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The potential of forest-based carbon sequestration on floodplain land owned by Environment Southland

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Executive summary

Environment Southland owns over 2000ha of land around the Mataura estuary on the South Coast of NZ. The land was originally purchased for flood management purposes but is now seen also as strategically important for protecting biodiversity and improving Southland's climate change resilience. With these additional objectives, opportunities arise to manage the land, so it provides ongoing flood protection and at the same time increase its capacity to sequester carbon and protect indigenous biodiversity.

The problem

The potential for carbon sequestration by utilising native and exotic tree species is unknown under the unique conditions of the Mataura floodplain. While multiple options for land management exist, the potential for carbon sequestration needs to be assessed to ensure good land management decisions are made.

This project

Scion has been contracted to provide a report on likely carbon sequestration and carbon stocks for tree species that are suitable for the unique environment, characterised by frequent flooding, high wind conditions and a cool climate. Based on an initial survey of existing woody vegetation on the floodplains and expert knowledge, Scion conducted a desk-top study to estimate carbon sequestration for key tree species that are suitable for this site.

Key results

Native tree species that are present on Environment Southland land around the Mataura estuary have the potential to sequester up to 5.9 tCO_2e[1]$\cdot ha^{-1}\cdot yr^{-1}$ (manuka), if planted at sufficient density (1000 stems per hectare), with an average across multiple species of 3.3 $tCO_2e\cdot ha^{-1}\cdot yr^{-1}$. Existing natural stands of native species (as a mixture) have accumulated approximately 220-256 $tCO_2e\cdot ha^{-1}$ since their establishment. Very densely stocked natural stands of manuka carrying around 135 $tCO_2e\cdot ha^{-1}$.
Poplar as the best suited exotic tree species for the site is able to sequester around 10 $tCO_2e\cdot ha^{-1}\cdot yr^{-1}$ if grown at a density of 200 stems per hectare, reaching up to 300 $tCO_2e\cdot ha^{-1}$ at age 30 years. Lower stocked stands that still allow for grazing or potentially underplanting can sequester up to 6.6 $tCO_2e\cdot ha^{-1}\cdot yr^{-1}$ and reach stocks of around 200 $tCO_2e\cdot ha^{-1}$ at age 30 years.

Implications of results for the client

The results of this desk top study can be used to evaluate variable options that include carbon sequestration by trees. Ideally the species-specific carbon sequestration rates should be used on a stratified site map of the Mataura floodplain that identifies microsites most suited for a particular species or species combination based on the frequency and intensity of flooding e.g. totara on less frequently flooded sites than kahikatea. Importantly, Environment Southland can identify such suitable sites through additional work that will also account for biodiversity and flood management benefits so as to develop a map to assist in indentifying where trees can be grown efficiently for carbon sequestration. Therefore, providing indicative carbon sequestration rates is a first step towards a more integrated management approach for the Environment Southland land on the Mataura floodplain.

Further work

The Mataura floodplain is a unique environment for which little data exists to support accurate modelling of carbon and carbon stock changes in exotic or native species.

[1] CO_2e: Carbon dioxide equivalent. Carbon credits are commonly expressed as carbon dioxide equivalents. 1t of carbon is equivalent to approx. 3.6t CO_2.

If Environment Southland decides to go ahead with the planting of various native and exotic species such efforts should be accompanied by trials or ongoing monitoring to capture growth data that could support efforts to estimate carbon sequestration in these unique environments in the future. It would also provide more robust and precise data needed for registered carbon accounting for Environment Southland.

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Introduction

Environment Southland (ES) owns over 2000ha of land around the Mataura estuary on the South Coast of NZ. The land is currently grazed but retains pockets of wetland and remnant native forest. The land was originally purchased for flood management purposes and this has been the focus of subsequent management to date.

Council priorities have changed over recent years and the protection of indigenous biodiversity and investing in Southland’s resilience to climate change are now seen as strategically important activities.

