Workforce implications of large-scale land-use change in Aotearoa New Zealand

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Abstract

Many stakeholders across the research sector, central and local government, and Iwi Māori believe that diversifying land uses can help to achieve environmental and economic goals in Aotearoa New Zealand. This paper investigates how the workforce might constrain this process by developing a simulation model to examine the effect of land-use change on the labour market for regions in Aotearoa New Zealand. The model uses assumptions about workforce demand, population growth, the shortage reduction rate, and the labour supply elasticity to dynamically project changes in workforce size, wage rates, and workforce shortages in the food and fibre sector, at the regional scale. The 'Business as usual' scenario forecasts an average real wage growth of 12.7% and an average workforce expansion of 8.4% by the end of the simulation period in 2052. Additionally, it predicts an average peak regional workforce shortage of 8.3%. As a case study, we analyse the Northland region, simulating a regional push for horticulture developments beyond business-as-usual via investment in regional water storage projects. In our most expansive scenario, we simulate a real wage increase of 29.5%, a workforce increase of 43.2%, and a 14.9% peak shortage. In addition to the main scenario where the workforce increases due to higher wages, we analyse two alternative strategies to increase the workforce in response to this increased demand: growing the workforce via population growth and freeing up workers through converting pastoral land into forestry. Success for both strategies would require large deviations from status quo expectations. The results highlight that building a larger workforce will be a significant barrier to the ambition of labour-intensive land-use change, requiring a combination of strategies if land-use goals are to be met.

Introduction and background

Aotearoa New Zealand faces a significant challenge to reduce the impact of the primary sector on greenhouse gas emissions and water quality. Many stakeholders across research, central and local government, and Iwi (tribal organisations) believe large-scale land-use change is necessary to achieve the desired environmental improvements (Our Land and Water 2018). Because much of the land is currently in pasture and forestry, large-scale land-use change also presents an opportunity to develop more high-value land uses, such as high labour crops[1], thereby improving financial outcomes and the environment (Stats NZ 2021b).

However, as parts of New Zealand develop this ambition to move towards more horticulture[2], careful planning is required to understand how to resource this move (Renwick et al. 2019; 2022; Journeaux et

[1] This paper uses the term high labour crops, because most crops have higher work requirements than pasture.

[2] This paper uses New Zealand terminology. In New Zealand 'horticulture' is usually used to mean any number of perennial and annual fruit and vegetable crops. These include but are not limited to apple, pear, asparagus, avocado, blackcurrant, boysenberry, squash, citrus, feijoa, kiwifruit, onion, passionfruit, persimmon, potato, carrot, strawberry, stone fruits, and tomatoes. Horticulture often encompasses but is sometimes distinct from 'arable' crops. 'Arable' usually refers to a set of mostly annual crops including but not limited to maize, wheat, barley, grass seed, clover seed, vegetable seeds, process

al. 2017) and if projects are economically feasible. Raising capital for initial investments in planting and land preparation may present a barrier for many land managers with horticulture as an otherwise feasible option. Building a much larger workforce is potentially a more significant barrier to switching land use to horticulture at scale.

This paper aims to measure how much of a barrier the workforce is to the ambition of labour-intensive land-use change; in this context, this essentially means moving from pasture to horticulture. We develop a dynamic labour supply model that aims to project how wage rates, workforce shortages, and workforce size might evolve in response to a change in demand for labour at the regional level in New Zealand. This type of dynamic labour market modelling is especially important in this context as workforce issues may not become apparent to the market until significant sunk investment (in, for example, water storage projects) has occurred.

Our approach begins with a standard labour supply model, with wages and workforce size increasing as labour demand increases. However, because the standard static equilibrium model does not capture the transition pathway between equilibria, we augment the model with shortages and associated rates of change toward equilibrium.

This results in an annual simulation model that uses demand-change scenarios to explore the effects of different land-use change ambitions, population changes to account for underlying changes in labour supply, workforce shortages to account for imperfect market adjustment over time, and a constant-elasticity labour supply curve to understand expected wage-rate adjustment.

We simulate demand increases for ten years and then explore how quickly the model equilibrates by simulating for a further twenty years. Importantly, our model results shouldn't be interpreted as forecasts, especially in the final twenty years of our simulation period.

We then apply the simulation model to a case study centred on the Northland region's current and potential future land-use ambitions. The food-and-fibre sector, including horticulture, is developing in Northland, and there is a significant regional push for land uses that reduce greenhouse gases and improve water quality while improving returns. This case study starts with a 'Business as usual' (BAU) scenario using an existing labour demand forecast by Song et al. (2023), then models expansions enabled by new water storage projects. Finally, we model two strategies to meet this expanded demand (in addition to increasing wages) via population growth and converting further land into forestry.

In Northland, water availability is usually considered a physical limit on the economic viability of horticultural land uses. Water storage projects ensure a consistent and sufficient water source for viable horticulture enterprises. Our first case study expansion scenario ('Horticulture growth') is calibrated based on the projected impacts of two water projects that are in progress. The second expansion scenario ('Horticulture boom') then envisions a significant capital injection to fund an ambitious investment in water storage infrastructure, essentially implementing all the most feasible freshwater storage projects.

We propose two broad strategies to increase labour supply to achieve the expansion assumed in the ('Horticulture boom') scenario over a shorter period, with a lower peak shortage, and with a lower wage increase. The first strategy ('Population expansion') is encouraging net migration into the region, and the second ('Forestry expansion') is converting pastoral land (with moderate labour requirements) into carbon farming, which has relatively low labour requirements.

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vegetables, pulses, oats, oilseeds, and silage crops. In some cases, the classification appears to be ambiguous, so we combine the concepts here.

In the ‘Population expansion’ strategy, we envision net migration from multiple sources: Māori returning to their ancestral home due to better opportunities, more lenient international migration policies, and regional migration within New Zealand. Our discussions with stakeholders from hapū Māori (Māori sub-tribes) and local government indicate that many Māori will be motivated to return in tandem with the regional investment. The largest Iwi (tribe) in Northland, Ngāpuhi, has an estimated 130,000 (78.8%) descendants living outside the Northland region (Te Kāhui Raraunga Charitable Trust 2019), suggesting that there is a substantial pool of people who could be attracted back into the area.

Our search of the literature did not reveal a significant body of work relevant to our study that simulates workforce shortages or other aspects of the market at a regional level. Jackson (1994) explores various statistics relating to regional employment in New Zealand (e.g., change in part-time versus full-time female employment) and finds major differences in patterns across regions, supporting our approach of explicitly representing regions. Taylor Fry and the New Zealand Productivity Commission (2022) develop a skills shortage model; their study is backwards-looking, with the purpose of understanding recent shortages, whereas our forward-looking simulation approach aims to understand potential future shortages.

We are not aware of an example of a simulation model that uses a labour supply approach augmented with dynamic shortages to project scenarios of labour shortages. The closest study to our approach is Liu et al. (2017), which combines an econometric demand model with a mechanistic supply model to simulate shortages in the healthcare context. The key difference in our approach is that we dynamically simulate the quantity supplied in response to the shortage, allowing wages to equilibrate over time.

There is more existing literature on understanding the wage elasticity of labour supply, a key input parameter in our model. Hill et al. (2021) review the literature on the relationship between wages and agricultural labour supply. While there are many studies cited therein, the recent literature (Li and Reimer 2021; Hill 2020; Richards 2020) focuses exclusively on the intensive margin (i.e., how the number of hours worked responds to wages), whereas the key mechanism by which wages affects agricultural labour supply is via the extensive margin (i.e., more workers). Of the seven studies we deemed eligible to contribute to our estimate of the labour supply elasticity (see section Labour supply elasticity), the most recent is from 1990, indicating that measuring this quantity has become less important in the empirical economics literature.

Given the absence of significant literature on understanding how the workforce presents a barrier to industry expansion, we believe this paper makes an important contribution to begin filling this gap. Importantly, this paper explicitly and dynamically models shortages and highlights that high peak shortages can indicate when the workforce is a barrier to expansion ambitions.

The remainder of this paper’s sections contains the following: ‘Data and inputs’ which describes the sources of all model inputs; ‘Methods’ which describes the model mechanics, assumptions, and calculations we use to develop the scenarios and strategies; ‘Results’ which describes all model outputs from both the exploratory and case study scenarios and strategies, and ‘Discussion’ which analyses our assumptions and results in the context of Northland and Aotearoa as a whole.

Data and inputs

This section describes the data and input sources contributing to our simulation model assumptions.

Baseline workforce demand forecasts

Song et al. (2023) provide workforce forecasts for the food-and-fibre sector, both nationally and regionally. These authors use the proprietary economy-wide computable general equilibrium (CGE) model 'TERM-NZ', running three scenarios: 'Business as usual' (BAU), 'Increased use of technology', and 'Transformed sector'; we use results from the BAU scenario.

The BAU scenario primarily uses historical investment, productivity, and technology trends to project outcomes for the food-and-fibre sector in 2032. We use the current and future workforce projections to inform the path of labour demand in our model.

