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THE CASE FOR A NOVEL AGROFORESTRY SYSTEM AND CROSS-SECTOR COLLABORATION

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1.0 Introduction

As farms throughout NZ face increasing pressure to reduce livestock intensity, there is increasing support to plant more trees, for example the one billion tree programme. Agroforestry systems that incorporate woody perennial trees on farms are widely proven with dominant systems in NZ being discrete woodlots grown for timber and/or carbon sequestration, widely spaced trees for erosion control, and shelter and amenity plantings. As farmers are encouraged to take up next generation systems (NGS), being the redesigns of production systems or new enterprises or technologies that can break the lockstep relationship between profitability, production and environmental footprint, some rural entrepreneurs are showing a shared interest in new agroforestry systems that could dissolve the barriers between livestock, horticulture crops and forest trees.

This paper reviews the case for a novel agroforestry system in the Rotorua lakes catchments, based on an interest in trees that can produce edible nuts shared by three quite different rural entrepreneurs; a Māori forest owner, a small block/life-style farmer, and a sheep/beef/forest farmer. Each entrepreneur has been independently exploring the changes they can make to their land use systems by either implementing field trials through to getting a fine spatial resolution, biophysical suitability assessment that considers current and future climates. These entrepreneurs have also worked through a multi-criteria decision making (MCDM) framework developed to assess land use business decisions influenced by a range of factors, including regional environmental limits. The assessments identified that they all had common value priorities for the environment and social well-being. Posed as key next steps to de-risking this novel agroforestry system is to build on these value synergies using cross-sector collaborations, and to explore scalability options across the different landscapes.

1.1 Agroforestry and next generation systems

Interest has been growing globally in how farmers and small landholders can improve their earnings through **agroforestry systems**, and how this can offset serious issues such as climate change and resource scarcity (Liu et al., 2018). Agroforestry describes the "land-use systems

and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence" (FAO, 2015). The dominant on-farm agroforestry systems in NZ are silvopastoral, spanning woodlots grown for timber and/or carbon sequestration, widely spaced trees for erosion control, through to shelter and amenity plantings.

Since the latter part of the 20th century the drive for new ways of mixing trees and pasture in NZ waned and few new on-farm examples have been created. In forests however, new systems that mix trees with plants and food production have been developing. Examples include: farming fresh-water crayfish in ponds, deriving honey/oil products from indigenous trees, growing ginseng under *Pinus radiata* (pine) forests, and integrating pine forests with *Gevuina avellana* (gevuina) nut trees and high-value edible fungus. The decline in interest in agroforestry has been occurring at the same time as a rise in concern about the possible harm that intensive farming does to the environment – to landscapes, wildlife and biodiversity, and to the quality of soils, air and water (OECD, 2017). Posed as a solution to this are **next generation systems** (NGS), these being the redesign of enterprises and production systems, or new enterprises or technologies that can break the lockstep relationship between profitability, production and environmental footprint (Renwick et al., 2017). NGS effectively address a dilemma of concerns that could be resolved using agroforestry. With farmers facing increasing pressure to replace livestock with crops or trees, it is crucial that suitable agroforestry options for them are being developed.

In this paper we consider a novel agroforestry system relevant for both farms and forests, we present landowners values, and we briefly discuss the potential to de-risk the adoption of agroforestry through cross-sector collaboration and scalability starting with shared values. Located in the Rotorua lakes region, this case is based on the perspectives of three quite different rural entrepreneurs; a Māori forest owner, a small block/life-style farmer, and a sheep/beef/forest farmer, who are looking to change their existing systems and integrate tree nut crops.

1.2 About hazel and gevuina trees

Over the past decade tree nut production globally has risen year on year with 4.2 million metric tons produced in the 2017/2018 season, of which hazelnuts comprised 11.7 percent (INC, 2018). The NZ hazelnut industry is very small and comprises local/spot markets supplied domestically from about 430 hectares of *Corylus avellana* (hazels) tree selections. To grow the sector the challenge is to develop a domestic and/or export market. Export markets exist in the Asia-Pacific region particularly into Australia and China. It is estimated that nut production from at least 100,000 trees (200 hectares yielding about 500 tons of nuts) is the minimum scale to enter into the export markets (Holt & Murphy, 2017).

