction

New Zealand's net greenhouse gas emissions in 2018 were 55.5 million tonnes CO_2e[1]. Under ZCA obligations, New Zealand needs to reach net zero carbon emissions by 2050, excluding biogenic methane emissions, which must fall to 24 - 47% of 2010 levels[2]. Agriculture accounts for 48% of New Zealand's CO_2e emissions, making it the largest category of emitters in the country.

The primary method of meeting our Zero Carbon Bill targets is by using the Emissions Trading Scheme (ETS)[3] established through the Climate Change Response Act 2002[4]. However, agriculture, our largest primary industry, is exempt from ETS obligations. Recently MFE began proposing ideas, receiving submissions, and exploring options to price agricultural emissions. A common theme of MFE's proposals was to "recognise and reward carbon removals from on-farm vegetation" [5]. This is likely to encourage farmers to plant farmland with trees, providing climate benefits but reducing productivity and therefore income of farms. This is a challenging situation involving property rights and potential reduction of income for small businesses, and will only get New Zealand so far to reduce emissions. As agriculture is such a significant component of our emissions profile, much more is needed than planting on marginal land. Alongside investigating planting on marginal land, we need to further utilize our ocean resources which may help meet our ZCA obligations.

In this essay, producers of agricultural products are viewed as consumers. The New Zealand agricultural sector is a consumer of industrial products as it uses goods such as fertiliser, insecticides and farm machinery to produce products. The carbon footprint associated with these products is then passed to all consumers of New Zealand agriculture both in New Zealand and across the world.

"Limiting warming to 1.5°C implies reaching net zero CO2 emissions globally around 2050 and concurrent deep reductions in emissions of non-CO2 forcers, particularly methane (high confidence). Such mitigation pathways are characterized by energy-demand reductions, decarbonization of electricity and other fuels, electrification of energy end use, deep reductions in agricultural emissions, and some form of CDR with carbon storage on land or sequestration in geological reservoirs. Low energy demand and low demand for land- and GHG-intensive consumption goods facilitate limiting warming to as close as possible to 1.5°C." - IPCC 2018[6]

New Zealand urgently needs to reduce agriculture emissions, while simultaneously implementing long term carbon dioxide removal (CDR) solutions.

Marine Permaculture: A 'double benefit' approach to cutting agriculture emissions

The ocean is an important carbon sink, storing 55 times more carbon than in the entire atmosphere.[7] The photic zone absorbs most of the carbon emitted by human activities, and a process known as "the biological pump" takes carbon from the photic zone and stores it deep in the ocean[7]. This process could be accelerated to permanently sequester larger quantities of carbon[7].

Currently the New Zealand ETS rewards forestry blocks absorbing carbon from the atmosphere through *Pinus radiata*. The carbon sequestration capability of *P. radiata* is highly variable, easily altered by many factors. Figure 1 below is a typical profile of CO_2 sequestration per hectare over time. In March 2019 the government announced a shift to 'averaging'.[10] This means that carbon credits are awarded based on the average quantity of sequestered carbon, drawing a flat line through the growth/harvest cycles and simplifying the carbon accounting process.

Using averaging, *P. radiata* plantations reach peak carbon sequestration per hectare at around 20 years. Beyond 20 years, to sequester more carbon, more forests need to be planted (Figure 1). After the initial growth period, the pine plantation goes through periods of growth then harvest, causing a 'sawtooth' style line over time. However the average quantity of CDR flatlines (Figure 1).