Business as usual workforce forecast results

The summary results of the BAU scenario for each region are in Table 1. This scenario is based on historical performance to describe the situation in the food and fibre sectors in 2032. The projection estimates an increase in the food and fibre workforce to 391,000 workers in 2032. This is an increase of 7.7 percent over their base year (2020). We then interpolate the values to get the current workforce demand in our base year (2022).

Table 1: Regional workforce forecasts results for BAU scenario from Song et al. (2023)

Region	Current workforce demand (2022)	Future projected demand (2032)	Percentage change
Northland	16,919	18,073	6.82%
Auckland	62,901	65,126	3.54%
Waikato	40,958	43,444	6.07%
Bay of Plenty	35,098	38,452	9.56%
Te Tai Rāwhiti	10,693	11,534	7.86%
Hawke's Bay	26,794	30,173	12.61%
Taranaki	13,589	14,681	8.04%
Manawatū-Whanganui	25,538	26,933	5.46%
Wellington	17,565	18,151	3.34%
Tasman & Nelson	14,805	16,211	9.49%
Marlborough	9,435	9,739	3.22%
West Coast	3,759	3,943	4.88%
Canterbury	51,793	54,445	5.12%
Otago	19,506	20,622	5.72%
Southland	18,479	19,657	6.38%
New Zealand	**367,831**	**391,184**	**6.35%**

This table shows current and projected food and fibre workforce levels calculated from Song et al. (2023). We use these for the BAU demand projections in this paper.

Population projections

We collect population growth projections at the regional level from Statistics New Zealand. We use these projections to estimate annual growth rates in the labour force at the regional level for this model.

Specifically, we use population projections for the 15-39 age cohort from Stats NZ (2021a) where the medium projection corresponds to the 50th percentile (median) for the National Population Projections Stats NZ releases. When calculating our population growth distributions, we assume the 'low' and 'high' projections correspond to the 5th and 95th percentiles. We use the 15-39 age cohort to approximate the growth in new workers available.

Table 2: Population projections for 15-39 age cohort (Northland region to 2033)

Regional population estimates			
Year	*Low projection*	*Medium projection*	*High projection*
2022	55,100	55,100	55,100
2023	55,100	56,000	57,000
2028	55,700	57,700	59,700
2033	54,600	57,700	60,800

Data was gathered from regional population projections using different scenarios of regional growth (Stats NZ 2021a).

Table 2 shows example population projection data for the Northland region. The data suggests that the bulk of population growth from 2022 to 2033 will occur between 2023 and 2028, with projected five-year growth rates ranging from 1.09 to 4.74%. The median forecast predicts the 15-39 population will reach 57,700 by 2033.

Labour supply elasticity

The labour supply elasticity measures the responsiveness of the supply of workers to wage changes. It indicates the percentage change in the quantity of labour supplied in response to a percentage change in the wage rate. A high elasticity means that a small change in the wage rate will result in a relatively significant change in the quantity of labour supplied. In contrast, a low elasticity means that the quantity of labour supplied is relatively insensitive to changes in the wage rate. In our model, wages are an outcome, so the labour-supply elasticity drives how wages ultimately respond to changes in the other parts of the demand and supply system.

We survey the existing literature on labour supply elasticities, emphasising studies focused on the agriculture sector. In a review article, Hill, Ornelas, and Taylor (2021) collate 35 papers estimating labour supply elasticity for the agriculture sector, published between 1960 and 2019. Around half of the papers in their sample focused on the USA, while the others focused on European countries. Their results indicate that various measures of the agriculture labour supply elasticity range between 0 and 1.54 for the USA and 0 and 1.1 for other countries.

However, many studies cited therein come from simulation studies using agricultural household models rather than direct empirical measurement. Several studies also estimate just the intensive margin (how hours worked relates to wages), whereas we are primarily interested in the extensive margin when considering large-scale workforce changes.

We focus on eight estimates of the long-run labour supply elasticity cited in this review article, including the extensive margin, from seven studies (Schuh 1962; Johnson and Heady 1962; Tyrchniewicz and Schuh 1969; Cowling, Metcalf, and Rayner 1970; Traill 1982; Duffield 1990; Wang and Heady 1980). These are 0.78, 0.71, 1.54, 0.50, 1.10, 0.73, 0.98, and 1.34, with an average of 0.96. We base our elasticity assumptions on these results, using 1 as our central value and 0.6 and 1.4 as our low (5^{th} percentile) and high (95^{th} percentile) estimates.

Expert elicitation interviews

We are not aware of any direct empirical evidence on the current sizes of regional workforce shortages in the primary sector or how fast primary-sector shortages should decrease. These are important assumptions for our simulation model, so we developed an expert elicitation method using structured interviews to estimate these quantities. The interview approach allows us to engage with the experts in a way that lets them fully express their thoughts on the questions posed and explore their broad perspectives on the labour market. We interviewed three external experts and incorporated the views of Dr Barker. One of the external responses was not usable, so we combine the results of the three conversations. The interviews were conducted in April and May 2023.

Initial shortage by region

After introducing our project and its objectives, we presented each expert with a list of estimated average regional shortages for November 2021 for the dairy sector drawn from DairyNZ (2021) and the national average. These estimates then serve as the starting point for a discussion, aiming to ultimately produce estimates for current regional labour shortages for the full primary sector. Importantly, the definition of 'shortage' we use is the percentage increase in the current employed workforce required to fill all current vacancies, a similar definition to that in DairyNZ (2021).

All interviewees were comfortable with the accuracy of the national dairy workforce shortage from DairyNZ (2021) but not necessarily the regional breakdown. Interviewees then categorised regions using a 5-point scale (average, above average, etc.), representing how the regional November 2021 shortage for dairy differed from the national average, combining the results from the survey mentioned above with their other knowledge. Next, interviewees translated the 5-point scale into a numerical multiplier (e.g., 80% of the average).

Next, interviewees adjusted the estimate via a further multiplier (by region) to reflect how dairy compared to the broader primary sector. The third stage compared the present-day versus November 2021, including any influence of unemployment rate income trends. Finally, we asked interviewees for low and high estimates representing a 90% confidence range.

Shortage reduction per year

In the second stage of this interview, we also asked our experts about their views on how quickly labour shortages equilibrate naturally and how much shortages might persist in the long term. Figure 1 shows the interview questions for this stage.

Figure 1: Excerpt expert elicitation interviews on the shortage reduction rate.

Shortage reduction rate

Imagine that the current shortage is 5%. What would the shortage reduce to over long periods (i.e., decades) if neither the industry workforce requirements nor the workforce pool grew?

Low estimate	Most likely	High estimate

Imagine that the current shortage is 10%. What do you think the shortage would be in one year if neither the industry workforce requirements nor the workforce pool grew?

Low estimate	Most likely	High estimate

Imagine that the current shortage is 20%. What do you think the shortage would be in one year if neither the industry workforce requirements nor the workforce pool grew?

Low estimate	Most likely	High estimate

Imagine that the current shortage is 30%. What do you think the shortage would be in one year if neither the industry workforce requirements nor the workforce pool grew?

Low estimate	Most likely	High estimate

This figure shows an example of the questions posed to our experts when conducting the interviews. We used video conferencing software, sharing the instrument and inputting responses from the interviewees.

The portion of the interview regarding the shortage reduction rate similarly allowed for a free discussion. All experts agreed that the shortage would not be eliminated over long periods (i.e., a positive minimum shortage exists). For example, this permanent minimum shortage is driven by natural attrition and the time it takes to fill a role, even at a market-clearing wage. All experts also agreed that the shortage recovery rate is a fixed proportion of the difference between the current and minimum shortages. This fixed proportion is what we henceforth call the shortage recovery rate.

Uncertainty

To better understand the range of reasonable future model outputs, we model Monte Carlo uncertainty over several model inputs: the initial period shortage, population growth rate, shortage recovery rate, minimum shortage, labour supply elasticity, and labour-saving technological progress. We assume that the initial period shortage is distributed lognormal and truncated by the sampled minimum shortage, the population growth rate is distributed normal, the shortage recovery rate is distributed lognormal and truncated, the minimum shortage is distributed lognormal and truncated, the labour supply elasticity is distributed normal and truncated, and the labour-saving technological progress is distributed normal and truncated.

To estimate all distribution parameters bar labour-saving technological progress, we define three percentiles and find the implied (or best-fit) parameters using a numerical optimisation procedure.[3]

For labour-saving technological progress, we expect that, on average, future technological progress will be mixed between labour-saving and labour-costing progress, so we assume a mean of 0. We believe there is significant uncertainty in this technological path, so we set the standard deviation at 0.25% per

[3] We use the rriskdistributions package in R for this task.

year. Importantly, we do not resample the value for each year; the technological path is set for the duration of the sample.

The distributions we use are in Table 3 below.

Table 3: Uncertain model features with distributions.