With the intent to grow nut crops in the cooler climates, most of the hazel plantings in NZ are in the South Island. Although Redpath (2016) reckons that the best growing potential could be in the eastern areas of NZ from the Hawkes Bay to Marlborough, where the soils, rainfall, climate and topography are generally suitable. Other regions also have adequate soils and

climate for hazel trees, for example, about 3000 hectares of Class 3 land in the Rotorua catchment that is currently used for livestock farming could be suitable. If all this land was converted to hazels, not only would the trees produce nuts and sequester carbon, but it is estimated that such a system change would remove approximately 130 tons of nitrogen from the catchment annually (Redpath, 2014).[1]

Introduced into NZ over 50 years ago, gevuina is the southernmost grown species of macadamia. The tree is not strictly a hazel however it is known as the Chilean hazel as it produces edible nuts similar to the hazelnut. A key feature of gevuina is being frost tolerant and forest hardy and thus having the potential to be grown with, or alternate, to pine. Other features include being bee friendly/insect pollinated and providing honey-related opportunities, sequestering carbon and producing hardwood timber. A critical challenge with gevuina will be in developing new nut products and markets.[2]

Nuts in NZ, no matter what the type, have yet to demonstrate clear market success. Nut product options are wide ranging from simply selling the nuts in-shell or raw/roasted, through to more value added products such as nut oil, milk, coffee, flour, and uses for the shells etc. Given the range of features that go with these trees, the motivation for rural entrepreneurs to take on risk and mix nut trees into livestock farm or forest systems is multi-faceted, and driven by their context and values.

2.0 Objective and methods

The objective of this paper is to **increase the understanding of ways to progress a specific land use innovation and develop it into a NGS**. It is widely recognised that the primary sector requires greater innovation to move past business-as-usual, and that innovation is usually local context specific, and involves adaptive and anticipatory decision making (Renwick et al., 2017; Renwick et al., 2018). These points were considered in the following approach;

1) Profiling three neighbouring, but quite different land managers all looking to intermix hazel/gevuina trees into their forest/farm systems.
2) Comparing their values and identifying commonalities using a multi-criteria decision making (MCDM) framework (Renwick et al., 2017, 2018).
3) Using causal analysis to model ways their systems could be developed.

2.1 Applying the MCDM framework

The MCDM framework requires land managers to prioritise six domains important for systems change (financial, environment, regulation, knowledge base, social well-being, and market factors) and sub-criteria of these domains. The framework was initially tested by six different land managers to test the usability and reliability of the framework's insights into current land management values (used in the broadest sense).

[1] For more detailed information about growing hazels, nut production, markets and hazel economics in NZ, see Redpath (2016).
[2] For more information about growing gevuina, product opportunities, and an economic case in NZ, see Holt & Murphy (2017).

A Māori forest owner, a small block/life-style farmer, and a sheep/beef/forest farmer[3] were taken through the framework. Although these three managers have quite different land use systems, they are all interested in intermixing hazel/gevuina trees into their forest/farm systems, and are effectively neighbours in the Rotorua lakes region, being within 20 kilometres (by highway) of each other.

2.2 Modelling of next steps

The context and interests of the three land managers, interactive discussions, and the values identified in the MCDM assessment were used as a platform to carry out a causal analysis. A Causal Loop Diagram (CLD) was created to describe the factors and forces that would affect the transformation of farms/ forests with a hazel/gevuina tree nut system. CLDs provide "a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots" (as cited in Maani, et al., 2009). CLDs can help to create a coherent picture of a particular situation or issue (Williams & Hummelbrunner, 2011). The CLD made for this paper provides a macro-scale view of the high-level influences impacting the development of a new system. The factors and forces (variables) in the CLD, and the relationship between these variables were identified as either positive or negative, with the strength of the relationship (in general terms) indicated by the size of the arrow (not to scale). The values derived through the MCDM framework are shown underlined in the CLD with the diagram used to identify key factors involved in transforming the nut tree land use innovations into an agroforestry NGS.