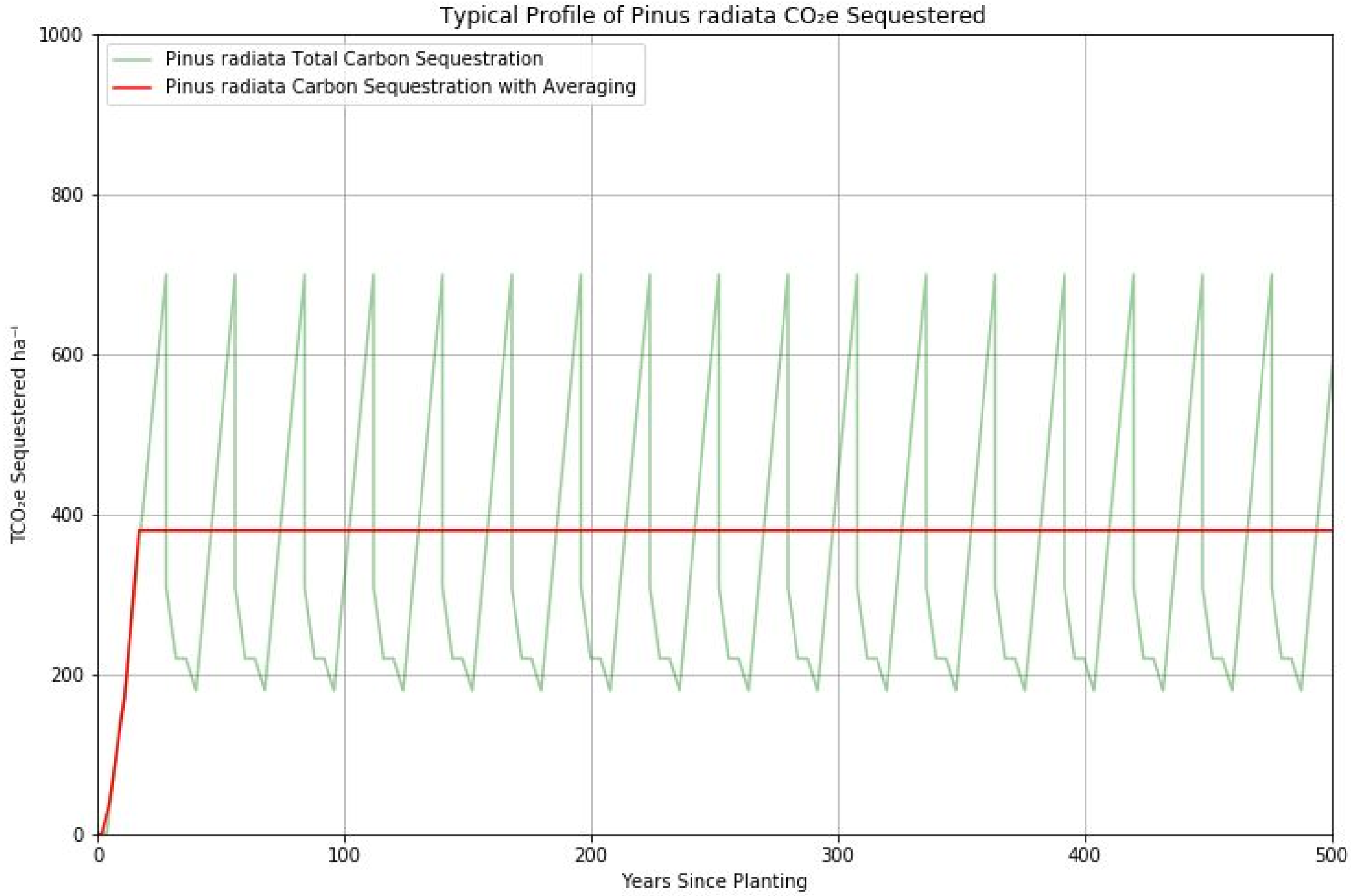

Figure 1 *- Data from 'Interpine - Averaging – A new method of carbon accounting in the Emissions Trading Scheme' [9].*

Marine Permaculture Arrays (MPAs), especially *Macrocystis pyrifera* (giant kelp) provide new possibilities to permanently sequester carbon offshore.

M. pyrifera is one of the fastest growing organisms on the planet, growing 28cm a day up to a length of 30m[13]. As a result, *M. pyrifera* has the potential to permanently sequester carbon many times faster than terrestrial vegetation. *M. pyrifera* has a net primary production (NPP) of around 5.2kg dry matter m^{-2} $year^{-1}$ in natural kelp forests. This equates to 5.25kg CO_2e m^{-2} $year^{-1}$ [11]. In contrast, *P. radiata* absorbs carbon at 1.74kg CO_2e m^{-2} $year^{-1}$ [12]. Hence, giant kelp absorbs carbon at three times the rate of typical pine plantations per unit area.

M. pyrifera produces detritus, which is shed biomass in the form of dissolved organic carbon (DOC) or the larger particulate organic carbon (POC). Once DOC & POC reaches a depth of more than 1000m, the carbon remains locked up in seafloor sediments for hundreds to thousands of years. This is a near permanent carbon sink [12].

An estimate on the fate of DOC and POC is given in Figure 2. Approximately 11.4% of DOC & POC remain permanently sequestered (on average), but this varies according to the factors such as:

- distance to ocean canyons
- ocean currents and downwellings
- composition of ocean floor sediments
- rate of detrital decomposition [12]