ES has an opportunity to change the way the land is managed so that it continues to provide flood protection, but also increases carbon sequestration and the protection of indigenous biodiversity. The number of suggested options for management are extensive and could include:

- Native forest restoration for carbon sequestration
- Exotic forest planting for carbon sequestration
- Exotic forest planted as a nursery crop for carbon sequestration and long-term native forest restoration
- Wetland restoration
- Continued grazing in farmed areas
- A mosaic of all the above

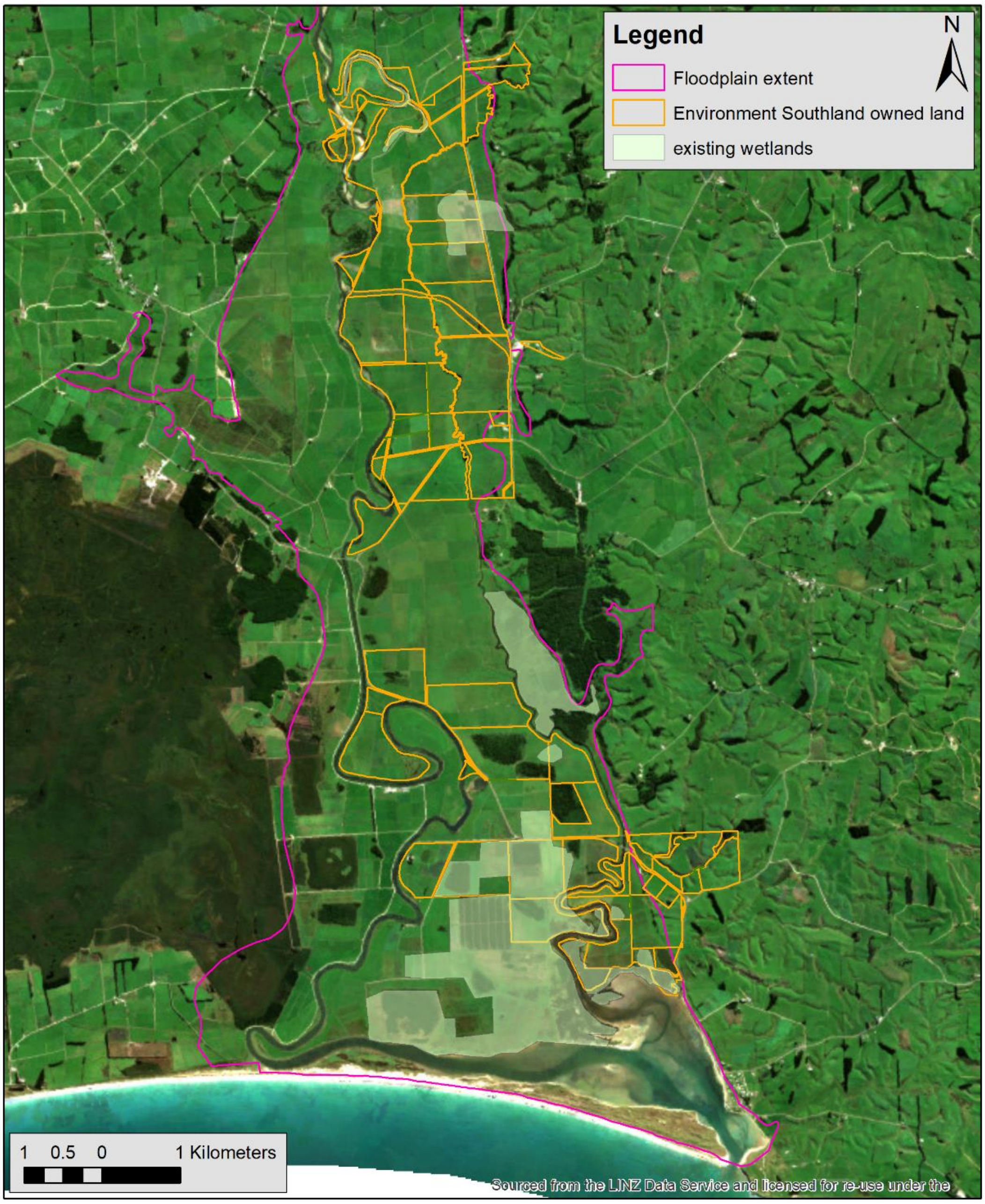
Each of the options suggested above has a different potential in regard to carbon sequestration and protecting or enhancing indigenous biodiversity. Understanding the merits and validity of each option will be essential for good decision making when it comes to the future management of ES land around the Mataura estuary. Importantly each option should be assessed in light of the sustainability, risk and feasibility to sequester carbon and protect indigenous biodiversity. While this report focuses on the potential for sequestering carbon through trees, which is beyond business as usual for ES, they will conduct further work to understand the biodiversity, biosecurity risk (invasive species) and flood management aspects of increasing the woody cover on their land.