3.0 Results

Table 3.1 – Overview of Land Managers.

Land Manager type	Description (*focused on the association with a nut tree innovation*)
Māori Trustees (MT)	***Who are they?*** The trustees represent 2000-plus Māori shareholders and many more descendants/future owners of a 1200 hectare pine forest east of Rotorua. ***Why are they interested in nut trees?*** Pine forestry is an environmentally suited, productive and profitable land use but soon all the forest will be harvested and replanted. They are interested in systems that are inter-generational and are able to strengthen the connection between people and the forest/land. They want to know if nut trees that crop annually after 5-8 years could be intermixed into the forest, and if this could provide them more work options, more products (timber and non-timber), and timelier cash flow. ***What are they doing?*** They have a fine spatial resolution, biophysical suitability assessment incorporating current and future climates being prepared for their land, and they are growing

[3] The sheep/beef/forest farmer was not involved in the initial testing of the framework, but worked through the framework for the purpose of this study.

	thousands of gevuina seedlings (sourced from more than 30 provenances in Chile) in a local nursery with the intent to plant some in their forest in 2019.
Smallholding (SH)	***Who are they?*** The family owner operators of this 7 hectare life-style farm (with livestock and small areas of a variety of tree plantings and gardens) have day jobs in addition to working the land. ***Why are they interested in nut trees?*** They are on the dry side of the Rotorua Lakes catchment, and are restricted in their land use by council requirements for nitrogen/phosphorous reduction. They are interested in making a fair and equitable income off the land, and taking a kaitiaki (guardian) view of the physical environment. They want to know about growing hazelnut crops on their land, and if nut tree crops could be scaled up across dairy land in the catchment to provide high value and environmental benefit. ***What are they doing?*** In 2018 they established a trial of two new hazelnut varieties (about 70 trees) not currently grown commercially in NZ.
Small Investment Trust Farmer (SITF/ Farmer)	***Who are they?*** The farmer manages 450-plus hectares of sheep, beef, pine trees, chickens and indigenous shrub/tree and other planted areas, on behalf of a few private investors. ***Why are they interested in nut trees?*** The farmer and his investors have interests in regenerative farming methods. Any system they employ needs to have a good business model with desirable environmental and social benefits. They were harvesting their 60 hectare woodlot in 2018, with the intent to not replant some/all of this back into pine trees. Instead they want to intermix pasture, livestock, hazel/gevuina (and other trees) at various spacing. ***What are they doing?*** They have been developing research projects that will build the case for intermixing pasture, livestock, hazel/gevuina trees at various spacing, and using regenerative farming practices.

Land manager values from the MCDM framework placed the environment, followed by social well-being, as the most valued domains for the Māori Trustees and Farmer (Figure 3.2). The environment was valued by the Smallholder, but was rated below the domains of regulation and market factors. At the environment sub-criteria level, Māori Trustees weighted erosion/sedimentation, nitrate leaching and environmental stewardship the highest, while the Farmer and Smallholder ranked environmental stewardship the highest. At the social well-being sub-criteria level, cultural values were weighted the highest by the Farmer and Māori Trustees, with the Farmer also rating value distribution (multiplier effect) high, and the Māori Trustees rating conditions of employment high. The ability to capture value added is important

