Map of the small-scale forest estate of New Zealand

Bruce Manley, Justin Morgenroth and Cong Xu

Abstract

From 2015 to 2021, final-year Bachelor of Forestry Science (BForSc) students at the University of Canterbury have developed, region by region, a map of the small-scale forest estate in New Zealand. Forest boundaries were mapped in a geographic information system (GIS), based on visual interpretation of aerial photography and satellite imagery. It was found that the mapped area is less than the National Exotic Forest Description (NEFD) estimate of area in eight wood supply regions and exceeds the NEFD area in the other four regions. The total nationwide mapped area is over 90,000 ha less than the NEFD area. The level of NEFD over-estimation is substantial for Central North Island, Canterbury, East Coast, Hawke's Bay and Southland.

The map of the small-scale estate allows the distribution of small-scale forest attributes to be explored, including site productivity (site index and 300 index) and attributes that affect delivered wood cost (slope, distance to public road, distance to port). If combined with LiDAR data, where available, it is also possible to estimate age and forest structure for the small-scale estate.

The study confirms the urgent need for an accurate and up-to-date spatial database of New Zealand's plantation forests. Not only would this provide accurate estimates of plantation area for wood availability forecasting, it would also enable detailed transportation and logistics planning, as well as quantification of the potential wood supply within specified distances from current and potential wood processing sites.

Introduction

New Zealand's small-scale plantation forest estate has become increasingly important for wood production as the large areas of land afforested in the 1990s matures. The Ministry for Primary Industries' Wood Availability Forecasts (WAFs) indicate that, 'For radiata pine, the large-scale owners' forests are able to supply an annual volume of around 19 to 22 million m^3 of logs. … From 2020, the potential wood available from the small-scale owners' forests increases to around 15 million m^3 per annum through to 2035' (MPI, 2016).

However, there is uncertainty about the actual area of the small-scale estate. The 2020 National Exotic Forest Description (NEFD) survey was sent out to all known forest owners with at least 40 ha of plantation forest (NEFD, 2020). This survey accounts for 1,380,000 ha. There is an additional 12,000 ha of previously surveyed resource that is less than 40 ha, plus 67,000 ha derived from a survey of small-scale forest growers carried out in 2004. The final 203,000 ha of area in the NEFD is imputation of new planting in 1992 to 2006. For these years additional areas, not directly captured in the NEFD surveys, were estimated based on annual nursery surveys that measured the sales of planting stock. Imputation was stopped after 2006 because of the low new land planting rate.

For 1992 to 2006, the total number of seedlings sold was used to estimate the total area of planting each year and, by subtracting the area of replanting, the area of new planting was estimated. The national new planting adjustment was calculated by subtracting the new planting area captured in the NEFD survey from this estimate of the total area of new planting. The national new planting adjustment for each year was distributed into territorial authorities (TAs) using the proportions indicated from the new planting collected in the NEFD survey (MPI, 2020). Consequently, there are questions about the estimated total area of the small-scale estate in New Zealand and its distribution by TA.

Since 2015, Management Case Study, the capstone course taken by all BForSc students at the University of Canterbury, has focused on improving our knowledge of the small-scale forest estate. Each year the small-scale estate in one or a number of wood supply regions has been mapped:

- 2015 Canterbury
- 2016 Otago and Southland
- 2017 Southern North Island
- 2018 Hawke's Bay and East Coast
- 2019 Marlborough, Nelson and West Coast
- 2020 Central North Island
- 2021 Northland (initial mapping done in 2020).

Results for the earlier years have been published. Manley et al. (2017) summarises results for Canterbury, Otago and Southland, while Manley et al. (2020) covers East Coast, Hawke's Bay and Southern North Island. The purpose here is to provide a summary of results for all regions, in particular:

- What is the area of the small-scale estate in each wood supply region?
- How do estimates of area compare to those of the NEFD?
- What are key attributes of the small-scale estate?