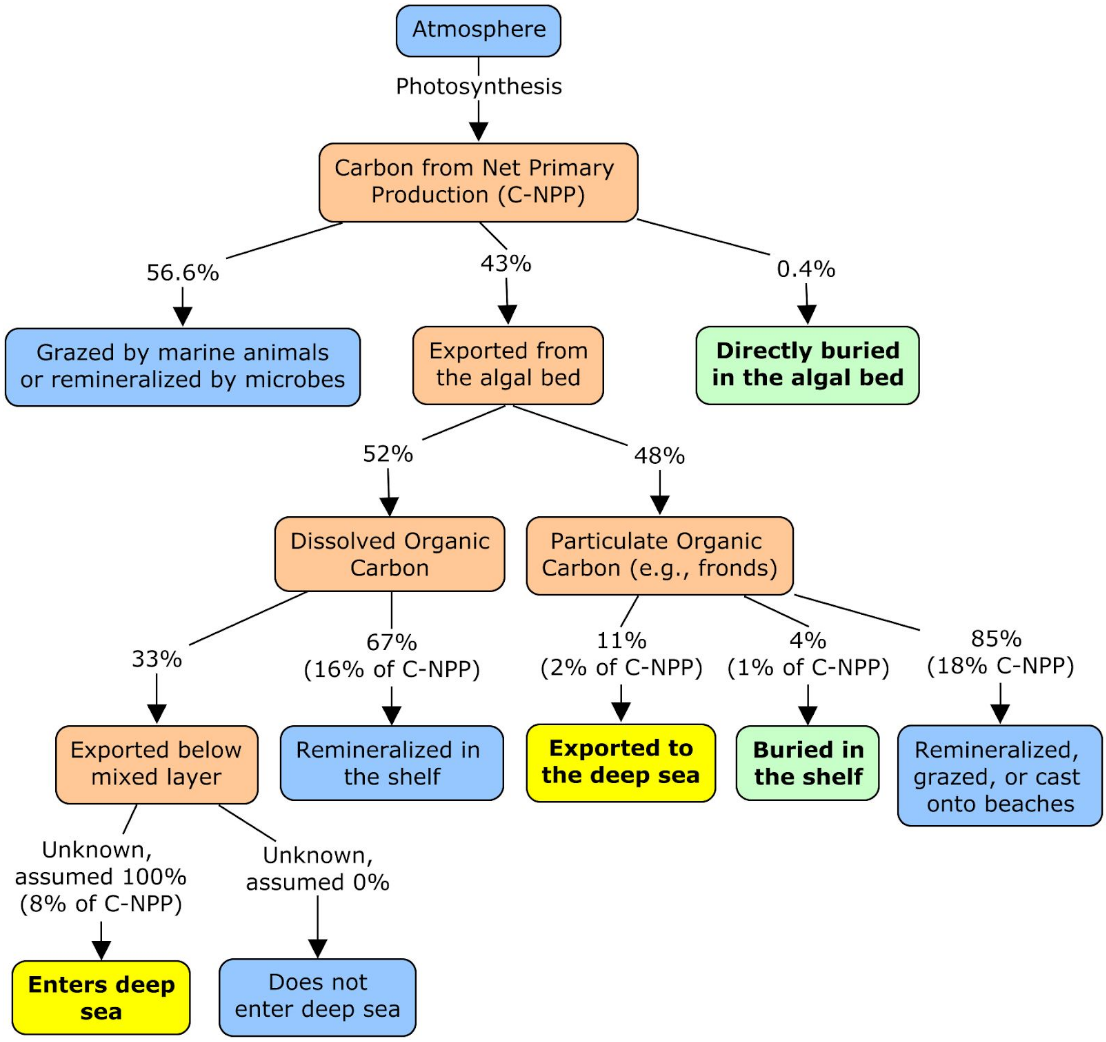

Figure 2 *- Bolded cells show permanent carbon storage, source [14].*

In New Zealand a machine learning algorithm could be trained to provide accurate estimates for the percentage of detritus permanently sequestered, by studying historical kelp populations and sampling nearby seabeds for DOC & POC. A detailed understanding of the proportion of DOC & POC permanently sequestered for defined locations would be crucial, so that MPAs could be strategically placed to maximise carbon storage. This technology would also provide measurements of the amount of carbon sequestered, so that it may be included into a farm-level emissions pricing system.

Given the NPP and percentage of detritus permanently stored in the ocean, the carbon storage capability of *M. pyrifera* can be modelled (Figure 3).

Under average conditions, *M. pyrifera* is dramatically more effective at permanently storing carbon than *P. radiata* (Figure 3). A confidence interval band of ±10% represents potential variability in NPP and the proportion of detritus being permanently stored (Figure 3).

In addition to MPAs ability to permanently absorb carbon, there are many other beneficial uses of seaweed products. In particular, kelp fertilisers have the potential to be used within the agriculture industry, providing a carbon positive solution to fertiliser use, and reducing the demand for polluting nitrogen, lime & dolomite fertilisers.