Because ES is unable to complete an indicative assessment of carbon sequestration for their area in the Mataura floodplains Scion was contracted to provide predicted carbon sequestration rates (excluding changes in soil carbon) for exotic and native tree species that are suitable as a woody tree cover for the 2000 hectares Environment Southland owns and manages.

Materials and methods

The site

The Mataura Floodplains (Map 1) and particularly the land parcels owned by Environment Southland are an important area for flood management purposes, but also offer the potential to protect biodiversity and increase resilience against the impacts of climate change such as increased flooding.



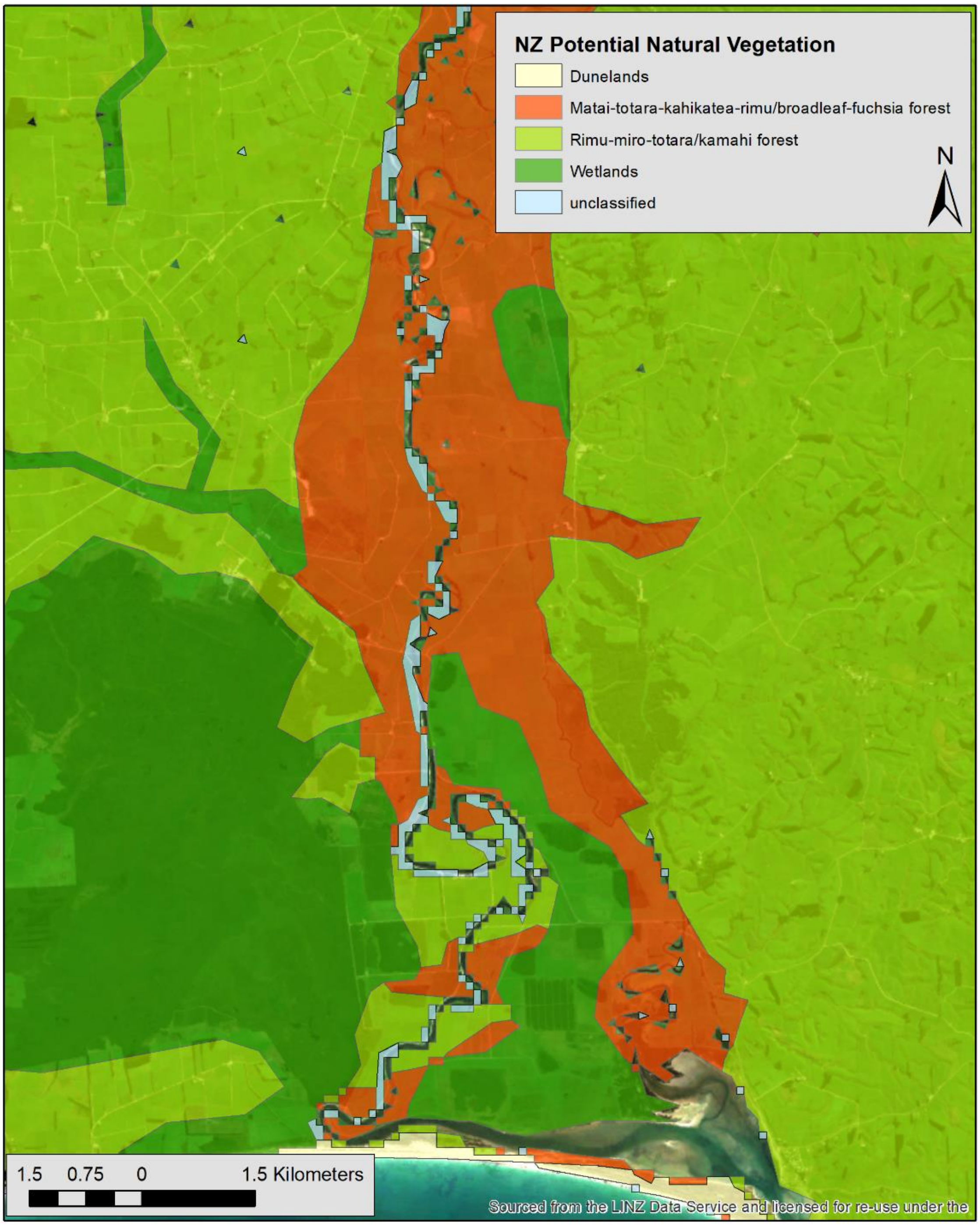
Map 1: Mataura floodplains and Environment Southland owned land within the floodplain. Currently mapped wetlands are also shown (transparent light green).