Methods

The definition of large-scale owners used here is the same as used in the 2014 MPI WAFs, i.e. large-scale owners are those owners that provided harvest intentions for the WAFs. Consequently, there was no

defined size cut-off – rather a set of large-scale owners was defined for each wood supply region. All other owners in each region were deemed to be small-scale owners. The same set of large-scale owners has been used for mapping the small-scale estate and for determining the NEFD estimates for each region.

The general approach was that the small-scale estate was mapped and the area calculated and compared with NEFD estimates. The small-scale estate was characterised by slope, Euclidean distance to public road and network distance to nearest port. Finally, productivity estimates were obtained.

Small-scale forest area mapping

Orthorectified aerial photography (resolution 30–50 cm) was primarily used for forest boundary mapping. All aerial photos were downloaded or ordered from the Land Information New Zealand Data Service. Sentinel imagery acquired in summer 2018–2019 (CNI and Northland) or 2016–2017 (all other regions) were provided by the Ministry for the Environment and used to update the status of forests, i.e. whether they were still stocked or were harvested.

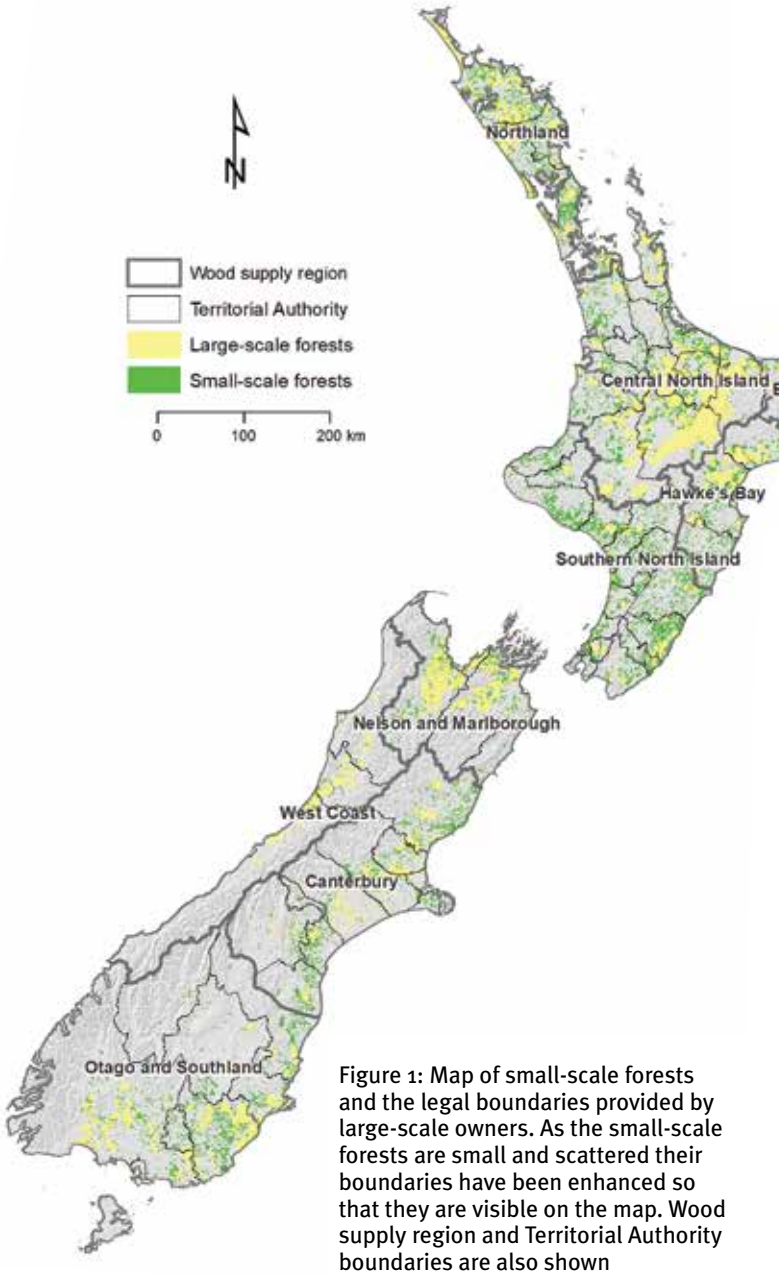

Figure 1: Map of small-scale forests and the legal boundaries provided by large-scale owners. As the small-scale forests are small and scattered their boundaries have been enhanced so that they are visible on the map. Wood supply region and Territorial Authority boundaries are also shown

