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Constraints to New Zealand's Sustainable Well-being

the ROYAL SOCIETY of NEW ZEALAND
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In this paper the Royal Society of New Zealand explores constraints to New Zealand's sustainable well-being as one of two papers on the country's sustainable carrying capacity. Much of the discussion around these factors has often taken the form of simplistic and linear trade-offs, whereas research shows that the effects of these factors upon well-being and prosperity are very complex. So what are these trade-offs, to what extent do these constraints alter the capability of New Zealand to generate well-being, and what kinds of response strategies are there?

Climate change – overshooting a global constraint

Achieving global targets for limiting climate change will require limiting global emissions of long-lived greenhouse gases. The United Nations Framework Convention on Climate Change-agreed target of two degrees Celsius of global warming provides a useful focal point for political negotiation but it should not be misinterpreted as a sharp boundary between safe and dangerous outcomes.

There is clear evidence of a straightforward relationship between cumulative emissions and global temperature change, although the relationship between emissions and impact on well-being is affected by non-linear biophysical responses, costs of mitigation, technological adaptation, socioeconomic vulnerabilities, and the rates of change in all these. The uncertainties in this relationship imply learning and ongoing revision, but the globe is already at a point where drastic cuts to emissions would be required to meet the two-degree target. A greater degree of warming this century is looking increasingly likely.

Domestically, New Zealand's economy has grown by 68% over the past twenty years,[1] while our emissions have increased by only 20%.[2] This rate of improvement in energy efficiency and carbon intensity is real but insufficient to decouple emissions growth from economic growth. New Zealand is well-positioned to make a transition to a defossilised economy, given our extensive supply of renewable energy and abundant natural resources, but this will require policies that provide certain and stable incentives for emission reductions. So far, it can be argued that existing policies have failed to achieve this goal. Current emissions trajectories suggest much more needs to be done if we are to meet globally-agreed targets. Whether the needed rate of emissions reduction is achievable is yet to be seen.[3]

Food production - optimising allocation between differing but interacting land uses

New Zealand's endowment of land is fixed, but there is continual adjustment between urban, agricultural, forestry, and less intensively transformed land uses. Current changes involve lifestyle blocks and urban areas expanding onto high-class agricultural land,[4,5] the growth of dairying in area and intensity, and the replacement of sheep and beef farming with dairy and forestry,[6] with all of the primary industries looking to increase both production and value from a finite environment.

Balancing interacting land use demands requires farmers, local government, and other land managers to change the use of land resources to satisfy many criteria and values. The Royal Society of New Zealand's *Competition for Land Use in New Zealand* paper provides more detailed discussion of the conflicts between "food production, biosecurity, biodiversity and wildlife, landscape conservation, climate change adaptation and mitigation, water management and recreational access" and potential biofuel production. All these considerations must seek to preserve options for future generations while balancing current economic output against an acceptable degree of resilience.

It is possible to deliver a desired mix of co-benefits once the nature, trends, and valuations of the natural capital of land and soil are understood. For instance, one scenario modelled in **Figure 1** considers a region facing erosion and nitrate leaching. Against this background, optimisation is sought for land use that best matches local variability in soil, climate, and terrain and that which also could minimise nitrate leaching and erosion while not reducing economic income.[7] Another example is the trade-off between water supply and carbon sequestration when replacing indigenous tussock with exotic forest in upper parts of watersheds.[8]

Thus our land use constraint becomes one of optimisation and management that must recognise the economic and cultural constraints on rates of change of land use and the push for ever-higher income from land. Informed trade-offs can be made between different mixes of benefits and costs, whereas improved efficiency and technology raise the overall possible level of benefits, whilst ensuring that sufficient resilience is still present to adapt to future changes in circumstances.