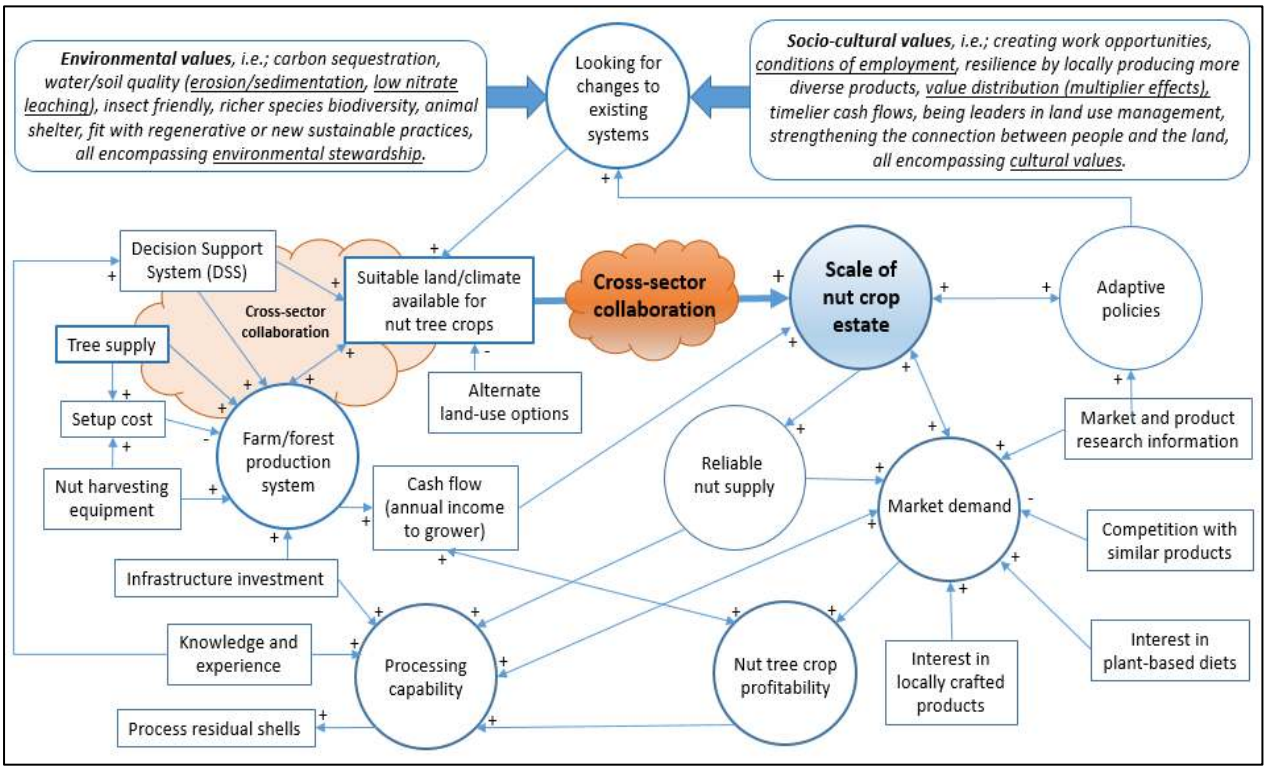
to the Smallholder, along with a range of regulation sub-criteria. The weighting given by the land managers to all the domains and their sub-criteria are shown in Figure 3.2.

Figure 3.2 – The domain level weights (top graph) and corresponding sub-criteria weights (bottom graph) for each land manager. A higher value indicates a higher weighting is given by the land manager.

The development of tree nut crops is affected by a number of factors that operate across the value chain simultaneously and sequentially, with various feedback loops. This is shown in the CLD in Figure 3.3. There is a dynamic mix of social, economic, biophysical, and cultural forces that influence the progression from innovation into a NGS. In this case the environmental and socio-cultural values have a strong relationship to land use system change. We pose that for transformation, the scale of the nut crop estate (scalability) is a key factor which can be strengthened through **cross-sector collaboration**.

Scalability is positively influenced by having suitable land/climate available for nut tree crops, cash flow (annual income to grower), market demand and adaptive policies. Scalability has an interrelationship with market demand with both factors having positive reinforcing effects on each other, i.e.; an increase in the estate scale will increase market demand, and an increase in market demand will increase estate scale. Scalability also has the same interrelationship with adaptive policies. Cross-sector collaboration is shown to strengthen the connection between the availability of land and scalability. This is dependent on the preference of land managers for a hazel/gevuina system versus an alternate option, and on a feedback loop through adaptive policies that influences their motivations for system changes.

Figure 3.3 – Causal loop diagram (CLD) describing the transformation of farms and forests with hazel/gevuina nut tree crops.