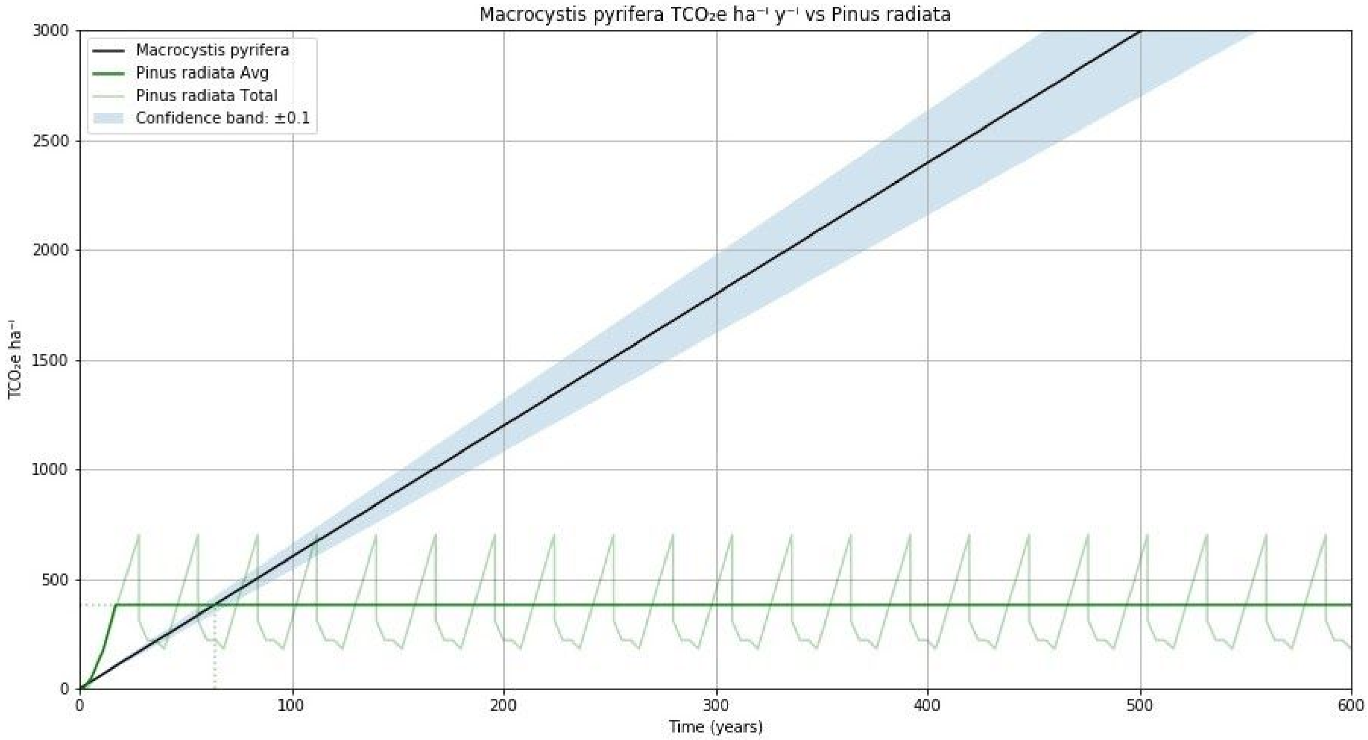

Figure 3 *- Author's model, cross-checked to a similar model by Robert Hickson, source [12].*

Kelp based fertilisers can be produced sustainably within New Zealand's exclusive economic zone, in stark contrast with current production of phosphate and nitrogen fertilisers. Currently, phosphate fertilisers are imported from a disputed territory in the Western Sahara, in a mining operation run by Morocco. The phosphate fertilisers disperse contaminants of cadmium, fluoride and uranium in a thin layer across New Zealand farmland, creating potential food safety concerns if contamination continues.[18] Nitrogen fertilisers are produced through the energy intensive Haber process, with a large carbon footprint attached to maintaining a high temperature and pressure during production.[20] Nitrogen fertiliser production plants also leak nitrous oxide[20] (N_2O), a greenhouse gas with global warming potential 265-298 times that of carbon dioxide.[21]

Fertilisers are an essential part of maintaining healthy soil and keeping farm productivity high. Fertiliser use is directly linked to productivity, and a decrease in productivity would lead to a decrease in real GDP output. In 2016, fertilisers were responsible for 3.4% of New Zealand's total greenhouse gas emissions, totalling 2.7 million tonnes of CO_2e emissions[15].

Not only is seaweed fertiliser a carbon-positive fertiliser option, but it is a highly effective fertiliser in its own right:

"Seaweed contains all major and minor nutrients, trace minerals, alginic acid, vitamins, tannins and natural sugars in a readily available and absorbable form. Seaweed is a natural source of organic iodine. Iodine acts as an antibiotic to kill germs, increasing growth rate, feed and production efficiency." - AgriSea New Zealand.[16]

Demand for fertilisers is likely to increase as the effects of climate change make for harsher farming conditions. Widespread adoption of seaweed fertiliser would result in lower demand for industrially produced fertilisers, reducing their quantity supplied, and subsequently reducing CO_2 emissions.

"Scientists expect drought, floods and reductions in winter frost will increase demands on water and fertiliser, change what can be produced and increase the presence of pests. It's also likely that extreme

weather events will reduce land quality and disrupt the supply chain, with impacts on profitability." - James Shaw, [5]

Marine permaculture infrastructure can be treated as an investment as it is likely the quantity demanded of fertilisers will increase in the future. By investing in marine permaculture infrastructure now, the country can capitalise on this industry and become global experts and exporters.

Using MPAs to grow and harvest seaweed would slightly reduce the carbon sequestration ability per hectare. As the seaweed is harvested, it takes 8-12 weeks to regrow, and detrital production subsequently decreases throughout this period. More research is needed to determine detritus production throughout *M. pyrifera's* growth period. For the purposes of this model (Figure 4), we will assume no detritus production throughout the growth period. This will make the model underperform slightly because detritus production is unlikely to drop to zero through this period.