The Mataura floodplains are located in the Waituna Ecological District, the southern-most ecological district in mainland New Zealand. The area is environmentally characterised by being a small flat area characterised by a low coastal relief and a climate that is cool, cloudy and windy with a rainfall of 1000-1200mm per annum. The soils are largely poorly drained with deep acid peat on flatter parts with strongly leached soils on surrounding gently undulating areas, as well as small areas of alluvial soils, coastal dunes and sand flats. Accordingly, it contains proportionately more wetland than any other ecological district.

Overall the area can be characterised topographically and ecologically as a river floodplain with only small elevation changes, which is prone to flooding from the Mataura river its tributaries and the Titiroa as shown in Map 2 during the 2018 floods.

Map 2: Mataura floodplains during the 2018 flood.

These small elevational changes alter the frequency and severity of flooding on a specific site within the floodplain but also, in combination with speed of water flow, alter sediment deposition and therefore long-term soil structure. This is known to alter tree species composition (Clarkson, Downs, & Merrett, 2002; Leathwick, 2016) and therefore the potential indigenous vegetation mosaic that would develop over time depending on those small elevation and soil changes. To illustrate this, the potential vegetation layer (Leathwick, Walker, & McGlone, 2015) shows that the study site would comprise of woody vegetation types dominated by podocarps and non-woody vegetation types particularly wetlands (Map 3).



Map 3: Potential Natural Vegetation layer for the Mataura floodplains based on a nationwide modelling exercise (Leathwick et al., 2015).

This contrasts with the current pattern of exotic and native vegetation observed on the Mataura floodplains, which has developed over time since the human inhabitation of the area. As a consequence of early Maori fires, much of the lowland forest was removed and replaced by manuka scrub or red tussock land (Environment Southland, 2010). European settlement and associated agricultural development further reduced the extent of forest as well as wetland vegetation types, replacing them largely with pasture. Marginal areas often retain a degree of naturalness even though they are modified by weeds, drainage, stock grazing and other agricultural activity.

Remaining woody vegetation (forest remnants) on environment Southland land around the Mataura River can provide an additional indication of the potential natural vegetation of the area. Forest that would have covered some of the areas are a mix of silver beech (*Lophozonia menziesii,* (Hook. f.)), totara (*Podocarpus leatus (*Hooibr. ex Endl.*),* kahikatea *(Dacrycarpus dacrydioides* (A.Rich.) de Laub.*),* matai *(Prumnopitys taxifolia* (Banks & Sol. ex D. Don) de Laub.*)* and miro *(Prumnopitys ferruginea* (G. Benn. ex D. Don) de Laub.*)* which would have dominated the upper canopy of these forests.

Estimation approaches for woody carbon stocks and potential sequestration rates

We estimate carbon stocks for indigenous tree species and exotic plantation species on a per hectare basis, and carbon sequestration rates based on annual changes in the stocks per hectare. This provides the ability to estimate total area carbon stocks and sequestration on a yearly basis once the floodplain area is stratified to identify sites that suit the relevant forest types and purpose (e.g. flooding channel). We modelled the above-ground biomass carbon stocks and sequestration rates in the first instances and modelled below-ground live biomass (roots) and additional aboveground biomass (e.g. branches, twigs etc) using the C_change model (Beets, Robertson, Ford-Robertson, Gordon, & Maclaren, 1999). We did not include mineral soil carbon in our calculations. Afforestation of pasture land typically leads to a loss of mineral soil carbon, which is modelled in New Zealand's greenhouse gas inventory as a loss of about 2.2 t CO_2 ha-1 year-1 over 20 years.