A mask was applied to the study areas to exclude large-scale plantation forests (with boundaries provided by forest owners – the same set of large-scale owners was used as for the MPI WAFs). Small-scale forests on all land outside this mask, including harvested area awaiting restocking, were systematically mapped in ArcGIS using the following rules:

- The area had to be over 1 ha and greater than 30 m wide, but the 1 ha rule was relaxed when there were contiguous small blocks that added to over 1 ha
- Gaps over 0.1 ha were excluded from the forest area polygons
- All mapping was done at a scale of 1:4,000 or greater.

Prior to mapping, students received training on how to identify plantation forests in aerial imagery, and were also taught best practices for forest boundary mapping. Quality control of mapping was undertaken. Line-work for all polygons mapped by students was verified, and checks were made to ensure that all small-scale plantations had been included and no other land covers had been inadvertently included as small-scale plantations. These steps ensured forest boundary mapping was accurate and minimised omission and commission errors. Every polygon mapped by the students as well as its classification was independently checked by experienced postgraduate students.

Forest area comparisons

Mapped forest areas, including both stocked area and area awaiting restocking, were compared against NEFD estimates. For the comparison, the total of the NEFD stocked area and area awaiting restocking classes was used. Comparison was done on the basis of wood supply region or sub-region. Three wood supply regions were split into sub-regions:

- Southern North Island into SNI-West and SNI-East based on the Ruahine, Tararua and Remutaka mountain ranges
- Nelson/Marlborough into Nelson and Marlborough
- Otago/Southland into Otago and Southland.

Attributes

For each mapped small-scale forest, the average slope was derived using the 'Zonal Statistics' tool in ArcGIS, with the input of a 25-m Digital Elevation Model developed by Landcare Research. The Euclidean distance between the forest polygon centroid and the nearest public road was calculated using the 'Near' function in ArcGIS. On-road network distance to log export port was

estimated for each mapped forest using the 'Network Analyst' in ArcGIS. The distance between each forest and port was calculated as the sum of the distance to nearest public road and on-road distance. Site productivity for each forest was obtained using the Kimberley et al. (2017) surfaces for site index and 300 index.

Results

Small-scale forest area

Mapped area of the small-scale estate is shown in Figure 1, together with the legal boundaries provided by large-scale owners. Mapped areas are compared with the NEFD area for each wood supply region (or sub-region) in Table 1. The NEFD area is for the latest year available at the time mapping was done. Although there is a lag of up to two years, it is unlikely this made much difference to the reported NEFD area for the small-scale estate.

Given that the mapping has been done over a six-year period the focus should be on the differences for each region (or sub-region) rather than the national totals. The mapped area is less than the NEFD area in eight wood supply regions and exceeds the NEFD area in the other four regions. The level of NEFD over-estimation is substantial for Central North Island, Canterbury, East Coast, Hawke's Bay and Southland. The total mapped area is over 90,000 ha less than the NEFD area.