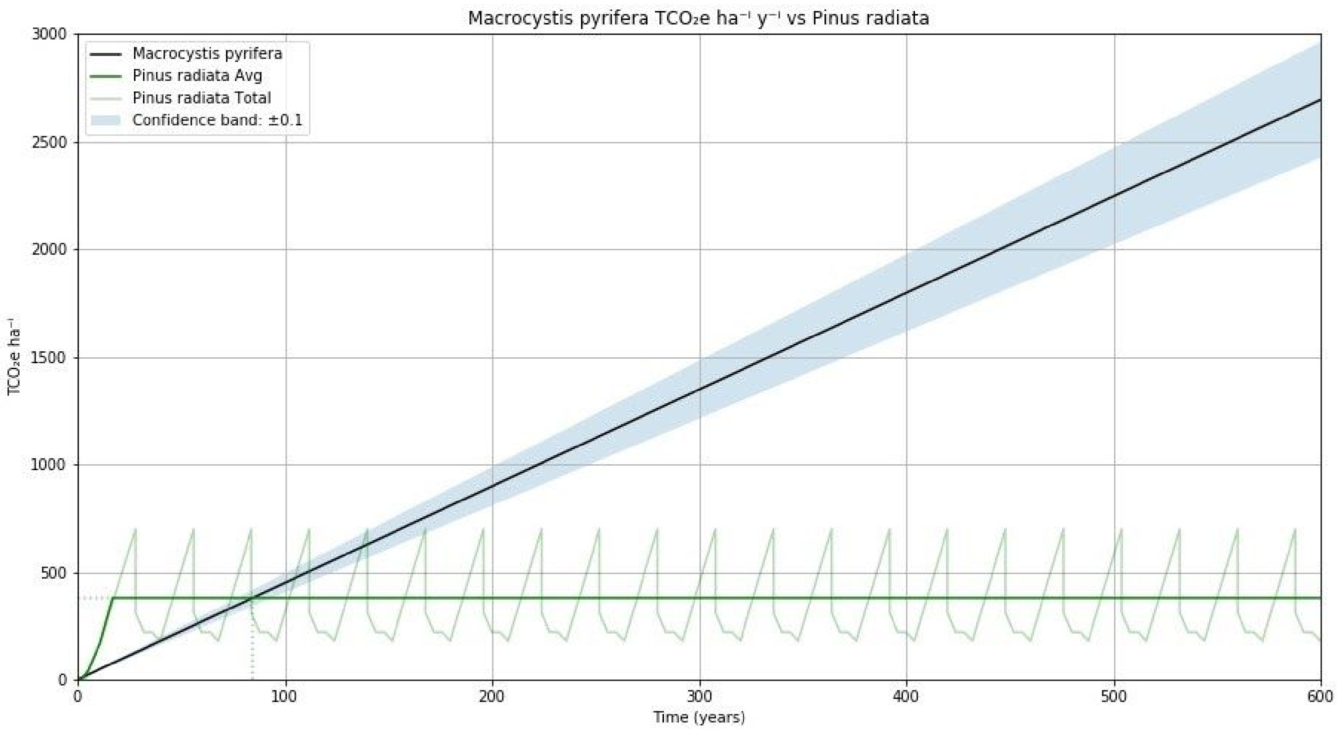

Figure 4 *- Author's model, M. pyrifera carbon sequestration over time including harvest/regrowth cycles.*

Integrating marine permaculture into emissions trading

To price on-farm emissions through the new scheme that MPI, MBIE, MFE and farmers are working towards proposing,[5] like the ETS it would make sense to reward carbon positive industries by allowing them to generate carbon credits and units.

Allowing marine permaculture to generate carbon units within the on-farm agricultural emissions proposal would help catalyze the marine permaculture industry in New Zealand by giving it a similar status to what forestry holds within the ETS currently.

Enabling carbon credit generation from MPAs would make marine permaculture products more valuable and therefore more viable as a business and industry. Based on MPA carbon sequestration models and the price of carbon, it is clear that credit generation would provide reliable income for the industry. If the price of carbon holds at the current fixed price option of $35/Tonne for the next 100 years, a MPA under average conditions will consistently receive $157 per year, per hectare.

Plantation forests stop generating ETS revenue after around 20 years (once the line 'Pinus Radiata Avg' flatlines (Figure 1)). As no extra carbon is being sequestered, ETS revenue halts after this point. But as marine permaculture continuously sequesters carbon in a linear fashion, it would consistently generate revenue through ETS payments year on year.

Carbon prices will increase as the government restricts supply of carbon credits to incentivise emissions reduction. To model *M. pyrifera* MPA annual revenue per hectare (Figure 5), the price of carbon begins at the current ETS fixed price option of $35[19], and increases by 2% each year.