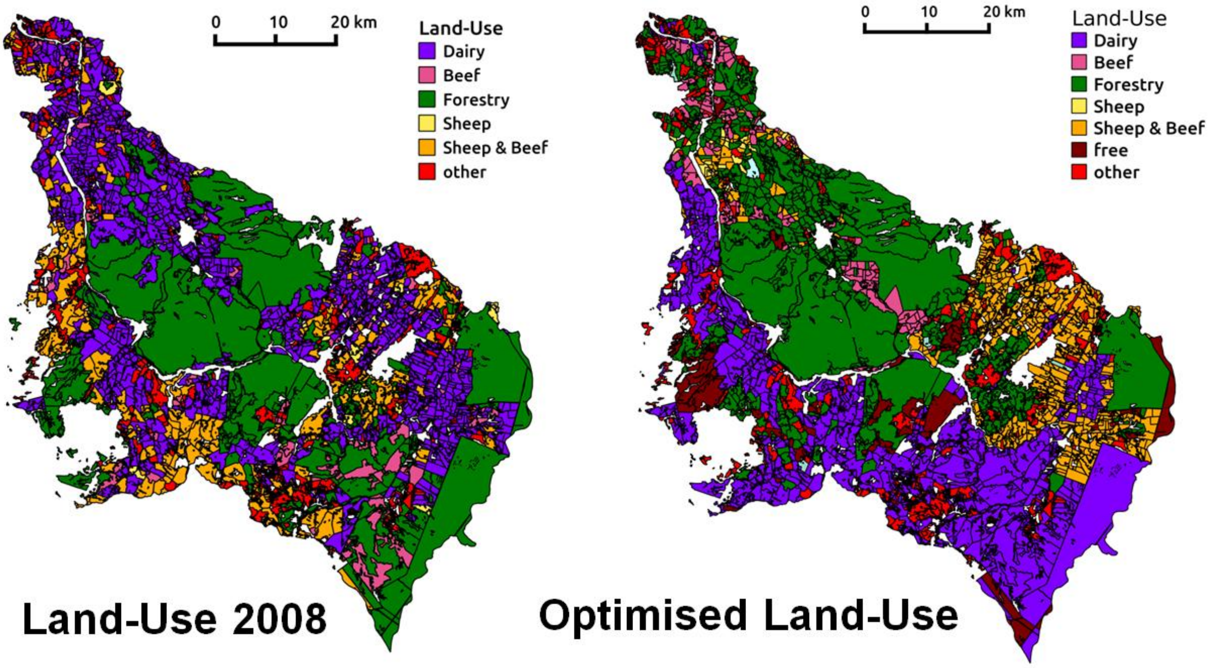

Figure 1: Using an ecosystem services approach to model optimised land use north of Lake Taupo explores how dairy could move off leaching-prone land, reducing nitrate leaching by 8% and soil erosion by 14% without changing farm income and food, wool, and wood production.[7]

Food production - water quality and quantity – collaboration in response to a current constraint

While land is clearly finite, the limits due to water use and pollution have become obvious as pastoral agriculture has intensified. The reactive nitrogen added to the New Zealand environment has increased over the past twenty years by nearly 40% due mostly to a seven-fold rise in nitrogenous fertiliser use as shown in **Figure 2**. Ten percent of this has arisen from imports of oil-palm kernel feed supplement.[6] In the process nitrogen has been incorporated into increased animal protein exports and soil organic nitrogen as well as being lost into ground and surface water, greenhouse gas emissions, and sediments. At the same time, the quality of our freshwater lakes, rivers, and streams has significantly deteriorated, with significant areas exceeding guideline values for nitrogen levels and pathogens.[9]

Similarly, the volume of water allocated for irrigation has grown to meet or exceed current limits in many catchments. The impacts of over-abstraction from waterways depend upon the ecosystem and the dynamics of competing uses. For example, the braided rivers of the Canterbury Plains require maintenance of summer flows to preserve fish and other biota and annual flushing flows to remove algae. Occasional floods also maintain the width of the riparian corridor. Floods and flows have other ecological roles to play - flooding replenishes nutrients and sediment to floodplains and flows transfer nutrient and sediment to coastal ecosystems.

The constraint on well-being around water comes from the intersection of the different values that people have for water bodies, in terms of the trade-off between the direct economic benefits from water, the indirect economic benefits, and essential New Zealand values such as mauri and the ecological health of our freshwater. There is a widely recognised need for improvement in how we use and protect our water resources.[10] The proposed way forward calls for absolute protection of iconic rivers and lakes and locally-agreed limits for both water allocation and acceptable levels of added nutrients based on the waterway's assimilative capacity. Within these caps, reallocation mechanisms should improve the efficiency of water and nitrogen use resulting in a range of co-benefits, raising the economic value created from water use while preserving non-market amenity, intrinsic, and spiritual values.