For planted indigenous forests we estimated the average carbon sequestration and final stocks for a period of 80 years. For exotic forests a different period was chosen, depending on the suitable rotation length for each species based on the intended utilisation of the forest (e.g. timber).

For indigenous forests

A survey of the Environment Southland land in the vicinity of the Mataura River was conducted in November 2020 to broadly characterise the existing forest types and importantly their structure (Map 3). Nine sites across the floodplains were visited that represented remnants of mature silver-beech-podocarp forest and manuka stands reaching over 5m in canopy height. Based on tree species composition and by identifying the Land Environment Class (LES; level 3) for the relevant areas we selected natural forest inventory plots representing the same types of forests (based on tree composition), latitude and LES class from the national representative natural forest inventory (Paul, Kimberley, & Beets, 2019). From our survey dataset of forest remnants, stand characteristics were estimated. These were compared with the national inventory data and carbon stocks and sequestration rates estimated based on similarity to the natural forest inventory plots. The estimated carbon stocks are used as an upper "ceiling" for long-term carbon stocks for naturally developing forests with similar composition on Environment Southland land around the Mataura.

While this approach allows the estimate of the long-term possible upper levels of carbon stocks for the present remnants and natural succession towards these forest types, this method does not estimate carbon sequestration rates for possible new plantings of the tree species present in the remnants. As an indication of the carbon sequestration potential of new native tree plantings, we selected the key tree species based on the main canopy tree species found in the remnant native forest stands to model their growth and therefore carbon sequestration. The following species were selected:

- Silver beech
- Totara
- Miro
- Kahikatea
- Rimu
- Manuka/kanuka

For these species we calculated carbon yields (carbon sequestration rates) when planted into grassland or cleared land. Carbon yield tables were derived as follows:

- Tree species specific volume tables were obtained by adjusting reference volume tables for totara on high, medium and low productivity sites (Bergin & Kimberley, 2000), using tree species-specific scale factors. Scale factors were developed based on tree height and diameter data for the relevant species, captured in plantations by Pardy, Bergin, and

Kimberley (1992). For the Mataura site we assumed a low productivity site level for all species volume tables.

- To estimate carbon from stem volume, we used species-specific wood basic density, assuming density is constant with age, and applied a scaling factor of 0.916 (Beets, Kimberley, & McKinley, 2007) to estimate whole stem density. Amounts of carbon in all biomass pools (excluding mineral soil carbon) was calculated using the C-Change model (Beets et al., 1999) with input from the volume tables and the calculated wood density for each species. As a standard planting regime for all species we modelled plantings with an initial stocking of 1000 stems/ha.

For exotic forests

Exotic production tree species, particularly radiata pine, show superior growth rates compared to native tree species on most sites. However, radiata pine has been shown to be not suitable for waterlogged and wet soil conditions. Under these conditions plantings commonly fail due to:

- Limited root growth in wet soils, which increases the probability of toppling and windthrow.
- root rot, resulting in greatly reduced survival in new plantings

Overall radiata pine does not tolerate very wet soils or salinity (Mead, 2013), with the latter a feature of the study area. Furthermore, radiata pine is prone to storm damage in high wind situations, not uncommon for the study site either.
For the reasons above the modelling of radiata pine growth and carbon sequestration for the study area was not carried out as any carbon stocks and sequestration rates would carry a high risk of being unsustainable.

Poplars species are probably the most suited exotic tree species for planting due to their ability to withstand water logged soils, temporary flooding, their known lower risk of becoming invasive when compared with other alternatives such as willows and the “wind-hardiness” of some clones (National Poplar and Willow User Group, 2007) . To estimate sequestration rates for planted poplar stands we used results from the single study that estimated sequestration based on poplar growth data of widely planted poplar stands on average hill sites (Guevara-Escobar, Mackay, Hodgson, & Kemp, 2002). We used a stem-number-based scaling approach for denser poplar stands (final stocking of 200 stems/ha) to show the sequestration potential for denser poplar plantations (Shepherd et al., 2016). To be able to estimate more site-specific carbon sequestration rates for poplars on Environment Southland lands, a growth model and measurement data would be required. While a volume growth model exists (McElwee & Knowles, 1998) and has been used in combination with the C_Change model, representative stand measurement data to run the model is not available. If representative measurement data becomes available, a more detailed growth modelling and carbon sequestration exercise could be carried out. In the mean time we used an estimated height growth rate of mean top height of 24m at age 30 years (representing a swampy site) based on data from (McElwee & Knowles, 1998).