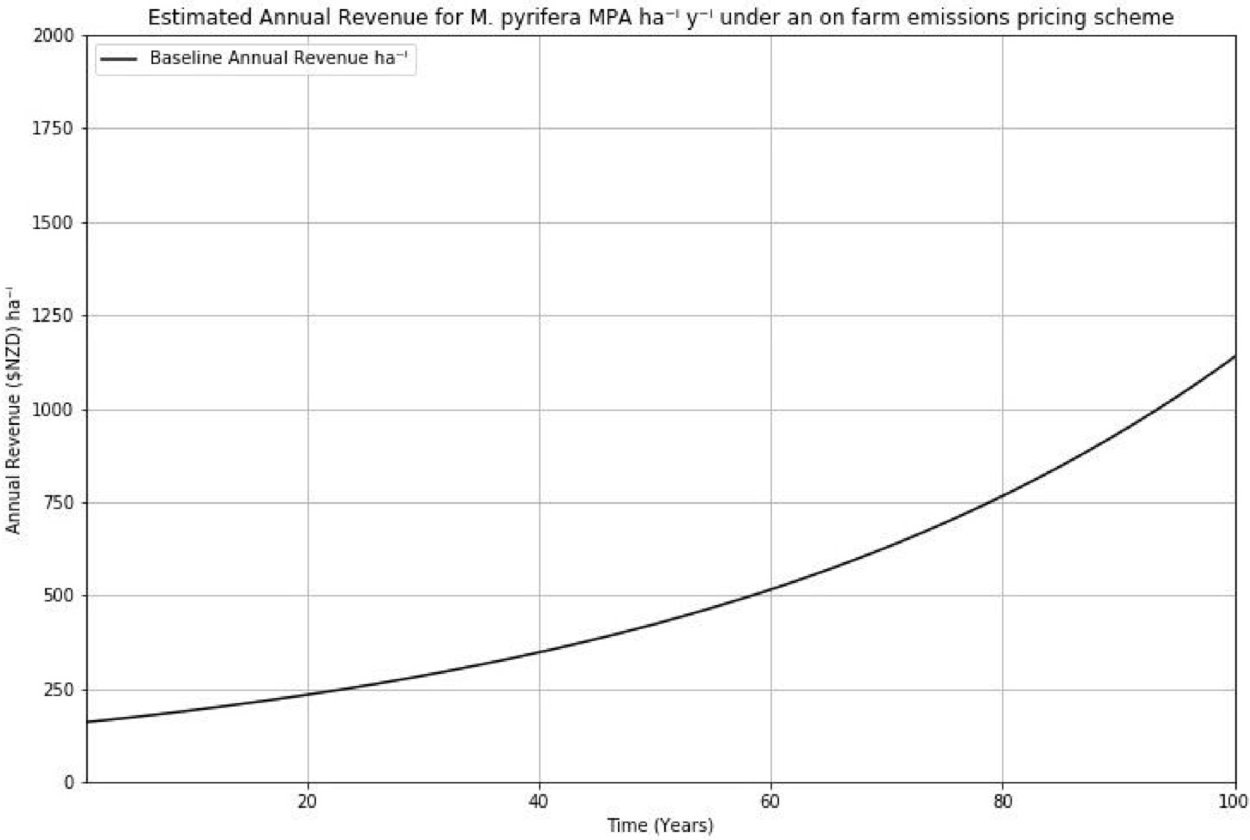

Figure 5 *- Author's model: carbon sequestration payments for M. pyrifera under average conditions, assuming payment of* 35×1.02^{year} */ tonne* CO_2e

The income generation per hectare of a standard *M. pyrifera* MPA for sequestering carbon will slowly increase over time, forming a reliable source of income as it sequesters more and more carbon each year. Therefore, using marine permaculture for carbon sequestration becomes far more effective than typical *P. radiata* plantations over time, and rewarding this within a carbon pricing scheme would help boost the uptake of such sequestration methods.

In a high growth scenario (Figure 6), one hectare of *M. pyrifera* takes just 52 years to permanently sequester as much carbon as one hectare of *P. radiata*. This is 62.5% faster than the baseline estimate, where one hectare of *M. pyrifera* takes 84 years to 'overtake' *P. radiata* with averaging. Notably, after the *M. pyrifera* MPA overtakes *P. radiata* in terms of carbon sequestration, the amount of carbon sequestered continues to increase, whereas *P. radiata* sequestration remains at the same level.

The high growth scenario (Figure 6) translates into higher income generation from a carbon pricing scheme shown in Figure 7.