Model feature	Model input	Distribution	Distribution parameters
Initial period shortage	Initial period shortage percentile	Lognormal, values range by region, truncated by sampled minimum shortage.	$\exp(\mu) = 0.054$ to 0.099 $\sigma^2 = 0.24^2$
Population growth rate	Population-level percentile	Normal in levels, percentile unique across years for each simulation. Values range by region and time period.	$\mu = -0.017$ to $+0.008$ $\sigma^2 = 0.002$ to 0.008
Shortage recovery rate	Shortage recovery rate percentile	Lognormal truncated at 0% and 100%.	$\exp(\mu) = 0.25, \sigma^2 = 0.54^2$ $a = 0, b = 1$
Minimum shortage	Minimum shortage percentile	Lognormal, truncated at 0% and 100%.	$\exp(\mu) = 0.037, \sigma^2 = 0.13^2$ $a = 0, b = 1$
Labour supply elasticity	Labour supply elasticity value	Normal, truncated at 0.5 and 1.5.	$\mu = 1.0, \sigma^2 = 0.24^2$ $a = 0.5, b = 1.5$
Labour-saving technological progress	Labour-saving technological progress percentile	Normal, truncated at -0.0055 and 0.0055.	$\mu = 0, \sigma^2 = 0.0025^2$ $a = -0.0055, b = 0.0055$

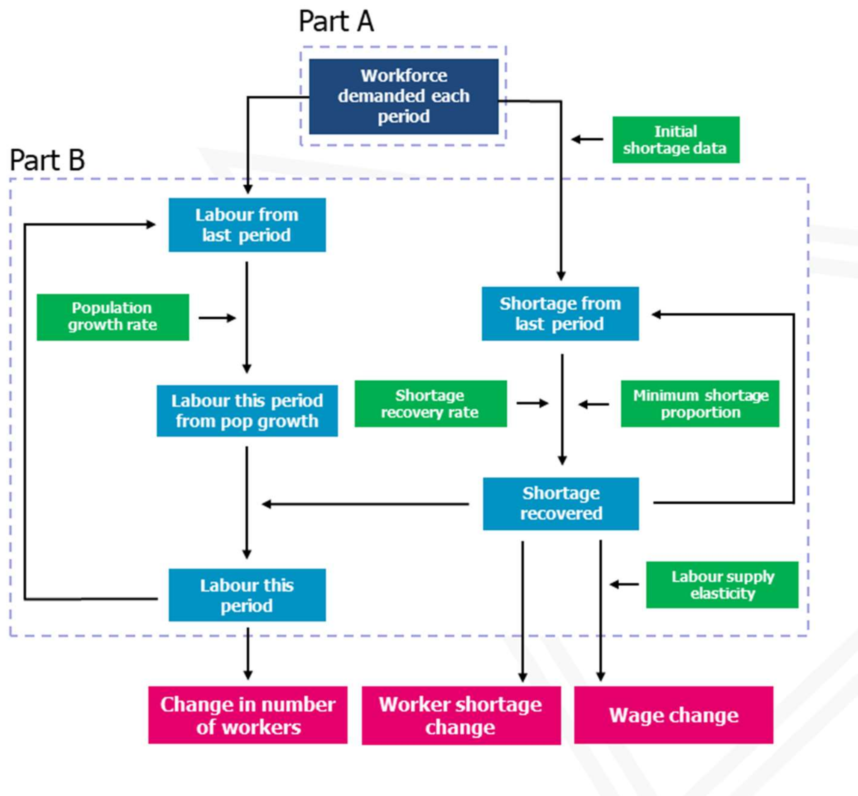
Model features describe the quantities sampled, and the model inputs describe the actual input values in the model code. For the initial period shortage and the population growth rate, μ varies by region as estimates were gathered for each region from the elicitation interviews and StatsNZ (2021a), respectively.

All uncertainty within the model is generated from the sampling variation in the parameters listed in Table 3 via Monte Carlo simulations, which we discuss in more detail in the 'Methods' section.

Methods

This section describes the methods we use in developing our annual simulation model to explore the effects of different land-use change ambitions on labour shortages, wage rates, and workforce size at the regional level in Aotearoa. A visual overview of our framework is detailed in Figure 2 below. Part A is described in the 'Baseline workforce demand forecasts' section, and Part B is described in the following 'Simulation model framework' section.

Figure 2: Regional labour and land-use simulation model flowchart.



Part A describes the NZIER modelling of workforce demand forecasts informed by MPI in Song et al. (2023). Part B describes the model mechanics, with inputs informed by interviews, literature, and StatsNZ data. Green boxes indicate inputs into the model, light blue boxes indicate calculation steps, and red boxes indicate outputs of the model.

The model begins with assumptions about labour demand and an initial shortage, with our baseline demand as described in the 'Baseline workforce demand forecasts' section and the initial shortage estimated in the expert elicitation process. We then simulate an expansion in the workforce (i.e., the actual number of workers) that results from population growth. Next, we simulate the shortage reduction (i.e., equilibration) process, with a fixed proportion of the difference between the shortage and the minimum shortage being recovered each period. Finally, we calculate the resultant workforce size, workforce shortage, and wage change, then initialise the next period. We do not model surpluses; when the model would simulate a surplus, we change wages to equilibrate demand and supply.

Simulation model framework

This section outlines the simulation model mechanics; to simplify the narrative, we write this section as if there are no uncertain parameters and for the BAU scenario. We begin by defining the initial period shortage $Q_{shortage_{0,r}}$ for region r:

$$Q_{shortage_{0,r}} = \gamma_{0,r} Q_{s_{0,r}} \tag{1}$$

where $Q_{s_{0,r}}$ is the workers supplied in region r from the Song et al. (2023) projections and $\gamma_{0,r}$ is the regionalised initial-period shortage percentage calculated from estimates provided in the expert elicitation interviews. The following identity holds in all periods, with shortage being the difference between demand and supply:

$$Q_{shortage_{t,r}} = Q_{d_{t,r}} - \ Q_{s_{t,r}} \tag{2}$$

where $Q_{d_{t,r}}$ is the quantity of workers demanded in region r and year t. $Q_{d_{t,r}}$ is assumed for all periods by adding the projected change from Song et al. to $Q_{d_{0,r}}$ (calculated using Equation (2)), such that the quantity demanded grows linearly. For each period, the quantity of labour supplied (i.e., actual workforce size) is calculated based on two components: the baseline labour supply in that period from the increased population and the growth in labour supplied through shortage recovery from the last period. The former mechanism occurs without wage changes (i.e., shifts the supply curve), and the latter only occurs with wage changes (moving up the supply curve). Thus, we calculate the labour supplied in each period using:

$$Q_{s_{t,r}} = \ Q_{s_{t-1,r}} * \left(1 + g_{15-3\ \ t,r}\right) + \delta\left(Q_{shortage_{t-1,r}} - \alpha Q_{s_{t-1,r}}\right) \tag{3}$$

where $g_{15-3\ \ t,r}$ is the population growth rate for the 15-39 age group at time t and for region r, δ is the shortage recovery rate, α is the minimum shortage proportion. $Q_{shortage_{t,r}}$ can then be calculated using Equation (2).

Finally, we calculate the implied wage change using the proportional change in workers supplied (after population growth) and the labour supply elasticity η. The proportional wage change in period t and region r is:

$$\frac{\Delta W_{t,r}}{W_{t-1,r}} = \frac{1}{\eta} * \frac{\delta\left(Q_{shortage_{t-1,r}} - \alpha Q_{s_{t-1,r}}\right)}{Q_{s_{t-1,r}}} \tag{4}$$

where Δ denotes the backward difference. We do not model a specific wage level in dollars, so readers can interpret the wage changes in this paper as real changes in the full wage distribution.

We assume that the demand increase starts in 2023 and ends in 2032, with no further changes to demand thereafter. For the remainder of the simulation period, population continues to grow, and the model equilibrates. Readers should not interpret our results as forecasts, especially after 2032, when the results are intended to communicate how quickly the system might be expected to equilibrate following a period of change in demand.

Monte Carlo simulation

Table 3 above describes the distributions assumed for each sampled parameter: the initial period shortage ($\gamma_{0,r}$), population growth rate ($g_{15-\quad t,r}$), shortage recovery rate (δ), minimum shortage (α), the labour supply elasticity (η), and labour-saving technological progress (implemented as reductions in $Q_{d_{t,r}}\ \forall t$). We assume that these distributions are independent. We calculate the results in this paper using 500 Monte Carlo draws and report the median, the interquartile range, and the 90% uncertainty interval.

Model exploration scenarios

We initially explore three scenarios intended to explore the range of outcomes that the model can produce: 'Business as usual' (BAU) is calibrated using median values and the demand change from Song et al., 'High demand increase' represents a more significant demand change due to increases in labour-intensive land-use change, 'Flexible labour market' is calibrated to parameter values which represent a highly flexible, but still plausible, labour market. The parameter values for each of these are in Table 4.

