Manuka planting for water quality

By Maria Gutierrez Gines, Institute of Environmental Science and Research; Brett Robinson, Canterbury University; Jennifer Prosse, Lowe Environmental Impact; and Juergen Esperschuetz, Minakshi Mishra and Jacqui Horswell from Lincoln University.

The recent report 'Our Fresh Water 2017' by the New Zealand Ministry for the Environment states that more than half of the river sites monitored in the past two decades have increased their nitrogen concentrations.

Only 34 percent of the monitored lakes are in a good state. Compared to rivers running through native ecosystems, our urban and rural waterways have levels of *Escherichia coli* that are 10 to 20 times higher.

As a consequence of this increasing degradation of water quality (and quantity) 72 percent of native fish, 34 percent of native invertebrates and 31 percent of aquatic native plants are threatened with, or at risk of, extinction.

Run-off from farming areas, livestock waste, fertilisers, pesticides, septic tanks, wastewater, and stormwater are the main contributors of nitrogen, phosphorous and pathogens into waterways and groundwater.

In addition to this, the deforestation of many areas adjacent to waterways has increased the erosion of river banks, and removed the natural barrier that reduced the inputs of nutrients (mainly N and P), sediments and pathogens to streams from agricultural and urban areas.

Nutrients, sediments and pathogens are the three main agents causing pollution to freshwater and coastal systems. Reducing these 'big three' has become part of regional council plans and policy throughout the country and establishing vegetation adjacent to waterways demonstrably improves water quality in most regions.

The benefits of restoring native vegetation along river and lake margins are numerous. Apart from the obvious value of ecosystem restoration, native vegetation can be a source of valuable natural products, which is a key economy sector recognised by New Zealand Trade and Enterprise. Manuka honey and essential oils brings in some $280 million per year to our economy.

There are developing markets for new natural products including kanuka essential oil, horopito antifungal medicine and horopito cooking condiments, and the totara antioxidant compound totarol. Less obvious, but critically important, is the contribution that restoring native vegetation can have on improving water quality.

Ten years ago, researchers of the Centre for Integrated Biowaste Research (CIBR) started investigating ways of using native species to improve environmental quality in rural and urban areas. The first step was to investigate whether the well-known antimicrobial properties of manuka and kanuka (*Leptospermum scoparium* and *Kunzea ericoides* – both natives to New Zealand and Australia) could be used for environmental purposes. They discovered that root extracts of these plants inhibit the growth of *E. coli* and other pathogens[1,2].

Since that discovery, many experiments demonstrated how the beneficial properties of these species could be used to treat organic wastes. Greenhouse experiments revealed that manuka and kanuka could reduce the survival of *E. coli* and *Salmonella* sp. in soil compared with pasture. The time taken to achieve 90 percent reduction in *E. coli* (decimal reduction time) was just five and eight days for kanuka and manuka respectively compared with 93 days for rye grass[3]. These results show that biowaste, including sewage sludge, biosolids, effluent, or dairy shed effluent, could be used to establish these species on marginal lands, where other farming activities are not possible. Both manuka and kanuka grew well in the high fertility environments created by the biowaste application, and reduced the pathogen load of such biowaste.

Since most pioneer species in New Zealand (such as manuka and kanuka) are adapted to low fertility soils, it was not clear whether they could thrive in the high fertility conditions created when biowastes are applied to land, as biowastes are a rich source of nutrients.

Further experiments with up to 13 pioneer species showed that they benefit from the addition of such nutrients[4,5], showing better growth and nutrient composition, so their use for land application of biowaste could be an excellent way of deriving those wastes from landfilling.

In the same way that manuka and kanuka roots systems had been demonstrated to reduce the growth of pathogens in soil, the idea of "what could they do" with the soil bacteria related with nitrogen cycling started to take form.

In vitro experiments with *Nitrospira* sp. and various plant extracts demonstrated a reduction of nitrate production in the presence of manuka and kanuka extracts[6]. Nitrate is generated by microbial organisms in the soil by nitrification from ammonium (Figure 1).