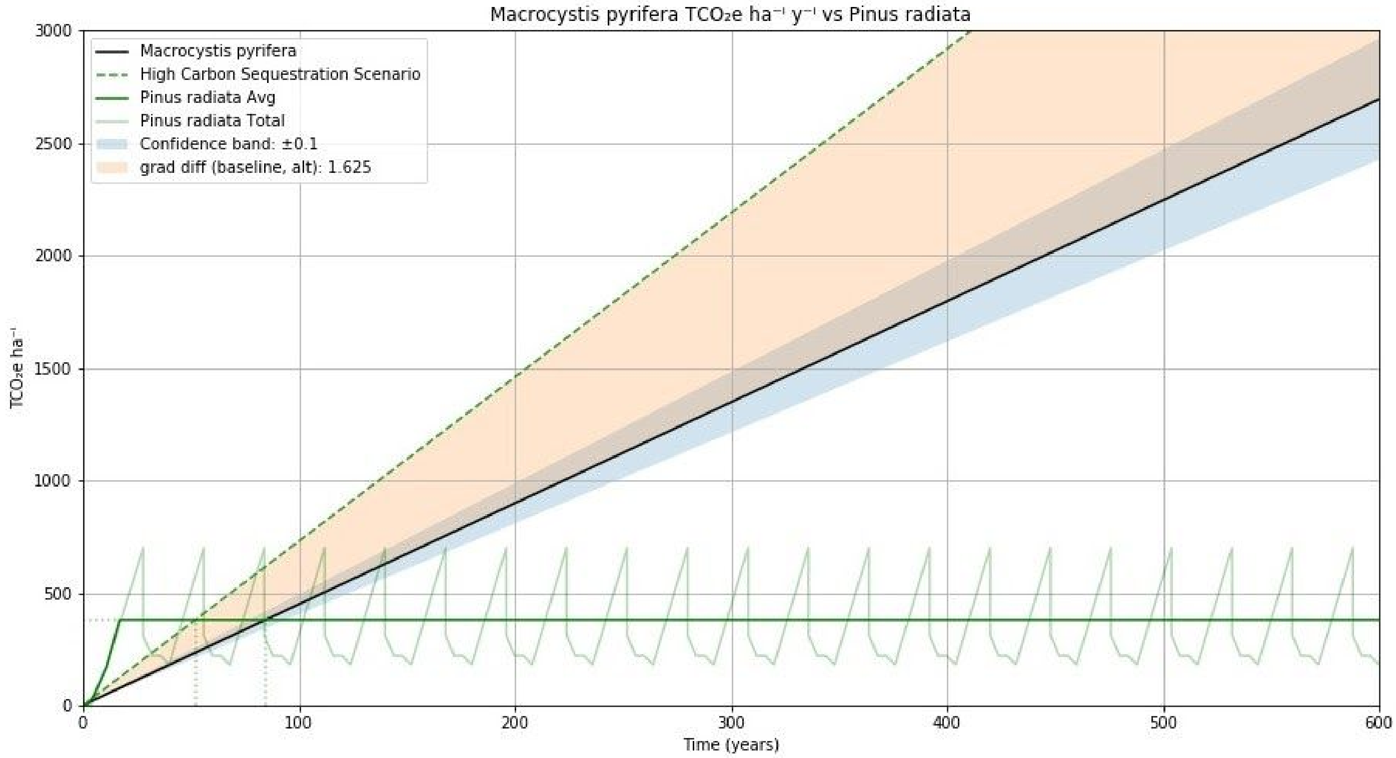

Figure 6 *- Author's model, displaying a high growth scenario where NPP and percentage of carbon permanently sequestered are both 20% higher than their baseline values. Additionally, the time that M. pyrifera takes to reach its maximum length has been reduced to 8 weeks rather than 12 weeks.*