Table 4: Parameter values that are unique to each model exploration scenario.

Parameter	Value		
	Business as usual	Flexible labour market	High demand increase
Labour-saving technological progress percentile	50%	75%	50%
Demand increase multiplier	1x	1x	3x
Population growth percentile	50%	75%	50%
Labour supply elasticity	1	1.4	1
Shortage recovery percentile	50%	75%	50%

Labour-saving technological progress is implemented as an annual reduction in quantity of labour demanded after other demand assumptions are made. Demand increase multiplier modifies the BAU demand increase from Song et al. (2023). Percentiles are drawn from the distributions defined in Table 3. Other parameters are common to all scenarios, and their values are as follows: End year of simulation = 2052, Demand increase period start = 2023, Demand increase period end = 2032, Number of Monte Carlo simulations = 500, Initial shortage percentile = 50th percentile, Minimum shortage percentile = 50th percentile.

Case study: Horticultural expansion in Northland

The case study aims to explore the implications of a hypothetical large expansion in the required workforce in the Northland region. We model two expansion scenarios, one based on water storage projects that are underway and one larger that aims to represent what would be possible if all physically feasible water projects were to be pursued (i.e. assuming no capital or regulatory constraints for water projects). We then model two strategies to meet this increased demand: population growth and reducing workforce requirements via conversion from pastoral farming to forestry.

The following sections describe how we calculate the inputs for each case study scenario and strategy from the data collected and described in Table 5; all other inputs are taken from the BAU scenario. Many of the inputs are not available in any literature so we rely on the judgement of local experts and our research team for several inputs.

Scenario 1: Business as usual

Scenario 1 is the same as the BAU scenario in the Model exploration scenarios subsection for Northland in terms of model inputs; the key input is that we assume demand increases by around 6.8% from 2022 to 2032 (see Table 1). This scenario is consistent with a small portion of pastoral land being converted into high-value crops and horticulture while retaining the remaining pastoral land in sheep/beef and dairy farming.

Scenario 2: Horticulture growth

The 'Horticulture growth' scenario builds off the baseline BAU scenario, where there is a small amount of conversion to horticulture. In the 'Horticulture growth' scenario, we base the pace of change towards more horticulture on the amount of land supported by two major reservoirs in Otawere and Kaipara, both of which are under construction as of December 2023 (Te Tai Tokerau Water Trust 2023).

If we assume, on average, irrigating one hectare of horticulture crops will require 3000m^3 of capacity, then at maximum, the Otawere and Kaipara reservoirs, with a combined capacity of 7.3 million m^{3,} will sustain 2400 ha of new crops. This amount of capacity is what the modelling supporting these projects has assumed. Rain patterns and expected usage in this area suggest that it will be rare for reservoirs not to be full at the beginning of summer when usage will begin for the growing season. However, after consultation with a local expert, we were informed that up to 1.1 million m^3 will be reserved for municipal use, reducing the maximum capacity to 6.2 million m^3 and land to 2066 ha of new crops.

To determine how many new workers this land would require, we must first calculate how many extra FTEs are necessary. It should be noted that the exact number of FTEs is contingent on which crops are selected. However, as an estimate, we use avocados (0.57 FTE / ha (Scarlatti 2023b)) as a placeholder for high labour-requirement horticulture crops and onions (0.04 FTE / ha (Scarlatti 2023b)) as a stand-in for lower labour-requirement crops[4]. Developing cropland will also require freight and processing, but the FTE rates above only consider workers in primary production (before the farm gate).

Using the core primary $H^j_{Primary}$ and processing $H^j_{Processing}$ headcounts from NZIER & MPI (2022), we estimate an average ratio of processing to primary workforce ϕ^j for horticulture and dairy farming nationally ($\phi^j = H^j_{Processing}/H^j_{Primary}$ for $j \in \{Horticulture, Dairy\}$). Hence, we can say that the total FTE / ha rates for the expansion of the full food & fibre workforce, E_{FF}, are:

$$E^j_{FF} = \left(1 + \phi^j\right) * E^j_{Primary} \tag{5}$$

where E^j_i denotes FTEs per ha for workforce scope i (i.e., primary or food-and-fibre) and land use j.

We then assume that the split between low and high labour requirements for the new crops will be, on average, 40:60 (chosen in consultation with a local expert). We assume that dairy land will be converted to the new uses. Thus, in total, the extra FTE required per ha is:

$$\Delta E_{FF} = 40\% * \left(E^{Onions}_{FF} - E^{Dairy}_{FF}\right) + 60\% * \left(E^{Avocados}_{FF} - E^{Dairy}_{FF}\right) \tag{6}$$

and using an average FTE per worker of 0.9 calculated using data from Scarlatti & Muka Tangata (2023), we can find the extra headcount required per hectare:

[4] Kūmara, for example, is proposed as a crop that would use these water projects and, to our understanding, has similar workforce requirements to onion. Note that this dashboard aims to include input requirements such as fertiliser, planting, and harvest contractors.

$$\Delta H_{FF} = \frac{\Delta E_{FF}}{0.9} \quad (7)$$

where ΔH_{FF} denotes the extra headcount per ha required for the full food-and-fibre sector. These assumptions imply that Northland would need 1,140 workers to grow and process the crops enabled by the Otawere and Kaipara reservoirs. This amount is similar to the change in the BAU scenario, resulting in approximately a doubling of the increase in demand.

Scenario 3: Horticulture boom

The 'Horticulture boom' scenario takes the water storage network currently in the pipeline described in the 'Horticulture growth' scenario and imagines a five-times expansion to a total of ten similarly sized reservoirs across the Northland region. It is somewhat idealised, as it would require substantial capital injection into the region to finance the infrastructure development. However, our consultation with a local expert suggests that it is an achievable scale considering the geography of the area and excluding energy-intensive storage methods such as desalination or aquifer refreshing.

In this scenario, we scale the workforce growth by five times that of the 'Horticulture growth' scenario, resulting in an increase of 5,699 workers, and this is reflected in an assumed change in demand of approximately six times compared to the forecasted increase by Song et al. (2023).

Strategy 1: Forestry expansion

Our first proposed strategy to meet the increased demand in the 'Horticulture boom' scenario is 'Forestry expansion', which aims to free up labour to meet the 'Horticulture boom' requirements by converting pasture land into forestry, using the 'Horticulture growth' scenario as a baseline. We use the workforce requirements for permanent carbon farming from Scarlatti (2023b) but the numbers can be roughly interpreted as representative of commercial forestry and low-cost native reversion[5]. These forest land uses can have markedly lower labour requirements than pasture land uses.

This strategy aims to answer the question: how many hectares of dairy or sheep/beef land would be required to free up enough workforce to expand the horticulture workforce to fulfil the 'Horticulture boom' scenario requirements, using the 'Horticulture growth' scenario as a baseline?

We first need to know how many workers will be made available per hectare of pasture converted to forestry. One important consideration is that there is a much higher proportion of employers involved in pastoral farming than in horticulture – 36% in dairy and 57% in sheep/beef compared to only 15% in horticulture and as those farmers exit pastoral agriculture, not all will form part of the horticulture workforce pool for various reasons including the latter having a higher physical labour component.

To address this consideration, we assume that only 50% of pastoral farming employers will be available to horticulture as the pastoral workforce contracts. We assume this because some employers will be near retirement age and decide to leave the workforce entirely, while others will decide not to retrain in the primary sector. We assume, however, that 100% of the employees will be available to the horticulture workforce.[6] We thus assume the following FTEs added to the horticulture workforce (including processing) per hectare of pastoral agriculture reduced:

[5] Native reforestation in practice can be labour intensive if it involves hand planting and substantial weed control. However, this labour-intensive period is at the beginning of the conversion and worker requirements for native forest drop to essentially 0. Because the requirements can vary substantially depending on the approach, we use the 'low-cost' qualification.

[6] We don't literally assume that the same individuals move from pastoral agriculture to horticulture, just that the causal effect of reducing the pastoral agriculture workforce is to increase the horticulture workforce by the given amount. The workers may circulate through other parts of the economy.

$$E_{FF}^{j,Available} = (1+\phi^j) * E_{Primary}^j * \left(0.5 * \pi_{Employers}^j + (1-\pi_{Employers}^j)\right)$$

(8)where $\pi_{Employers}^j$ is the proportion of employers in the workforce for pastoral land use j.

The final intermediate quantity we need is $TE_{FF}^{Required}$, the number of FTEs required to meet the 'Horticulture boom' requirements using the 'Horticulture growth' scenario as a baseline. This is simply $TE_{FF}^{Required} = 0.9 * TH_{FF}^{Required}$ where $TH_{FF}^{Required}$ is the calculated difference in the workforce requirements between scenarios (4,559).

We then examine four alternatives within this strategy: 1. Only sheep/beef pasture land is converted into forestry, 2. Only dairy pasture land is converted into forestry, 3. Sheep, beef, and dairy pasture are converted proportionally to their total area within the Northland region, and 4. Sheep/beef land is converted first (as it has much lower operating profit), then dairy. We use area numbers from Statistics New Zealand (2021b).