Results and discussion

Native carbon stocks and sequestration rates

The native remnants on Environment Southland land in the Mataura floodplain represent forest types composed in the upper height tier of silver beech, kahikatea, totara and miro. The tree height and basal area estimates made in those old remnants indicate that carbon stocks are comparatively low compared to the national average for forest types that contain these tree species as a dominant upper canopy feature in the far south. Based on the LUCAS National Forest Inventory (NFI) the relevant forest types in the far south have on average carbon stocks of 586 $tCO_2e \cdot ha^{-1}$ accumulated in the live aboveground biomass (AGB). The NFI plots with similar upper canopy tree composition have on average three times the basal area than the measured forest remnants. An upper ceiling of AGB carbon stocks at Mataura would therefore be lower and more around 220-256 $tCO_2e \cdot ha^{-1}$.

The single mānuka dominated remnant that was assessed can be classified as a mānuka successional shrubland (Wiser, 2016). In comparison to similar NFI plots, the assessed remnant represents an extremely dense stand of mānuka shrubland with a far greater basal area (29 $m^2 \cdot ha^{-1}$) than any plots of this vegetation type encountered in the Natural Forest Inventory. Based on basal area and height the stand currently carries around 135 tCO2e·ha-1 while the average in the NFI for this forest type is ~62.3 tCO2e·ha-1 in the south of the South Island and Stewart Island.

Planted indigenous forests

While existing indigenous stands can provide a good indication of the site potential for native trees to sequester carbon in the very long term, the planting of trees on currently un-forested sites (afforestation) provides additional carbon sinks that are eligible for carbon credits under the ETS. Table 1 provides an overview of the indicative carbon sequestration rates of native tree species found on Environment Southland land around the Mataura floodplain, when planted as a single species stand at 1000 stems/ ha.

Table 1: Native tree species and their estimated carbon sequestration rates and carbon stocks over a period of 80 years.

Tree species	Mean total annual sequestration rate over 80 years (tCO2e·ha-1·yr-1)	Carbon stocks at age 80 years (tCO2e·ha-1) AGB	Total
Silver beech	4.5	301.5	363.9
Totara	3.1	205.7	249.15
Kahikatea	2.6	173.9	210.5
Miro	0.9	62.0	74.5
Rimu	2.7	178.2	215.4
Kanuka/Manuka	5.9	391.8	478.7

Silver beech provides the greatest long-term carbon accumulation of all species modelled, as it shows good early growth and is a mid-late-successional species. Manuka/kanuka as an early-succession species shows greater earlier sequestration rates but are expected to be not as long-lived (manuka is more short-lived then kanuka). It is also important to note that the sequestration rate of manuka might be overestimated especially over 80 years because of the modelling approach that was taken. Evidence for this is indicated by the comparison with the field assessment of the densely stocked Manuka stand at Mataura (135 t CO2e ha-1), which can be characterised as a fully stocked late stage manuka stand which has reached its maximum stocking and height. Even the silver beech carbon stocks at age 80 years may be slightly overestimated as the natural stands visited held approximately 220-260 tCO2e·ha-1 compared to the modelled 301 tCO2e·ha-1 (aboveground live only). However, well managed planted forests of native species have been shown to grow faster (Steward, Kimberley, Mason, & Dungey, 2014) and sequester carbon more quickly than naturally regenerating sites (Bergin, 2003; Kimberley, Bergin, & Beets, 2014).