In this approach, bottom lines must be set for biophysical indicators, but even then there are trade-offs to be made as the impacts of water use upon ecological functioning are rarely clearly defined. Even for an obvious ecological flip such as the eutrophication of a lake, the triggering levels of nutrient addition depend upon the pre-existing ecological health of that water body. Allowing trading within a use cap implies a lost opportunity when not using that resource up to the limit, potentially increasing use. The potential stringency of any proposed cap puts a premium on the research needed to accurately inform the setting of that cap.

The ultimate goal for farm management within a nitrogen cap will be to maximise the fraction of nitrogen brought

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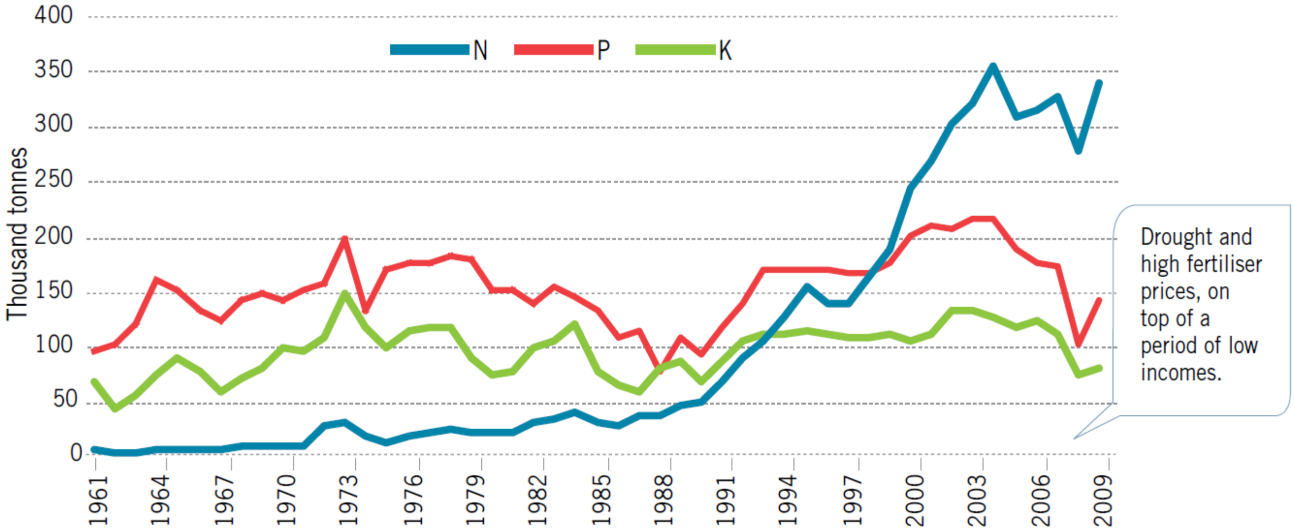

Figure 2: Use of nitrogen (N), phosphorous (P) and potassium (K) fertiliser in New Zealand.[11]

onto the farm that leaves as animal protein rather than as losses to water or the atmosphere. Much of the research currently under way aims at providing farmers with a set of options to allow them to optimise farm practices with the goal of increasing profit per unit of nitrogen lost to the environment. Where farmers face nitrogen caps (for instance, around Lake Taupo) this is already in progress using annual estimates of nitrogen loss. However, measuring actual on-farm nitrogen losses to inform daily farm management remains difficult.

The current data available on the efficiency of nitrogen use on farms are very limited, covering only 2002-2009. These data suggest that nitrogen efficiency in dairying has not changed over that period, a surprising finding given the expense of fertiliser.[11] For the efficiency of water use on farms, there are no robust national-level data for pastoral farms[11] or even for the value of water use on farms.[12] Equally, there are few projections of water use that account for land use changes and potential improvements in use efficiency. This lack of data presents a problem for informing policy, projecting and optimising water use and guiding the development of efficient farm practices.