Strategy 2: Population expansion

The 'Population expansion' strategy is our second method of meeting the increased demand for workers in the 'Horticulture boom' scenario by encouraging net migration into the Northland region. This extra population can, in principle, come from a combination of regional migration, return migration of New Zealanders from overseas, and from international migration. Māori stakeholders that we have spoken to are optimistic that descendants of the area would readily return if there were better economic opportunities.

Further, we are assuming that many factors encourage people to return or immigrate to Northland: desirable new jobs, potential wage increases, being reunited with family, a better lifestyle, unique job opportunities/career pathways, and housing being built to foster new communities. Conversations with experts suggest regional efforts are already being made in this vein, with several Māori-led community housing builds in the pipeline to provide housing for returnees and general regional investment in community facilities. Many Māori community groups are optimistic about these factors being influential enough to encourage people to return or immigrate.

In this strategy, we don't calculate the required population change; rather, we calculate the required number of extra workers to meet demand in the 'Horticulture boom' scenario, using the 'Horticulture growth' scenario as a baseline. We do, however, compare this to the equivalent population growth rate in the discussion.

Northland case study inputs

The data for our case studies were collected from several sources, and we co-developed the case study methodology and sense-checked our final inputs with several experts/stakeholders. The calculations and our assumptions for the final inputs are above in the corresponding 'Case study: Horticultural expansion in Northland' subsections. All the numerical assumptions used to generate the case study inputs are contained in Table 5 below. As noted earlier, a lack of existing literature in this area has meant that a number of assumptions have been necessary.

Table 5: All data sources used to calculate the case study inputs.

Input	Value	Source
2022 workforce forecast	16,919	(Song et al. 2023)
2032 workforce forecast	18,073	(Song et al. 2023)
FTE per headcount	0.9	(Scarlatti and Muka Tangata 2023) and author calculations
Proportion of employers in the dairy industry	36%	(Scarlatti and Muka Tangata 2023) and author calculations
Proportion of employers in the sheep/beef industry	57%	(Scarlatti and Muka Tangata 2023) and author calculations
Proportion of employers made available	50%	Assumption
Proportion of employees made available	100%	Assumption
Carbon farming FTE/hectare	0.000505	(Scarlatti 2023b)
Dairy farming FTE/hectare	0.025	(Scarlatti 2023b)
Sheep/beef farming FTE/hectare	0.007	(Scarlatti 2023b)
Onions (kūmara substitute) FTE/hectare	0.04	(Scarlatti 2023b)
Avocado FTE/hectare	0.57	(Scarlatti 2023b)
Proportion of land converted into high requirements use (e.g. Avocado)	60%	Obtained from an expert
Proportion of land converted into low requirements use (e.g. Kūmera)	40%	Obtained from an expert
Kaipara water storage project, number of horticulture hectares it can sustain	1100	(Te Tai Tokerau Water Trust 2023)
Otawere water storage project, number of horticulture hectares it can sustain	1300	(Te Tai Tokerau Water Trust 2023)
Kaipara water storage project, million m^3 of water needed for municipal use	0.5	Obtained from an expert
Otawere water storage project, million m^3 of water needed for municipal use	0.6	Obtained from an expert
National horticulture core primary workforce (headcount)	35,358	(NZIER and MPI 2022)
National horticulture core processing workforce (headcount)	25,733	(NZIER and MPI 2022)
Current number of sheep/beef land-use hectares	270,662	(Stats NZ 2021b)
Current number of dairy land-use hectares	166,101	(Stats NZ 2021b)

The final inputs and how they are calculated are described in the 'Case study: Horticultural expansion in Northland' methods section, along with corresponding assumptions. Those inputs whose source contains author calculations were decided through a combination of consultation with internal subject experts and previous projects.

Results

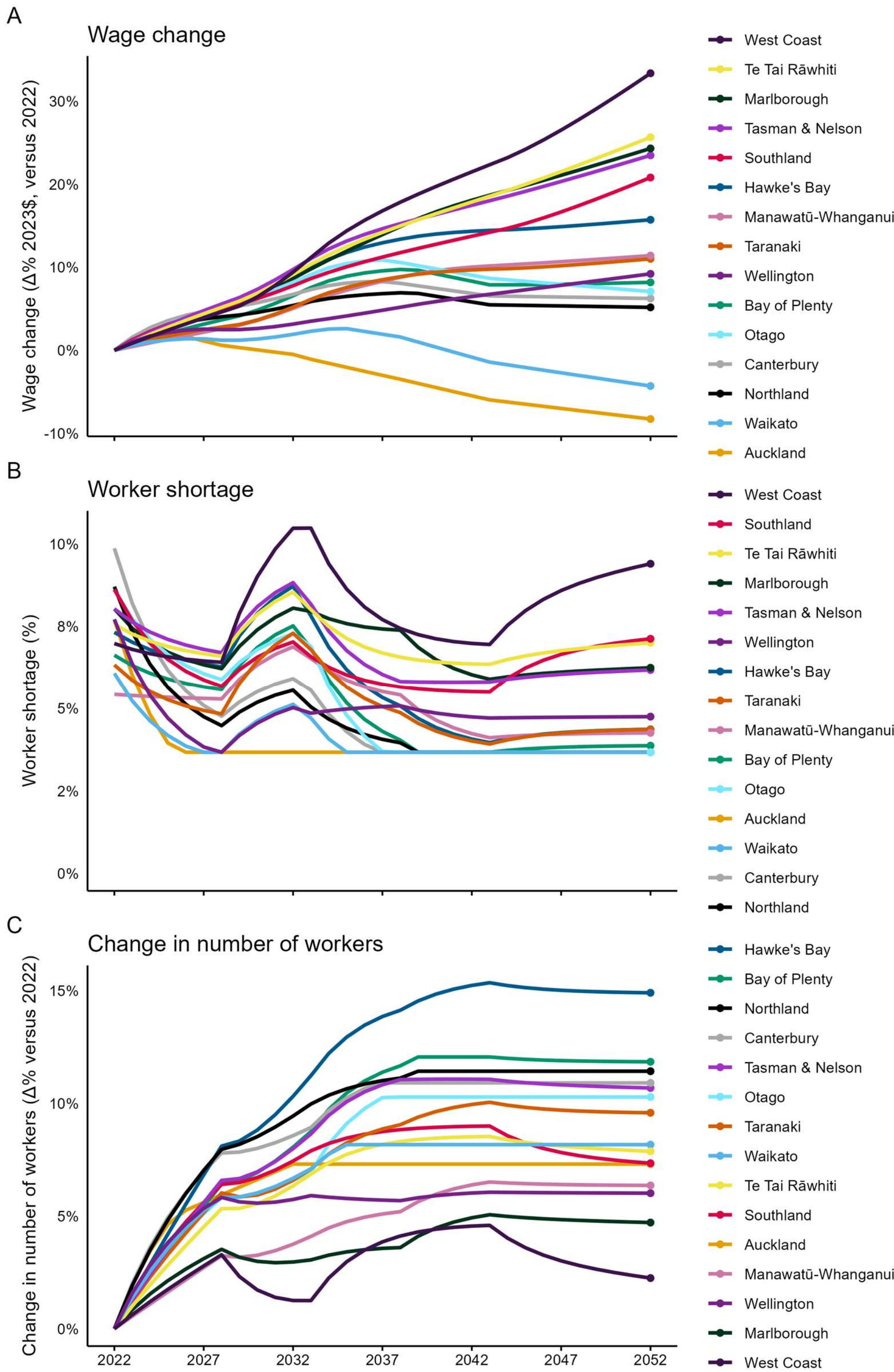
This section presents our results from both the model exploration scenarios that explore the effects of changing several inputs and the case study that models horticultural expansion in Northland and analyses possible strategies to meet the extra demand. We present results up to and including 2052; recall that worker demand increases for ten years, and the model equilibrates thereafter.

The model exploration scenarios are discussed in the 'Regional results' and 'Uncertainty results' sections, while the case study strategies are discussed in the 'Case study: Horticultural expansion in Northland' subsections.

Regional results

This section explores the BAU model exploration scenario for all New Zealand regions. Regionalised demand forecasts, population projections, and initial shortages drive the differences between regions, with other inputs being the same across all regions.

Figure 3: Model outputs from 2022-2052 by region.



Panel A: Real wage change as a percent change versus 2022. Panel B: Worker shortage as a percent of the number of workers. Panel C: Change in number of workers as a percent change versus 2022. Regionalised demand forecasts, population projections, and initial shortages drive regional differences. Worker shortage changes are bounded below by the minimum shortage, which accounts for worker churn and current vacancies, while wage changes can be positive or negative to reflect worker shortages or surpluses. Demand increases up to 2032 and then remains constant. Population growth projections from StatsNZ (2021a) are applied for all years and generally vary at 5-year intervals. Some regions see population declines which exacerbates worker shortages. Line colours are kept the same between the three panels for each region and the order of the regions in each legend is based on the order of the final value in the corresponding plot.