The four native conifers modelled showed a large variation in growth rates and therefore carbon sequestration. Carbon sequestration estimates for totara of 3.1 tCO2e·ha-1·yr-1 are probably the most reliable estimates, as this species' growth has been extensively studied in a plantation context across New Zealand (Bergin, 2003; Bergin & Kimberley, 2000; Bergin, Kimberley, & Low, 2008). Plantings of totara would be best suited for any better draining soils while kahikatea with its slightly lower sequestration rate of 2.6 tCO2e·ha-1·yr-1 would be better suited for the poor draining soils. While Rimu and Miro do occur as a canopy tree in natural stands, their establishment as a single species plantation into grassland might be a less suitable option. However, as a later underplanting into canopy gaps or areas where the initial planting of individual trees of other species failed might be a suitable option under a long-term management regime. With their lower carbon sequestration and their greater shade tolerance compared to the other native conifer species their main benefit would be as enhancement planting to enrich the tree diversity of earlier established plantings.

Poplar carbon stocks and sequestration rates

Carbon sequestration rates of poplar stands are shown in table 2. For widely spaced poplar stands (37 stems·ha-1) carbon sequestration was estimated as 2.0 tCO2e·ha-1·yr-1 by Guevara-Escobar et al. (2002) on hill country with a maximum stock of 42.2 tCO2e·ha-1 (Burrows et al., 2018). Assuming the same sequestration rate applies at the Mataura site, a poplar stand with a greater stand density of 200 stems·ha-1 would have a sequestration rate of 10.8 tCO2e·ha-1·yr-1.
Using a basic height model and volume model for poor sites (McElwee & Knowles, 1998) and the C_change partitioning model (Beets et al., 1999) a nominal poplar stand at a stocking of 200 stems/ha would have sequestered 299 tCO2e·ha-1 at age 30, which is equivalent to an average sequestration rate of 9.97 tCO2e·ha-1·yr-1. For wider spaced poplar stands (e.g. 40 stems per hectare) which maintain some grazing ability and still meet the requirement of 30% canopy cover, the estimated carbon stocks at age 30 years would be 198 tCO2e·ha-1 and average annual sequestration would be 6.6 tCO2e·ha-1·yr-1.

Table 2: Poplar stands at different stockings (stems/ha) and their estimated carbon sequestration rates and carbon stocks over a period of 30 years modelled using two different models.

	Mean total annual sequestration rate (tCO2e·ha-1·yr-1)	**Total carbon stocks at age 30 years (tCO2e·ha-1)**	**Approach**
Poplar at 37 stem/ha	2.0	42.2	Guevara-Escobar et al. (2002) described in Burrows et al. (2018)
Poplar at 200 stems/ha	10.8	228.1	
Poplar modelled at 40 stems /ha	6.6	198.0	McElwee and Knowles (1998) & Beets (2006)
Poplar modelled at 200 stems/ha	9.9	299.9	

While there are differences in carbon sequestration rates at lower stockings with a minimum of 2.0 and a maximum of 6.6 tCO2e·ha-1·yr-1 due to different trajectories in the early growth rates of low stocked stands, the sequestration rates for denser stocked poplar stands are similar.

While poplars do not contribute to any indigenous biodiversity gain, they have been used in agroforestry systems primarily to stabilise erodible land through their extensive root system. Using lower tree numbers per hectare (<100 stems/ha) allows grazing to be maintained, although there is a reduction in pasture production depending on tree numbers and canopy-cover (shading) of trees. To be eligible under the ETS, a poplar stand needs to reach at least 30% canopy cover, which would reduce pasture production to 75% of that of open pasture (Wall, 2006).

Poplar plantations do also present some issues. Large poplar trees tend to become dangerous in high wind events as poplars are prone to branch and stem breakage and can accumulate dead wood early on. Such dead wood can be a risk to infrastructure especially during flooding. Poplar plantations should be managed as a rotation regime with harvesting stands reaching 20-30 years and sites need to be cleared to avoid slash build-up. If managed under a rotational harvesting regime the ETS averaging approach would come into force providing carbon credits during the first rotation up to the long-term average carbon stock.

Underplanting a poplar plantation with indigenous tree species could be considered to accelerate the transition towards a permanent indigenous forest by providing shelter and a forest-like microclimate. However, no data exists yet to quantify the sequestration potential of such a regime.

Currently for areas less than 100 ha, use of the ETS lookup tables is mandatory for estimating sequestration. This provides a mean rate of 6.5 t CO_2 ha-1 year-1 over 50 years for indigenous forests, and an exotic hardwood table that would be applied to poplars. The national indigenous table is based largely on fully-stocked stands of manuka, while the national exotic hardwoods table is based on *Eucalyptus nitens* and is currently being revised by Scion under contract to MPI. The revision may result in a separate lookup table for poplars and willows. For forest areas over 100 ha sequestration must be estimated based on field measurements.