Table 1: Area of small-scale estate in each wood supply region or sub-region. Mapped areas are compared with NEFD estimates. The Northland area is provisional and awaiting final confirmation

Wood supply region	Year mapped	NEFD as at	Mapped area (ha)	NEFD area (ha)	Difference (ha)
Canterbury	2015	2014	39,864	70,561	−30,697
Otago	2016	2015	41,665	43,519	−1,854
Southland	2016	2015	24,376	32,665	−8,289
SNI-West	2017	2016	75,051	74,676	375
SNI-East	2017	2016	52,721	51,723	998
Hawke's Bay	2018	2016	58,118	66,778	−8,660
East Coast	2018	2016	62,441	75,056	−12,615
Nelson	2019	2017	23,982	22,687	1,295
Marlborough	2019	2017	33,843	35,813	−1,971
West Coast	2019	2017	5,256	6,313	−1,057
CNI	2020	2019	117,446	154,198	−36,751
Northland	2020	2019	82,263[p]	74,878	7,385
Total			**617,026**	**708,867**	−91,841

Attributes

Site productivity

There is a general north-to-south pattern of reducing site productivity (Table 2). East Coast has the highest average site productivity and Canterbury the lowest. Within all regions there is a wide range of site quality (Figures 2 and 3).

Table 2: Average values for key attributes of the small-scale estate in each wood supply region or sub-region. Averages are calculated on an area-weighted basis

Wood supply region	Site index (m)	300 index (m^3/ha/year)	Slope (degrees)	Distance to public road (km)	Distance to port (km)
Northland	31.7	29.3	17	0.20	115
CNI	33.3	31.6	20	0.27	129
East Coast	32.3	35.3	26	0.35	75
Hawke's Bay	32.2	32.9	24	0.14	74
SNI East	30.5	32.2	23	0.44	137
SNI West	31.2	32.2	24	0.24	129
Marlborough	28.6	27.2	31	0.62	61
Nelson	29.8	27.1	27	0.24	67
West Coast	28.4	25.2	7	0.19	239
Canterbury	24.1	24.1	18	0.38	79
Otago	24.6	26.0	17	0.22	100
Southland	24.4	27.0	14	0.41	110
NZ	30.2	30.3	21	0.29	106

Attributes affecting delivered wood cost

Key attributes that affect delivered wood cost and hence harvest viability are:

- Slope (Figure 4), which influences harvesting and roading costs
- Distance to nearest public road (Figure 5), which influences roading cost
- Distance to nearest port (Figure 6), which influences transport cost.

Some patterns are evident in the distribution of these attributes by region:

- The West Coast stands out as having a high proportion of small-scale forest on flat sites, while Marlborough and Nelson have a high proportion on steep sites (Figure 4)
- All regions have a similar distribution for distance to public road. The distributions are skewed with the majority of small-scale forests being less than 0.1 km from a public road but with a small proportion over 1 km from a public road (Figure 5)
- East Coast, Marlborough and Nelson have the majority of small-scale forests within 60 km of a port. Most of the West Coast small-scale forest is at least 240 km from an export log port (Figure 6).

Discussion

The results presented here confirm those of Manley et al. (2017) and Manley et al. (2020). The small-scale estate is an increasingly important component of the New Zealand estate, yet this country's Tier 1 database (the NEFD) does not accurately estimate the total area of the small-scale estate and, by extension, the total New Zealand plantation area.

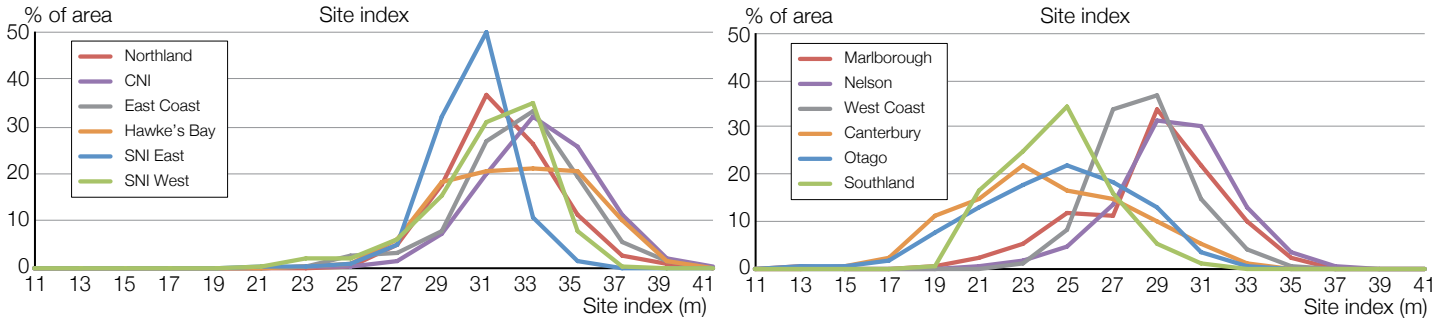

Figure 2: Distribution of site index by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 2 m classes with the site index shown being the mid-point of the class