Our results in Figure 3 show that the baseline model inputs produce a wide range of behaviour depending on the region. We see simulated shortages increasing substantially in some regions and closing quickly in others. Wage changes are substantial in some regions, with all but two regions requiring at least some degree of wage increase. Similarly, the change in the number of workers is considerable in most regions, with all but two regions seeing at least a 5% increase in the working population.

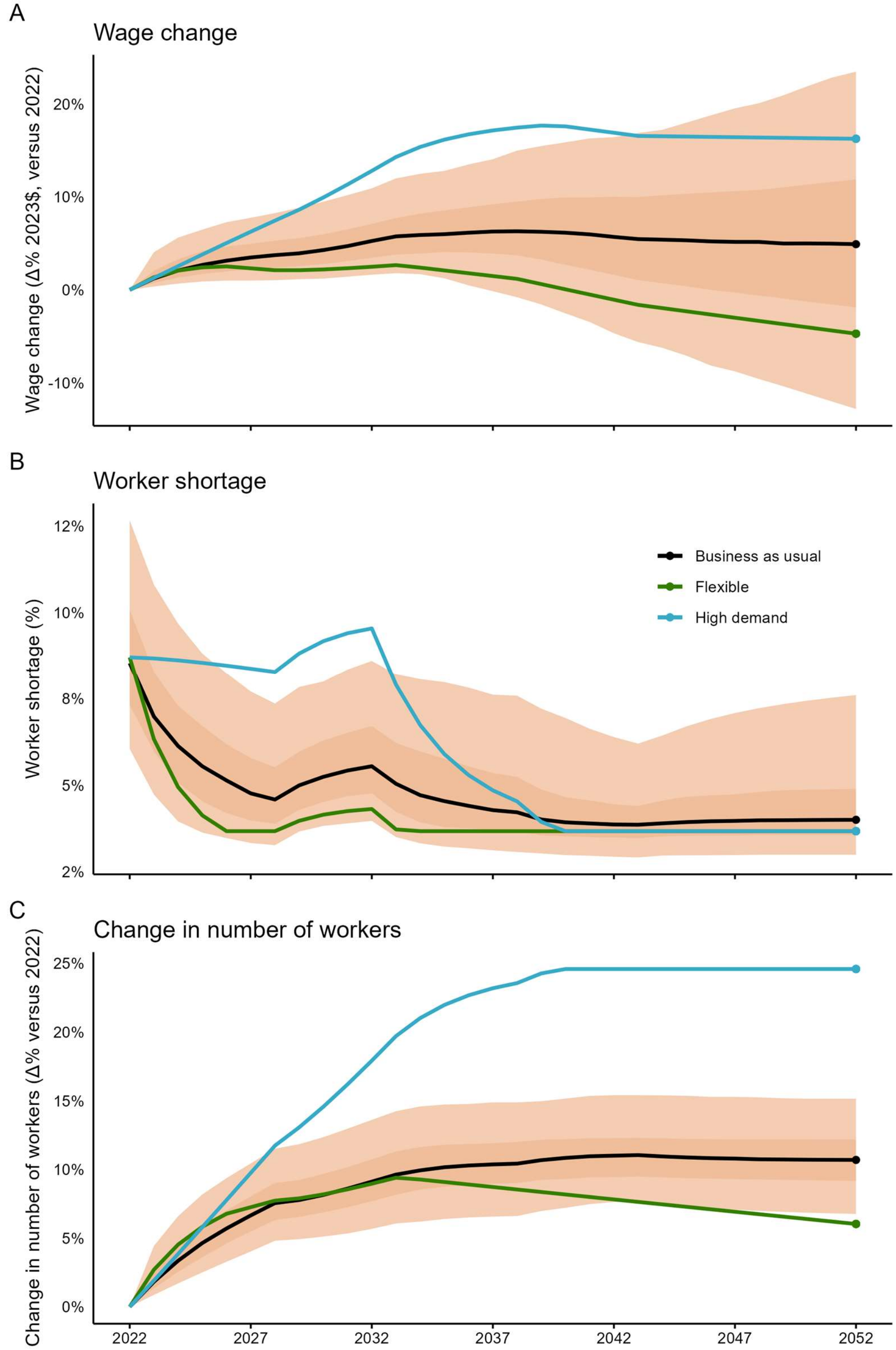
The shortages in several regions are reduced to the minimum within ten years after the end of the demand increase period (10 years after 2032), and all regions besides the West Coast see some reduction in shortages within the entire 30-year period. All regions other than Auckland and Waikato require at least a 5% increase in wages over the period, with Auckland and Waikato seeing wage decreases due to population growth. Around a third of the regions see more than a 20% increase in wages. Most of the change in the number of workers across regions occurs before 2042.

Uncertainty results

This section explores uncertainty in our results both via our Monte Carlo analysis, showing 50% and 90% intervals, and using two exploratory scenarios: 'Flexible labour market', which makes assumptions that tend to make filling vacancies easier (e.g., higher population growth), and 'High demand increase', which triples the baseline rate of demand increase versus the BAU scenario. We use the Northland region as an example in this paper but make other region's results available in an online dashboard[7].

[7] Regional results for multiple input values are available at landftes.scarlatti.co.nz/regionalmodel.

Figure 4: Model results incorporating Monte Carlo uncertainty and model exploration scenarios for the Northland region.



Panel A: Real wage change as a percent change versus 2022. Panel B: Worker shortage as a percent of the number of workers. Panel C: Change in number of workers as a percent change versus 2022. Inner uncertainty bands are the interquartile range and outer uncertainty bands are the 5th to 95th percentile range, both for the BAU scenario. Uncertainty is driven by the initial period shortage, the population growth rate, the shortage recovery rate, the minimum shortage, the labour supply elasticity, and labour-saving technological progress. The 'Flexible' scenario assumes higher population growth, faster shortage recovery, more labour-saving technological progress, and a higher labour supply elasticity (i.e., lower wage changes) versus BAU. The 'High demand increase' scenario triples the demand increase versus BAU.

Figure 4 shows our Monte Carlo uncertainty results for the BAU scenario as well as the results for two model exploration scenarios, respectively representing a flexible labour market and a high demand increase versus BAU. Our sources of uncertainty are listed in Table 3. A key message from these results is that all outcomes have a high degree of uncertainty under BAU, especially wages (~-10% to + 20% by 2052) and shortages (~2.5% to 8% by 2053), with the overall workforce size somewhat more consistent across runs (~107%-115% of 2022 by 2053).

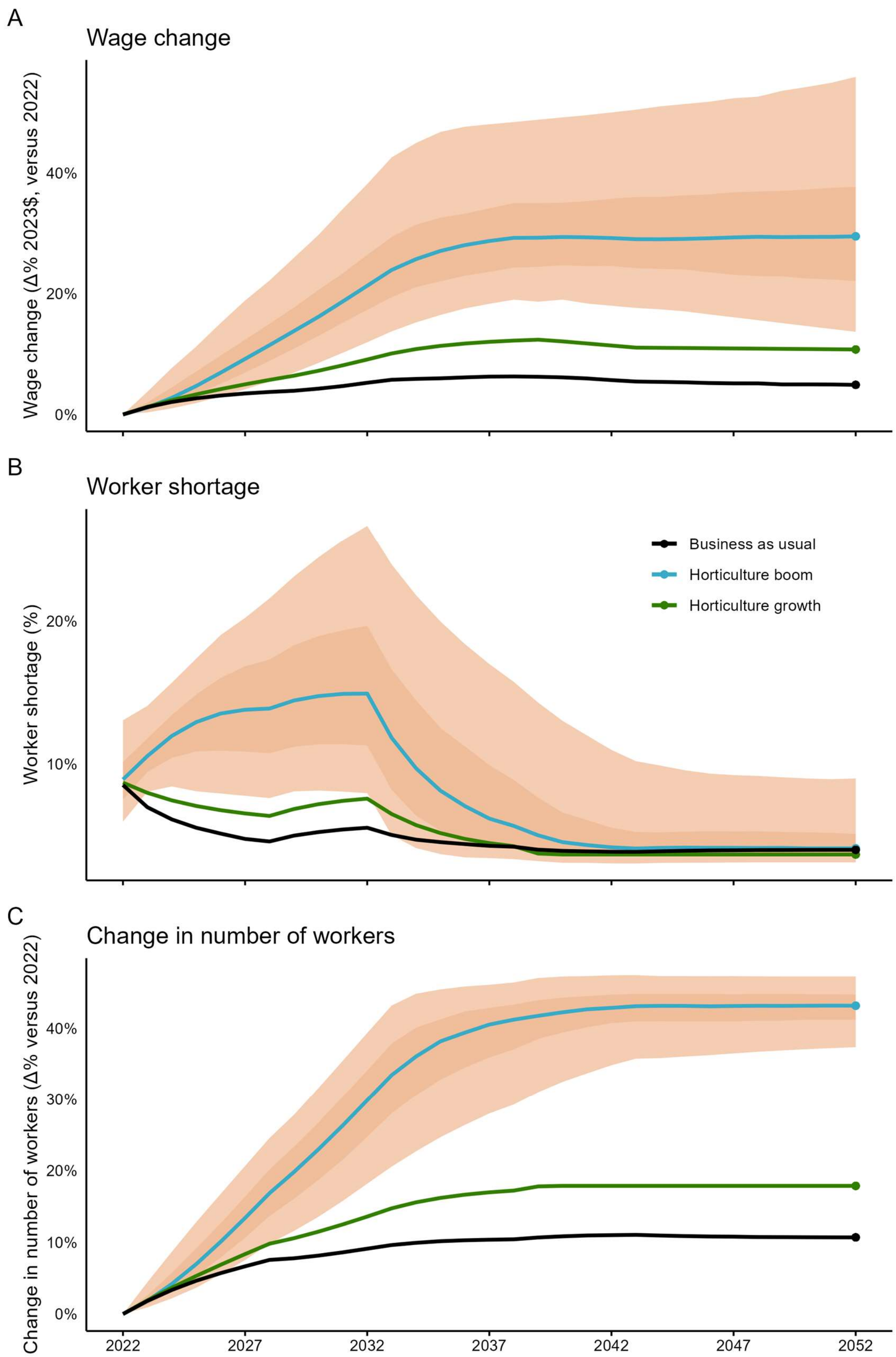
Tripling the rate of increase in demand in the 'High demand increase' scenario causes all outcomes to change substantially versus BAU. The change in wages is approximately three times higher by the end of the simulation versus BAU, the initial shortage persists for much longer, and the number of additional workers is more than double.