Native biodiversity – balancing different sets of benefits

Since humanity arrived in New Zealand, there has been a marked and irreversible decline in biodiversity. New Zealand has pledged, under the Convention on Biological Diversity, to halt this decline and to meet our responsibilities for taonga species under the Treaty of Waitangi as addressed by the Wai 262 findings. New Zealand's indigenous and endemic species contribute to well-being through their value as a part of New Zealand's natural and cultural heritage, through the intrinsic value of their existence and their contribution to our sense of place, through benefit to tourism, and through the option value of their potential future uses. Urban green space and wilderness provide undeniable well-being through their physical, social, and psychological/spiritual benefits, although these benefits are often overlooked in analyses of the values of these ecosystems.[13]

Historical development of land for agriculture and forestry within New Zealand was characterised by a reduction in the extent and quality of native habitat and the introduction of competitors, predators, pests and diseases (possums, mustelids, etc.). As a consequence of transforming and managing our land, we have reduced our endowment of native species. However, the impact of the ongoing decline in native biodiversity on human well-being is complex - in transforming and managing our land and waters, we have followed a global pattern of biological homogenisation and developed a reliance on non-native agricultural, horticultural, forestry and livestock species. Conversion of land to accommodate primary sector production was accompanied by the introduction of a suite of non-native species that confer ecosystem services within these modified systems (e.g. nutrient cycling by earthworms, pollination by insects, pest control by bird species). While a number of valuable introduced species seemingly thrive in production landscapes, these species-sparse areas are similarly sensitive to the same activities associated with intensification and land use change.

Native biodiversity is part of the healthy ecosystems that provide clean air and water, regulated water flows, and carbon storage. All of these sevices support our more-intensively managed lands. The range of species in a diverse ecosystem provides the functional redundancy that enables ecological processes to continue despite changes in conditions, delivering resilience. When there is diversity and redundancy then there is no sharp threshold for biodiversity where the loss of one more species would have catastrophic impacts but every species loss decreases that redundancy. Both the native character and the resilient and regulatory properties of ecosystems become increasingly compromised as component species are lost and environmental parameters (such as exposure, humidity, water tables, the availability of pollinators, seed dispersers, etc) are altered.

Thus biodiversity fits into discussions around land use and well-being through both gradual and sharp trade-offs. Expanding intensive use of land gradually reduces the provision of ecosystem services that support intensive use. In contrast, polices to preserve particular species must consider the irreversibility of extinction and aim to avoid those sharp boundaries.

Imported nutrients and liquid transport fuels –price and supply constraints

New Zealand imports the vast majority of its liquid transport fuels and some fertiliser components (e.g. phosphorus, potassium, and magnesium). This dependency upon non-renewable imports imparts a constraint on the well-being developed from mobility and food production via the exposure to price instability and the risk of both short-term supply interruptions and longer-term supply reductions.[14]

While we have copious renewable electricity potential (see **Box 1** for the potential for expansion of geothermal power) that can replace fossil fuels for residential and industrial needs, substituting electricity for transport and agricultural fuel remains a major challenge. Similarly, fertilisers are vital to maintain food production and our phosphorus, potassium, and magnesium come mostly from non-renewable sources overseas.

New Zealand already faces and manages a degree of price variability for liquid fuels and fertilisers. However, depletion of existing easily-accessed oil reserves combined with growing, price-insensitive demand are expected to lead to a peak in oil production that is likely to coincide with higher prices, higher price variability, and potential supply interruptions. A wide range of estimates has been published about the severity and timing of difficulties with fossil fuel supplies, from potentially catastrophic to entirely manageable and peaking six years ago or unlikely to occur before 2035.[15] In the same manner, estimates of high quality low-cadmium mineral phosphorus resources vary widely, from 30 to 300 years. Fertiliser prices are volatile with phosphate rock spiking in price by 800% in 2008.[16] Few resource estimates have been made for other nutrients.

To an unknown extent New Zealand is therefore exposed to risk from price instabilities, supply interruptions, and prolonged price rises. There are three strategies in response to these constraints, all aimed at building resilience to price and supply risks: increasing efficiency of resource use; substituting high-risk imported resources with less risky imported resources; and local production of these resources.

More efficient vehicles and modes of transport can create more well-being from a constrained fuel supply and a wide variety of technologies and policies are available to improve such efficiency. However, the fuel efficiency for New Zealand's fleet of light vehicles[17] and for road, rail, maritime, and aviation[18] has remained constant over the past decade. Similarly, on-farm fertiliser use efficiency shows only gradual improvement,[11] despite the availability of several options for increasing nutrient uptake, recycling nutrients, and reducing nutrient loss.[19] Improved efficiency in such situations is rarely delivered without an effective policy impetus.