4.0 Discussion and next steps

4.1 Innovation and cross-sector collaboration

This case demonstrates how land managers and their values can drive land use innovation. The CLD shows **innovation** starting with the values of the land managers, through to testing ideas (e.g.; field trials and crop suitability assessments to build their decision support system), and with other innovation opportunities across all the system pathways (e.g.; use of technology in production systems). This diagram aligns with a design thinking description of innovation being three overlapping, interconnected spaces that can loop back through each other. The first space is inspiration, being the problem or opportunity that motivates the search for solutions. Second is ideation, this being the process of generating, developing, and testing ideas. Third is implementation, being the path that leads to the market (Brown & Katz, 2011).

The step challenge for land managers is to look beyond their own value-practice interactions and identify whether/how they could turn their innovations into a NGS. Renwick et al. (2018) emphasises that research can support and de-risk a manager's decisions about land use change. As shown in the CLD, the development of tree nut crops is affected by a number of factors that operate across the value chain from the farming system to nut processing to market development. Scientific and business research, engineering design and technology each has a place that could improve this system. However, methods associated with these disciplines often involve a "scope, generate, evaluate, and realize ideas" approach associated with a "best way" which may not fit across three quite different land managers. Design thinking (Brown & Katz, 2011; Simons et al., 2011; Norman, 2013) or a similar approach that can synthesise ideas from different perspectives is needed to take this system through the innovation process.

No matter what the approach, **cross-sector collaboration is critical**. Development of the system will require the support of a wide range of stakeholders, including government agencies, research institutes and other private sector actors. Agroforestry systems are linked to multiple sectors, in this case to the agriculture, forestry and horticulture industries via land managers operating at a local scale. Stakeholders in the system each have a different role, and integration and cooperation amongst them is key to achieving the end result.

The CLD shows that cross-sector collaboration is occurring at the decision support system level by the land manager, for example: the Māori Trustees seek knowledge from horticulture about crop suitability; the Farmer seeks knowledge from forestry about growing nut trees and; the Smallholder seeks knowledge from agriculture about dairy land potential. That said, cross-sector collaboration to positively affect the scale of the nut crop estate is yet to occur. This requires radical collaboration amongst different land managers, and between sectors. Radical collaboration is based on a key principle of design thinking that incorporates co-creation, and moving beyond unconscious bias (Simons et al., 2011). The challenge for land managers is to strategically engage with each other and with other stakeholders. The prospect for them is to de-risk the system by spreading the innovation cost and share learnings, and most importantly, to identify a coalition of the willing to scale up the nut crop estate.

4.2 Scalability

The 1200 hectare forest of the Māori Trustees is small in forestry terms, but has the largest landholding in this agroforestry study. In the Māori Trustees' forest nearly 200 hectares of land classed as LUC 3 has the potential to be converted to gevuina, with a geospatial analysis estimating that a further 20 hectares of LUC 4, 6 and 7 could be converted by single row planting alongside road infrastructure. Extrapolating the geospatial analysis to 100,000 hectares of forest near Rotorua suggests that nearly 2000 hectares of (now) suitable road-side land in these forests could be planted in nut trees (Holt & Murphy, 2017).

In the Rotorua catchment a further 3000 hectares of livestock farm land LUC 3 is also suitable for hazel/gevuina trees (Redpath, 2014). Combined with the forest land, the potential to scale up nut tree crops to an industrial level is significant in the Rotorua region. In this study, the issue is not about suitability but availability of land, which is dependent on land use choices

and on changes to be made by land managers. As shown in the CLD, land use changes are influenced by values and adaptive policies. Current local land use policies are especially affecting the Smallholder (as shown in the MCDM analysis in Figure 3.2). In the CLD, policies considered include national programmes such as planting for erosion control or the One Billion Trees Programme, however these policies need to be adaptive in order to support this novel system.

Market demand also has an interrelationship with scalability, with both factors positively reinforcing each other. If global nut markets continue to grow a market pull could occur to influence the scale up of the system, and alternately, increased scale could be design driven and propelled by a vision about possible breakthroughs that could drive growth in markets.