The 'Flexible labour market' scenario, which makes assumptions that either reduce worker requirements or make vacancies easier to fill, shows wage decreases over the simulation period, the initial shortage essentially going to the minimum over the course of just a few years, and the number of additional workers being slightly more than half that of BAU.

Case study results

This section analyses the Northland case study: first looking at the 'Horticulture growth' and 'Horticulture boom' scenarios where the focus is on converting land into higher value land uses, and second looking at how to address the consequential uptick in worker demand through two different strategies - net migration, and large-scale conversion of pastoral land to forest (native, carbon farming, or commercial forest).

Figure 5: Model results from the Northland case study examining the impact of large horticultural expansion.



Panel A: Real wage change as a percent change versus 2022. Panel B: Worker shortage change as a percentage of the number of workers. Panel C: Change in number of workers as a percent change verses 2022. 'Horticulture growth' increases demand versus BAU based on the land area enabled by two real-life water storage projects; approximately 2x the increase in BAU. 'Horticulture boom' increases the additional demand versus 'Horticulture growth' by five times (approximately 6x the increase in BAU). Uncertainty bands are included for the 'Horticulture boom' scenario with the inner band being the interquartile range and the outer band being the 5th to 95th percentile range across Monte Carlo simulations.

Figure 5 shows our outcomes for the Northland region case study. The results are qualitatively similar to the results for the 'High demand increase' scenario, with both growth scenarios showing higher wages, shortages, and workforces versus BAU.

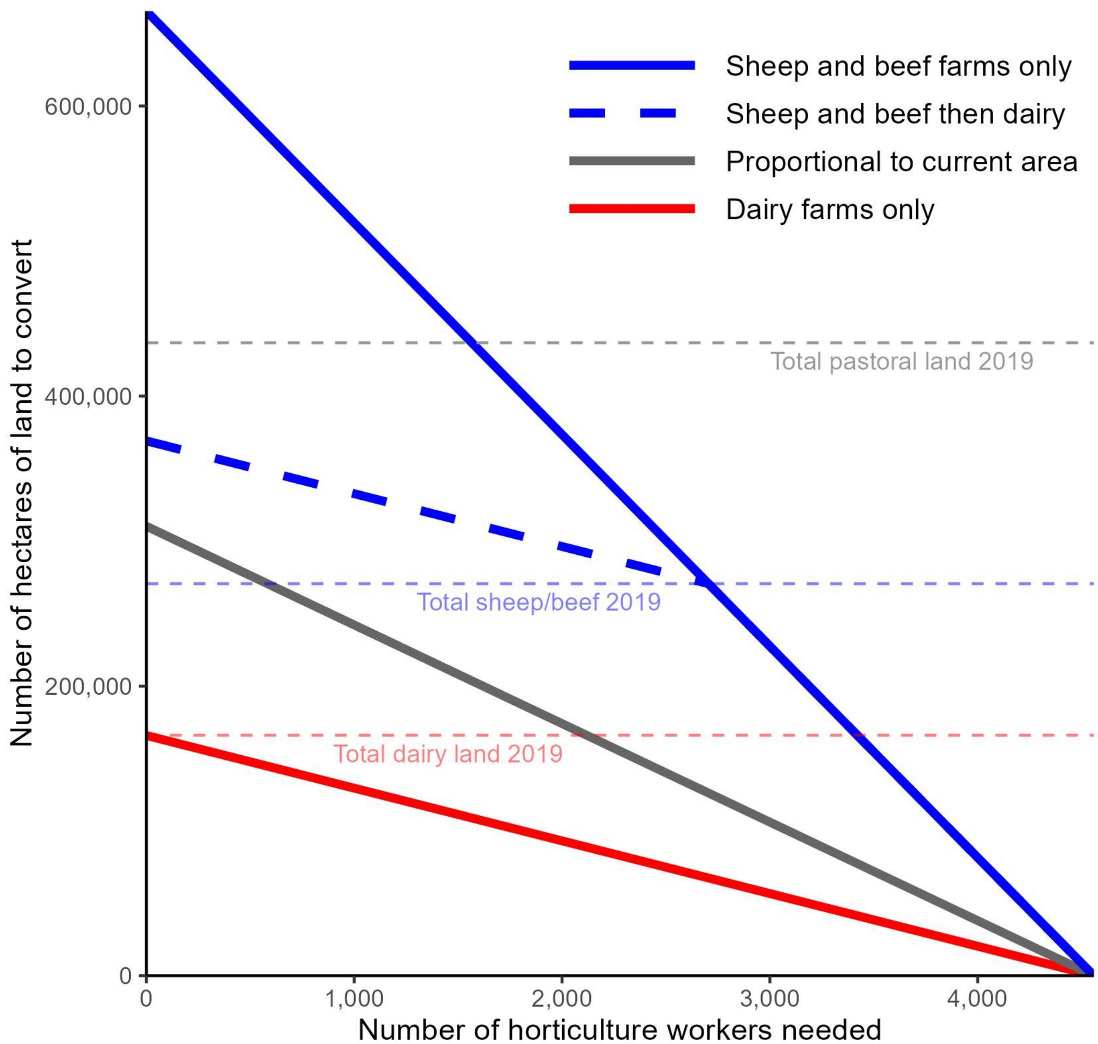
Part of the aim of this case study is to investigate the feasibility of these large-scale land use change scenarios. The key questions we would ask to assess feasibility are: 'Are simulated wage changes implausibly large?' and 'Do shortages ever grow to implausibly high rates?'. If our model is simulating these outcomes, we have evidence that our inputs are not reasonable.

The 'Horticulture growth' scenario appears to be feasible, with the peak shortage being the current period shortage; shortages never grow to a worse level than now. Real wages in this scenario grow around 10% over 30 years which is far from implausible for any sector. These results provide no evidence for concern for the real-life expansions that will be enabled by the Otawere and Kaipara water storage projects (the basis for the 'Horticulture growth' scenario).

However, the more ambitious 'Horticulture boom' scenario produces much less plausible results. The peak shortage grows to a level that would imply that for every 6 food-and-fibre jobs we would see 1 vacancy in Northland. We don't see this level of shortage in any region today and believe that expanding operations would simply need to delay work under these circumstances. Likewise, we simulate approximately a 30% change in real wages over 30 years. While this is not impossible, we find this outcome highly unlikely and again believe that if this level of demand were to materialise, some other outcome would have to change, such as a delay in land conversion.

Given that our results suggest that the 'Horticulture boom' scenario is unlikely to be feasible, the remainder of this paper explores the feasibility of other strategies to meet the increased demand, in addition to high wage increases and long shortages (Figure 5) and delaying expansion (not modelled).

Figure 6: Feasible combinations of hectares of land converted to forest and net migration to meet demand for the 'Horticulture boom' scenario.