Due to its high solubility, nitrate is the main species of nitrogen responsible for pollution of rivers, streams and lakes, causing algal blooms. In the following years, the research moved from test tubes to small pot and lysimeter experiments where manuka and kanuka were grown with different sources of nitrogen such as urea, or different biowastes like dairy shed effluent or sewage sludge. The results of all the experiments demonstrated that manuka and kanuka can significantly change the nitrogen cycle. When sewage sludge was added to the soil, the total amount of nitrate leached under manuka was just one third of the nitrate leached under pasture.

When urea was added to the soil, the nitrate leached under manuka and kanuka was 25 times less than under radiata pine[7].

Similarly, the emission of nitrous oxide – a potent greenhouse gas – was seven times lower when kanuka was growing than when pasture was growing, after applying dairy shed effluent[8].

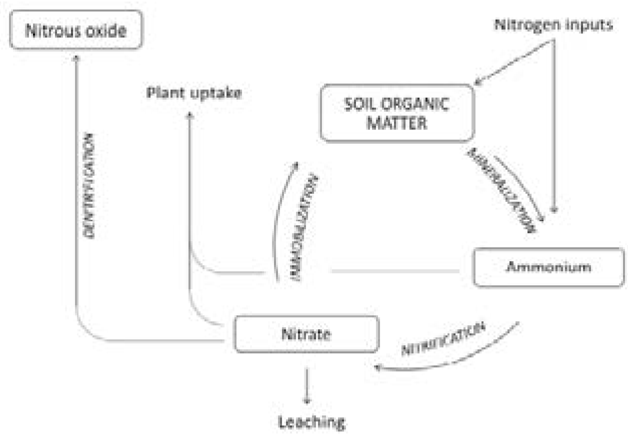

Figure 1. Nitrogen cycle.

The root architecture of manuka and kanuka is a crucial factor affecting their interactions with pathogens and nitrogen.

Our experiments have shown that under high irrigation regimes, the roots of manuka and kanuka create routes of preferential infiltration, compared with pasture. In pasture water can pond on the surface for long periods of time.

This means that under heavy rain events, or high application of liquid biowaste – such as treated municipal wastewater or dairy shed effluent – manuka and kanuka could contribute to reduced run-off, and increase infiltration of biowaste and water into the root systems, where the antimicrobial effect takes place.

Moreover, when solid biowaste (ie, biosolids) is applied to land, manuka roots forage patches of biosolids [9], increasing the presence of roots in the biosolids, where roots will uptake nutrients, reduce the conversion of ammonium to nitrate and inhibit the growth of pathogens.

The implications of such findings are highly important, since these plants are not only able to reduce the pathogen and nitrate leaching from biowaste, but also access the nutrients those wastes contain. So far all our experiments have been conducted in controlled conditions ie, laboratory, greenhouse and lysimeters; we now need to move into real problems in the real world.

There is a general interest in increasing the land application of treated municipal wastewater, and to divert discharge from waterways, where it can increase the nutrients, creating algal blooms.

We hypothesized that manuka, kanuka, and other native species could be used to land-treat this effluent, since these plants would reduce the leachate of nitrate, pathogens, and would benefit from the nutrients present in the treated wastewater.

Christchurch City Council funded a project carried out by the CIBR team investigating the potential of discharging treated municipal wastewater into different assemblages of native vegetation.

After two years of irrigation into native species, results show an increase in growth of all the species tested, compared with non-irrigation.

Furthermore, we have not found any evidence of nitrate leaching, or any negative effects of irrigation on soil structure. These results led us to propose a real scheme of land treatment of treated municipal wastewater over a manuka and kanuka plantation.

The Freshwater Improvement Fund (Ministry for the Environment) and Horowhenua District Council are funding a project led by Lowe Environmental Impact, where CIBR is collaborating, for irrigating 10 hectares of manuka and kanuka with treated wastewater, and demonstrate a reduction of inputs of nitrogen into Waiwiri Stream, caused by the current irrigation on a pine plantation.

These above experiments led us to pose the question of introducing native species into the livestock exclusion zones around waterways.

As well as the well-known benefits of riparian plantings (increased infiltration and reduced erosion), the presence of native species such as manuka and kanuka could actively reduce the pathogen and nitrate leaching into the waterways.