4.3 Next steps

This paper has explored ways to progress the hazel/gevuina land use innovations of three land managers into a new agroforestry NGS. From this study two key steps emerge for land managers. First is the need for a **stakeholder engagement strategy**. The aim of this would be to build a multidisciplinary coalition of the willing to scale up the nut crop estate. Collaboration will likely need to be radical, with shared values and partnerships formed, and clear roles and responsibilities defined. The second step would be to **develop a hazel/gevuina agroforestry system plan**. Design thinking could suit this process, with the aim of coordinating and prioritising the research and field activities, and to share knowledge and the associated development costs.

The challenge of maintaining economic and social benefits while reducing the negative environmental impacts of land use is not the sole responsibility of land managers. Other steps that could be taken to support farmers, foresters and smallholders alike, is to develop a suite of new agroforest system options for NZ, to develop and adapt policies to enable these systems, and to develop research to fill gaps in knowledge required by land managers investing in NGS. For the hazel/gevuina trees to grow in scale and transform farm and forest landscapes will require some risk taking, market insight, business model innovation, incentives and radical cross-sector collaboration.

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References

Brown, T., & Katz, B. (2011). Change by design. *Journal of product innovation management, 28*(3), 381-383.

Coriolis (2017). An investor's guide to emerging growth opportunities in New Zealand food and beverage exports. Final report. Part of the Food and Beverage Information Project V1.02. https://www.mbie.govt.nz/search/SearchForm?Search=An+investor%E2%80%99s+guide+to+emerging+growth+opportunities+in+New+Zealand+food+and+beverage+exports.

Food & Agriculture Organisation of the United Nations (FAO). (2015). Agroforestry: Definition. http://www.fao.org/forestry/agroforestry/80338/en/.

Holt, L., & Murphy, G. (2017). The economic potential of Gevuina avellana in New Zealand planted forests. *Agroforestry Systems*, 1-14. DOI 10.1007/s10457-017-0072-y.

International Nut & Dried Fruit Council (INC). (2018). Nuts and dried fruits: Statistical yearbook 2017/2018. https://www.nutfruit.org/industry/technical-resources?category=statistical-yearbooks.

Liu, C. L. C., Kuchma, O., & Krutovsky, K. V. (2018). Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. *Global Ecology and Conservation, 15*, e00419.

Maani, K. E., & Cavana, R. Y. (2009). Introduction to systems thinking. Rosedale, New Zealand: Pearson Education New Zealand.

Norman, D. A., & Verganti, R. (2014). Incremental and radical innovation: Design research vs. technology and meaning change. *Design issues, 30*(1), 78-96.

OECD. (2017). OECD Economic Surveys: New Zealand, *OECD Publishing*, Paris, https://dx.doi.org/10.1787/eco_surveys-nzl-2017-en.

Redpath, M. (2014). Hazelnut production: Potential for the Lake Rotorua catchment. Rotorua Innovative Landuse report.

Redpath, M. (2016). Providing an information resource for landowners growing or intending to grow hazelnuts. Sustainable Farming Fund workshop presentation.

Renwick, A., Wreford, A., Dynes, R., Johnstone, P., Edwards, G., Hedley, C., … & Clinton, P. (2017). Next generation systems; A framework for prioritising innovation. *Science and policy: nutrient management challenges for the next generation (Eds LD Currie and MJ Hedley). http://flrc.massey.ac.nz/publications. Html. Occasional Report*, (30).

Renwick, A., King, W., Penelope, J., Holt, L., Johnstone, P., & Dynes R. (2018). Applying a multi-criteria decision making framework to facilitate adoption of next generation land-use systems. *Submitted and under review: Land use policy*.

Simons, T., Gupta, A., & Buchanan, M. (2011). Innovation in R&D: Using design thinking to develop new models of inventiveness, productivity and collaboration. *Journal of Commercial Biotechnology, 17*(4), 301-307.

Williams, R., & Hummelbrunner, R. (2011). Systems concepts in action: A practitioners toolkit. Standford, CA: Standford.