This figure shows the feasible combinations of the number of hectares of pastoral agriculture converted to forestry and the number of new horticulture workers from higher net migration. The solid red line assumes only dairy land is converted to forest. The solid blue line assumes only sheep/beef land is converted to forest. The solid grey line assumes both land types are converted proportionately to current area. The dashed blue line assumes sheep/beef is converted to forest before dairy. Horizontal dashed lines indicate the total current land area for dairy land (red), sheep/beef land (blue) and all pastoral agriculture (grey). Total number of workers required (4,559) is the extra workers required in the 'Horticulture boom' scenario versus the 'Horticulture growth' scenario. If a combination of these strategies is successful (a point on one of these lines, our model would suggest wage changes and shortages similar to those for the 'Horticulture growth' scenario and workforce size changes similar to the 'Horticulture boom' scenario.

Part of the aim of this case study is to investigate the feasibility of these large-scale land use change scenarios. The key questions we would ask to assess feasibility are: 'Are simulated wage changes implausibly large?’ and ‘Do shortages ever grow to implausibly high rates?’. If our model is simulating these outcomes, we have evidence that our inputs are not reasonable.

The ‘Horticulture growth’ scenario appears to be feasible, with the peak shortage being the current period shortage; shortages never grow to a worse level than now. Real wages in this scenario grow around 10% over 30 years which is far from implausible for any sector. These results provide no evidence for concern for the real-life expansions that will be enabled by the Otawere and Kaipara water storage projects (the basis for the ‘Horticulture growth’ scenario).

However, the more ambitious ‘Horticulture boom’ scenario produces much less plausible results. The peak shortage grows to a level that would imply that for every 6 food-and-fibre jobs we would see 1 vacancy in Northland. We don’t see this level of shortage in any region today and believe that expanding operations would simply need to delay work under these circumstances. Likewise, we simulate approximately a 30% change in real wages over 30 years. While this is not impossible, we find this outcome highly unlikely and again believe that if this level of demand were to materialise, some other outcome would have to change, such as a delay in land conversion.

Given that our results suggest that the ‘Horticulture boom’ scenario is unlikely to be feasible, the remainder of this paper explores the feasibility of other strategies to meet the increased demand, in addition to high wage increases and long shortages (Figure 5) and delaying expansion (not modelled).

Figure 6 shows the combinations of land conversion from pasture to forest (in ha) and the number of new workers from net migration that would meet the demand in the ‘Horticulture boom’ scenario, using the ‘Horticulture growth’ scenario as a baseline. If Northland were to implement a strategy, for example, where 2000 workers were attracted via increased net migration and 190,000 hectares of pastoral land (a mix of dairy and sheep/beef) were converted to forest (encouraging approximately a further 4,559 into the horticultural workforce), the scale of land conversion imagined in the ‘Horticulture boom’ scenario would be achievable with similar wage changes and shortages as in the ‘Horticulture growth’ scenario (Figure 5).

Thus, Part of the aim of this case study is to investigate the feasibility of these large-scale land use change scenarios. The key questions we would ask to assess feasibility are: ‘Are simulated wage changes implausibly large?’ and ‘Do shortages ever grow to implausibly high rates?’. If our model is simulating these outcomes, we have evidence that our inputs are not reasonable.

The ‘Horticulture growth’ scenario appears to be feasible, with the peak shortage being the current period shortage; shortages never grow to a worse level than now. Real wages in this scenario grow around 10% over 30 years which is far from implausible for any sector. These results provide no evidence for concern for the real-life expansions that will be enabled by the Otawere and Kaipara water storage projects (the basis for the ‘Horticulture growth’ scenario).

However, the more ambitious ‘Horticulture boom’ scenario produces much less plausible results. The peak shortage grows to a level that would imply that for every 6 food-and-fibre jobs we would see 1 vacancy in Northland. We don’t see this level of shortage in any region today and believe that expanding operations would simply need to delay work under these circumstances. Likewise, we simulate approximately a 30% change in real wages over 30 years. While this is not impossible, we find this outcome highly unlikely and again believe that if this level of demand were to materialise, some other outcome would have to change, such as a delay in land conversion.

Given that our results suggest that the 'Horticulture boom' scenario is unlikely to be feasible, the remainder of this paper explores the feasibility of other strategies to meet the increased demand, in addition to high wage increases and long shortages (Figure 5) and delaying expansion (not modelled).

Figure 6 aims to present the available options to achieve large-scale land-use change using a mixture of population growth strategies and land conversion to forestry / retirement. As we did relating to the standard 'strategy' in economics of increasing wages, we can assess how realistic these population and conversion to forestry strategies might be.

We find that both the scale of required land conversion and the scale of population growth were they to occur, would represent very large deviations from expectations. For example, we would need to assume a population growth rate 7 standard deviations above the mean that we assume in our model to add 4,559 workers. Likewise, the rate of conversion out of pastoral land would be far higher than historical rates. Pastoral land declined in Northland by around 1% per year from 2012 to 2017; were this conversion to occur over ten years, say, we would require pastoral land to decline by approximately 8.5% per year (using the sheep/beef, then dairy option). Sheep/beef farms have much lower capital requirements, so are much less locked into the land use compared to dairy farms. If the burden were shared equally between the two strategies, the population would need to grow at 3.5 standard deviations above the mean and pastoral land would need to decline 4.25 times faster than recent trends; this scenario also appears unlikely.

Discussion

There are several key messages from our results: first, we find that our model projects a range of outcomes across regions (Figure 3), with some regions projected to have difficulty expanding the workforce (i.e., persistent high shortages, Figure 3B) under baseline settings, and others having relatively easy expansions (shortages declining, Figure 3B).

Second, our quantified sources of uncertainty (population growth, technological change, initial shortage, shortage reduction rate, minimum shortage, and labour supply elasticity) imply that wide ranges are possible for our outcomes for a given region, especially for wages and shortages (Figure 4).

Finally, our Northland case study shows that the relatively moderate expansion implied by the major water projects in progress ('Horticulture growth' scenario) will put pressure on the workforce with our central result suggesting that this expansion scenario would cause the current shortage to roughly persist, rather than decline, over our expansion period (Figure 5B, 2022-2032, 'Horticulture growth'). Additionally, the large hypothetical expansion imagined in the 'Horticulture boom' scenario would put significant additional pressure on the workforce, with the projected shortage increasing to a peak of 15% (Figure 5B). In our view, a shortage of 15% is not feasible and if stakeholders have this hypothetical level of ambition (Our Land and Water 2018), some aspect of the system would need to differ from our assumptions.

In our Northland case study, we analyse two ways the future may differ from our standard assumptions, higher population growth and a larger available workforce pool due to land conversion from pasture to forest. In both cases, we find that the workforce expansion required would represent a drastic change from status quo expectations. Our model would say that population growth would have to be 7 standard deviations above the mean of the Statistics New Zealand forecast distribution or land conversion out of pasture would have to be approximately eight times higher than recent rates of conversion out of pastoral land.

Our model implicitly assumes that the proportion of the population in the food & fibre workforce remains the same (given fixed wages), so if the industry can attract a higher proportion of the population the overall population would not need to grow by as much. However, attracting workers into food and fibre is difficult, with some research suggesting that the cost of attracting people is very high (Scarlatti 2023a). International immigration settings could likely be changed to achieve this level of workforce growth, if the new settings specifically incentivise entering the food-and-fibre industry.

One potential pathway for population growth is much higher return migration of Māori from other regions of New Zealand and Australia. Connection to place is core to a Māori worldview, and several stakeholders believe that with increased economic opportunities in their ancestral home, many Māori will return. Many of the enterprises considering horticultural expansions today are Māori businesses under collective ownership, and contributing to these enterprises may also be a driver to attract Māori into this industry. This pathway provides some cause for optimism regarding population growth making large-scale horticultural expansion feasible.

Regarding the move from pastoral agriculture to forestry, if this transition were to accelerate, a key driver would have to be policy support, primarily via emissions trading scheme (ETS) credits and biodiversity subsidies. The current ETS settings may drive significant afforestation, especially on marginal sheep/beef land. However, the settings in the ETS have been modified substantially over recent years, often associated with large price increases or decreases and GHG reduction policy preferences are not shared across political parties. The market uncertainty that this policy uncertainty causes will be a significant barrier to conversion to carbon farming.

All of these results relating to our 'Horticulture boom' scenario importantly assume the enabling conditions that would drive this level of expansion, the most significant of which are capital availability (for water storage projects, planting, and other setup costs), land availability in the areas with water availability, and the availability of horticultural management skills in the market.

Capital availability for these types of investments is certainly a material barrier, though capital could come into the region via treaty settlements, government investment, or increased awareness of the opportunities in private capital markets. Land availability may be an issue, most pastoral farmers would not have the skillset to switch from pastoral farming to horticulture themselves (Clark et al. 2007) and may prefer to hold onto land rather than sell or lease to a prospective horticulturalist. Horticultural management skills are already scarce in the workforce, so training initiatives would have to fill this skills gap.

Conclusion

Building a larger workforce will be a significant barrier to the ambition of labour-intensive land-use change, requiring significant wage increases, population growth, or land conversion to forestry to be feasible. While our analysis suggests that large-scale land use change is unlikely to be feasible, if it is to occur, it will require clear investment signals, including clear policy support for enabling conditions that the private market does not provide.

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