Native vs exotic carbon sequestration

While carbon sequestration should not be the only factor influencing land management decisions, it is still important as under the current setting it can provide an income stream that mitigates potential losses from e.g. grazing leases. When comparing our modelled indigenous and exotic tree carbon sequestration, factors such as stocking and site conditions need to be considered. For example, establishing natives has the aim of achieving fast site occupation (to minimise long term tending and weed control), and initial stocking rates of 1000 stems per hectare are intended to achieve this. By using such an approach a greater early sequestration rate of up to 5.9 tCO2e·ha-1·yr-1 can be achieved (for manuka). This is in contrast to the greater carbon sequestration rates of poplars that sequester nearly twice the amount of carbon per year with a fifth of the number of trees established (10.8 tCO2e·ha-1·yr-1). This would result in a clear preference for exotic species if other measures such as biodiversity and long-term flood plain management are not considered. Furthermore, the greater carbon sequestration rates by poplars will be achieved for a shorter period than with native plantings of long-lived and slower growing species such as silver beech and native conifers.

Recommendations and conclusions

The work presented here describes the potential biomass carbon sequestration on a per hectare basis that could be achieved by planting a range of native trees or poplars[2] on Environment Southland land on the floodplains of the Mataura River. It will support ES to make good land management decisions that should allow optimisation of carbon sequestration, biodiversity and flood protection. These decisions could result in substantial changes to the way the current 2000 ha owned by ES is managed if the implementation of the management will be included in the next long-term plan. The ES ownership of the land means that any investments in tree planting or wetland restoration will be protected into the future.

We did not attempt to use our modelling results to estimate the full potential of carbon sequestration in the 2000 ha that ES manages. Such a further step would require a detailed site characterisation to assign forest types (and identify areas not suitable for woody tree carbon sequestration). Topography-based fine-scale site characterisation would allow site stratification based on flooding frequency and intensity, which would enable the assignment of specific forest types and carbon sequestration rates across the area and delineate any area that is unsuitable for woody vegetation (wetlands). Such an approach will become possible in the near future as detailed topographies of the area will become available (e.g. high resolution digital terrain maps generated with LiDAR data).

Planting of exotic tree species such as poplars will provide sequestration rates that are larger than those of natives for the first 20-30 years with the additional potential benefit of allowing grazing to continue. However, species like poplars should be managed under a rotational regime on floodplains to avoid over-aging and the resulting accumulation of dead wood debris as stands become older or wind damaged. An integrated approach with planting natives under a poplar canopy has also been proposed by ES but not tested regarding its carbon sequestration potential as no data is available on such a regime. Establishing a number of trial sites testing such a regime would widen the possible options to sequester carbon in floodplains in the long term.

By planting native tree species that are already represented in the Mataura floodplains the area of indigenous vegetation cover can be extended with the benefit of an increase in indigenous biodiversity and the potential to link current remnants with each other. The accompanying sequestration of carbon will support New Zealand’s efforts to mitigate climate change into the long-term future and allows a potential income stream to fund further restoration towards an indigenous woody cover and to maintain existing plantings. ETS costs and revenues will be affected by whether national lookup tables can be used or measurement plots must be established (mandatory for areas over 100 ha). Ideally any plantings established on the floodplains of the Mataura should be monitored to gain site specific growth and survival data which is not currently available, to inform future model predictions of tree growth and survival on this unique site.

Lastly the observed remnants on the Mataura floodplains contribute significantly to the indigenous biodiversity on Environment Southland land and represent a significant carbon store. While they provide a good indication what forest type could occupy Environment Southland land, recent changes in environmental conditions might have altered the future site suitability of these remnants. There is a probability that with the ongoing changes in the whole catchment, the flooding and draining regime will also have changed since the natural establishment of these remnants. While the remnants appeared to be healthy and natural regeneration was observed, establishment of the dominant species might become more difficult in future.

[2] Common other exotic tree species are deemed to be unsuitable due to the site conditions (e.g. radiata pine) or because of their potential to be invasive (e.g. willows)

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