The Waikato River Authority is funding a five-year project that will look at re-planting four hectares of manuka dominated native ecosystems on the banks of Lake Waikare in the Waikato.

The project is a collaboration between Nga Muka (Ltd), Te Riu o Waikato (Ltd), Matahuru Marae/Nikau Farm Trust and the Waikato Regional Council.

CIBR, along with representatives of the local Maori interests, will monitor the water quality at the site to determine if manuka-based ecosystems effectively attenuate pathogens, plant nutrients and sediment entering the lake.

A similar field trial is being undertaken around Lake Wairarapa with support and assistance from Greater Wellington Regional Council, Rangitane, Kahungunu ki Wairarapa and Manuka Farms.

Although we are optimistic about the scientific results that we will obtain with these projects, the working in real scenarios poses new challenges and opportunities that are not evident in the laboratory environment.

A key aspect of on-farm planting is the costs and incentives for the land-owner. While the improvement in water quality is a laudable and near-universal aim for all stakeholders, retiring areas of productive farmland and

paying for fencing, planting and maintenance of on-farm planting is expensive, sometimes prohibitively so.

Also, these experiments take place in areas with their own history, and local communities have their own expectations and values that are far beyond scientific purposes.

According to local Maori, at one time Lake Waikare was a source of sustenance, with history and connection for them. It was then safe to swim in. The degradation of the lake over the years has negatively affected the relationship of the iwi (local Maori) with the lake, so re-planting the lake margins goes beyond the potential of manuka to reduce nitrate and pathogen leaching. In this regard, this project is incorporating a significant amount of 'matauranga' Maori (pre-European Maori knowledge).

The field trials around Lake Waikare and Lake Wairarapa will provide working examples of the manuka-dominated planting that can be used as 'flagship' sites to promote future plantings. The data gathered can provide robust data on nitrogen and *E. coli* reductions for potential incorporation into farm models such as OVERSEER.

Most importantly perhaps, the trials involve direct involvement and participation of the local communities to maintain and monitor the sites and develop local capabilities.

It has taken nearly 100 years to degrade the water quality in many of our rivers and lakes, and we expect it will take at least a decade to restore the ecosystems.

Given time nature can heal itself, and our research has shown that native species have amazing properties and capabilities, many of which are still to be discovered. **WNZ**

Bibliography

1. Prosser, J.A. Manuka (Leptospermum scoparium) as a Remediation Species for Biosolids Amended Land. 2011, Massey University: Manawatu, New Zealand.
2. Prosser, J.A., et al. Can manuka (Leptospermum scoparium) antimicrobial properties be utilised in the remediation of pathogen contaminated land? *Soil Biology and Biochemistry*, 2014. 75: p. 167-174.
3. Prosser J.A., et al. The potential in-situ antimicrobial ability of Myrtaceae plant species on pathogens in soil. *Soil Biology & Biochemistry*, 2016. 96: p. 1-3.
4. Dickinson, N., et al. Endemic Plants as Browse Crops in Agricultural Landscapes of New Zealand. *Agroecology and Sustainable Food Systems*, 2015. 39(2): p. 224-242.
5. Gutiérrez Ginés, M.J., et al. Potential Use Of Biosolids To Reforest Degraded Areas With New Zealand Native Vegetation. *Journal of Environmental Quality*, 2017.
6. Downward, R.L. Nitrification inhibition by common plants in New Zealand's agricultural landscapes. 2013, Lincoln University: Lincoln, New Zealand.
7. Esperschuetz J., et al. The potential of L. scoparium, K. robusta and P. radiata to mitigate N-losses in silvopastural systems. *Environmental Pollution*, 2017. 225: p. 12-19.
8. Franklin H.M., et al. Nitrous oxide emissions following dairy shed effluent application beneath Kunzea robusta (Myrtaceae) trees. *Ecological Engineering*, 2017. 99: p. 473-478.
9. Reis, F.V.P., et al. Manuka (Leptospermum scoparium) roots forage biosolids in low fertility soil. *Environmental and Experimental Botany*, 2017. 133: p. 151-158.