Box 1: Geothermal Power – Large But Not Unlimited Potential for Expansion

Geothermal power provides an example of the use of a vast but not infinite natural resource (heat from the Earth) that has the potential to expand greatly with only limited environmental impact. Estimates of the potential growth in generation vary from a doubling of existing production (currently providing 13% of national electricity supply) to ten times existing production, allowing for future improvements in drilling techniques. The direct use of geothermal heat is more resource-efficient, provides more employment than electricity generation *per se* and has equal potential to expand. Most geothermal developments are environmentally benign and have low carbon dioxide emissions.

However, while the energy source is vast, the power from that source is limited by the rate of heat flow up from deeper zones. Moreover, excessive extraction over decades causes subterranean heat depletion to uneconomic levels and heat renewal can take decades although adaptive management informed through chemical, geophysical and reservoir monitoring will reduce the risk. Taking the heat depletion factor into account, no thorough assessment of the energy potential of the national geothermal resource has yet been carried out.[20]

Numerous technologies exist or are in development to deliver the benefits of mobility and replace liquid transport fuels, from direct replacements such as battery electric vehicles to approaches such as videoconferencing and no-till agriculture that reduce the need for mobility or traction. In contrast, nutrients are elements and cannot be replaced – plants need phosphorus.

Local production of nitrogen fertilisers from atmospheric nitrogen via the energy-intensive Haber process provides around half of New Zealand's nitrogenous fertiliser from natural gas. New Zealand's low cost renewable energy supplies may allow an expanded local industry to be viable and sustainable. We are well-stocked with limestone for calcium fertilisers. For transport fuels and other nutrients, some non-renewable New Zealand sources exist. We produce and export substantial amounts of oil with the potential to develop more. We also have some deposits of phosphate-bearing rock and a potential source of phosphate from nodules on the Chatham Rise seabed.[21]

These three strategies for building resilience would require substantial movement away from current practice (except for the expansion of local oil and gas production). Such transitions would have three major costs: the raised price of mobility or nutrients as the transition is under way; the technological danger of investing in dead-end technologies that may not become viable solutions; and the loss of existing capital and infrastructure that currently depends upon affordable fossil fuels and nutrients. For instance, battery electric tractors are technically feasible and tractor use patterns potentially fit well with electric power: they operate at low speed where the high torque of electric motors is a benefit and they rarely travel far from a home base making charging or battery replacement feasible. However, switching to electric tractors would be problematic: such tractors are not yet on the market let alone available at a competitive cost; it may be that other technologies will have more of an impact on fossil fuel use (e.g. the development of no-till agriculture which reduces ploughing); and farmers already have capital tied up in diesel tractors.

The progress towards resilience in these areas has so far been limited and New Zealand looks likely to remain exposed to these constraints. There has been little research to inform our comprehension of these risks.

Wild fisheries – accepting a constraint and choosing to live within it

Wild fisheries provide one of the few examples where we have accepted a constraint and chosen to live within it. We recognise, in principle, that fish stocks are finite and so we have set catch limits to preserve those fish stocks. However, there remains uncertainty in our knowledge of the population variability of these stocks and their associated underpinning biological processes. This lack of understanding requires a conservative approach to adaptive management of the stock through the Quota Management System. Where we seek to gain more economic value from the constrained flow of benefits, we recognise that we must do so through adding value to a finite take of fish. We will attempt to avoid fishing species to extinction, allowing us to benefit from that stock in perpetuity.[22]

Strategies for delivering well-being ensue from the diversity and nature of the constraints

The Society's paper on *The Sustainable Carrying Capacity of New Zealand* outlines issues with current thinking about how New Zealand generates well-being for New Zealanders and trade partners. The paper presents many of the limits and trade-offs that we face as founded upon biophysical scarcities but also strongly influenced by socioeconomic factors that are best considered as constraints rather than limits. These limits vary in timescale, physical scale, impact, risk, uncertainty, and acuteness of impact. Some constraints being encountered in a gradual way, yet others show sudden and irreversible thresholds[23,24].

These constraints are complex, going beyond the static idea of a sustainable carrying capacity. For each of the examples discussed above, research suggests clear strategies for operating within them. These strategies should include efficiency of resource use, the need for bottom lines when justified, and the ability to optimise resource use for a chosen mix of benefits. By using these strategies, resource managers and users can balance the need for higher benefits with the need for resilient and persistent benefits. However, often the rate of improvement in both resource use and resource conservation is inadequate to deliver that desired mix.

Further reading:

Royal Society of New Zealand "Competition for Land Use in New Zealand" 2011

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