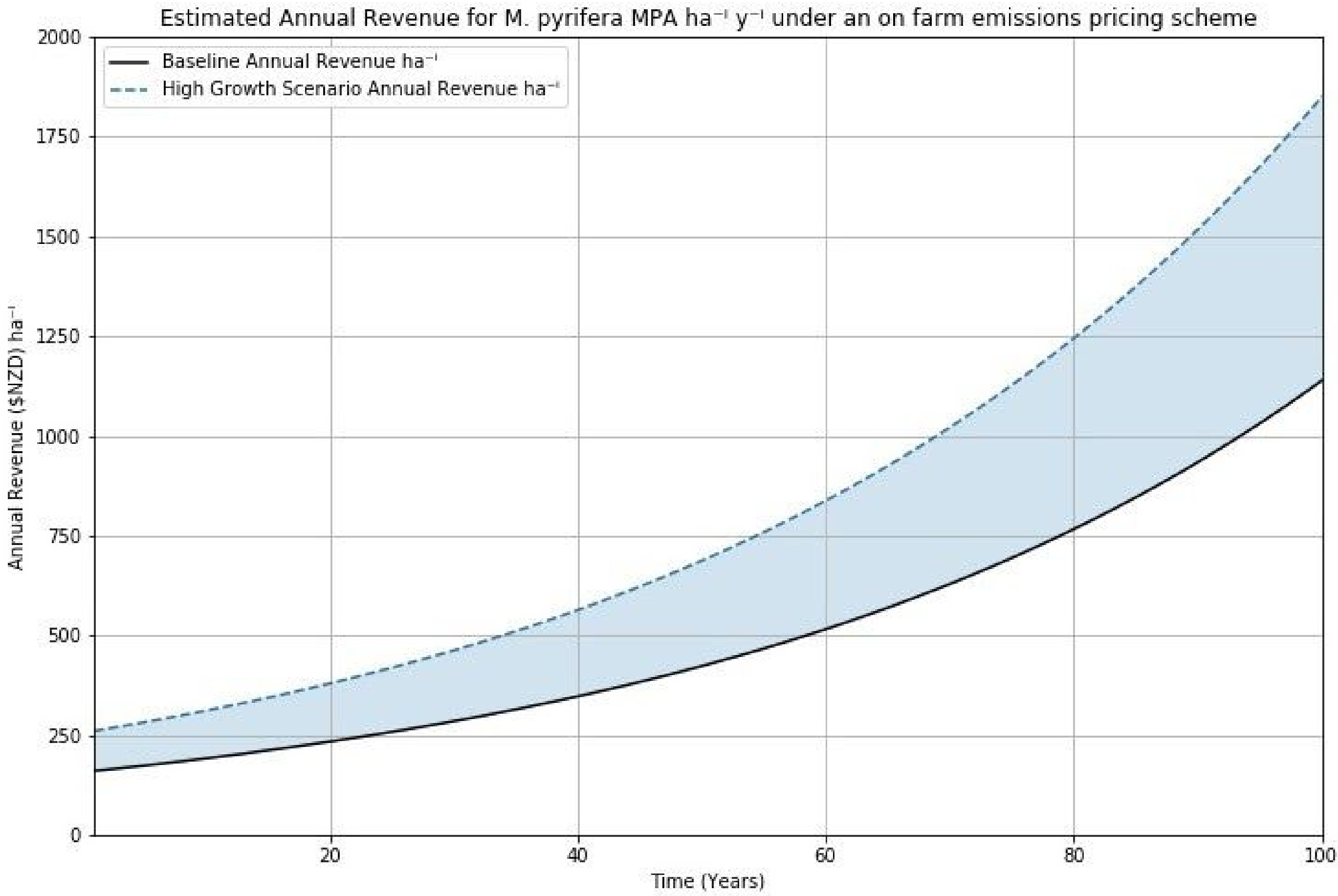

Figure 7 *- Author's model, showing the increased carbon sequestration revenue generated from a high growth scenario as compared to baseline carbon sequestration rates.*

As the marine permaculture industry grows, more research effort will potentially boost the carbon sequestration capability of *M. pyrifera* and other seaweed/kelp species with advantageous properties. Technological advancements are also likely to boost growth rates. For example, wave powered pumps that pump nutrient-laden water from deep in the ocean up to the photic zone would allow MPAs to absorb more nutrients, boosting growth and detritus production.[7] These developments have the potential to boost NPP, sequestering more carbon and generating more carbon sequestration revenue.

By including marine permaculture into carbon pricing negotiations, an exciting positive feedback loop is created, benefiting both consumers of fertilisers in the agricultural sector and the marine permaculture industry. Greenhouse gas emissions payments could become a positive for the agriculture sector, as their payments effectively subsidise an industry which produces carbon-positive fertilisers, making it cheaper for fertiliser consumers to reduce their emissions. As the emissions payments provide a secondary income stream for the marine permaculture industry, the industry becomes more well established, and prices of carbon positive fertilisers fall as the supply increases.

A major discussion point in the MFE document 'Action on Agricultural Emissions'[5] is whether fertiliser-related emissions are charged as on farm emissions, or charged against fertiliser producers/importers. By using emissions payments to subsidise carbon positive seaweed-based fertilisers, charging fertiliser emissions at the farm level would boost demand for seaweed fertilisers, as they would be exempt from additional emissions charges. This will further increase the viability of marine permaculture as the demand for their products increases. As the demand for polluting fertilisers falls the quantity supplied will decrease, reducing carbon emissions from this sector as a result.

MPAs would move carbon sequestration efforts offshore into under-utilized waters in New Zealand's exclusive economic zone. There is concern that the agriculture on-farm scheme will encourage the conversion of productive farmland into pine forest, 'wasting' valuable productive land for carbon sequestration purposes. By moving carbon sequestration offshore, less productive land is lost to forestry, and an under-utilized area offshore is made productive. This would be a win-win for New Zealand's GDP, agriculture, and the emerging deepwater aquaculture industry.

Seaweed for biogenic methane reduction

Exciting research is being done overseas and at Cawthron Institute in New Zealand, investigating the possibility of NZ native red seaweed species *Asparagopsis armata* being used to reduce biogenic methane emissions from cows. As an additive to cattle feed, the seaweed species has been shown to reduce biogenic methane emissions by up to 80%.[17]

"The next phase of research is to develop an early proof of concept of the aquaculture production systems needed to develop Asparagopsis at scale." - Cawthron Institute [17]

This could be a total game changer for the agriculture industry. Unlike *M. pyrifera*, large scale cultivation of *A. armata* needs to be better understood before prediction as to rates of carbon sequestration can be made. However, setting up the framework for MPAs and carbon sequestration payments now could prove highly advantageous in the future, if large scale production similar to *M. pyrifera* proves feasible.

Conclusion

By incentivising MPAs for carbon sequestration and organic fertiliser production, a positive feedback loop is created for fertiliser consumers in the agriculture industry. Carbon emission payments to carbon-positive MPAs boost New Zealand's carbon sequestration efforts, and absorb carbon far more effectively in the mid-to long-term than conventional pine plantations. Crucially, farmers' emissions payments would subsidise a carbon-positive fertiliser, which will increasingly be in demand as the effects of climate change impact farm productivity. Pricing fertiliser emissions at the farm level will also accelerate the uptake of seaweed-based fertilisers. The carbon footprint of agricultural products is reduced, and a lower carbon footprint would be passed on to consumers of New Zealand agricultural products worldwide. Government policy to make marine permaculture a carbon-offset option alongside agricultural emissions pricing negotiations builds a 'double benefit' approach to cutting carbon emissions. Marine permaculture would become a carbon offset, while simultaneously cutting demand for polluting fertiliser options. This altered emission pricing model for agriculture would incentivise consumers within the agriculture industry to use seaweed based carbon-positive fertiliser, while efficiently offsetting emissions at the same time. These would be wins across the board for agriculture, aquaculture, the economy, climate and all consumers of NZ agriculture.

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