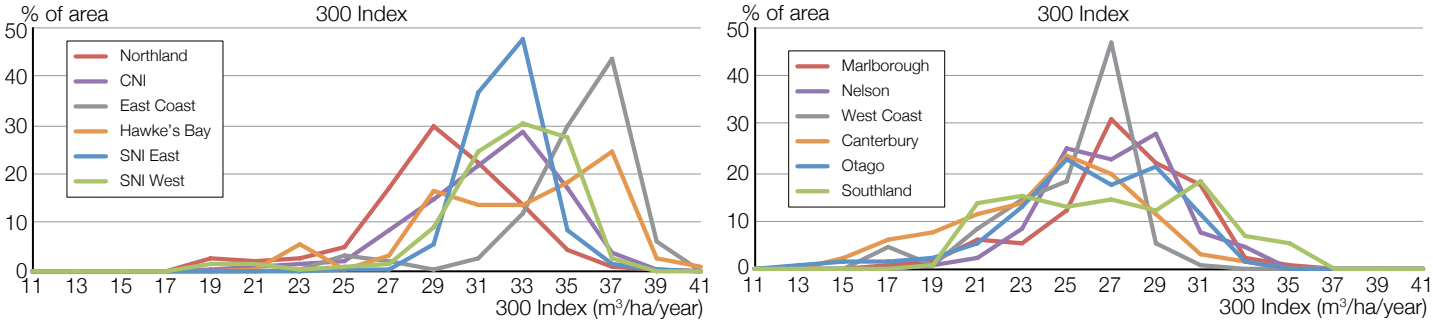

Figure 3: Distribution of 300 index by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 2 m³/ha/year classes with the 300 index shown being the mid-point of the class

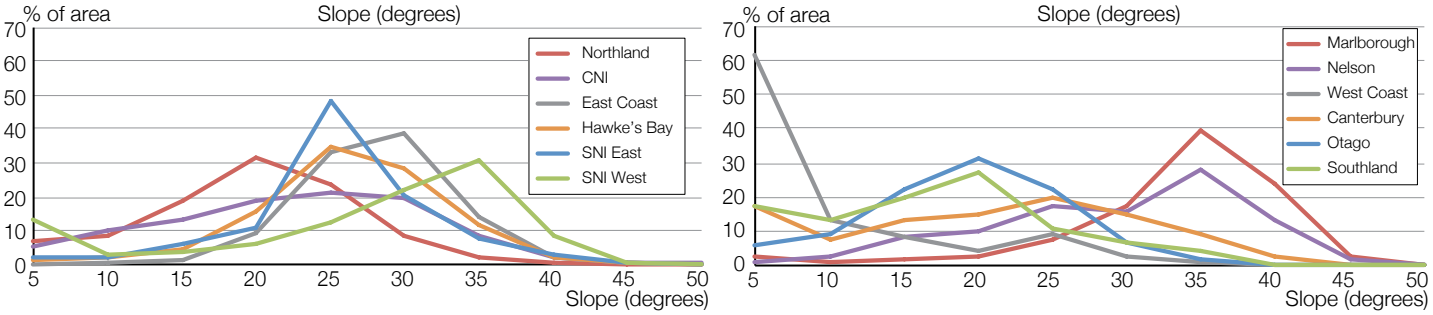

Figure 4: Distribution of slope by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 5 degree classes with the slope shown being the maximum of the class

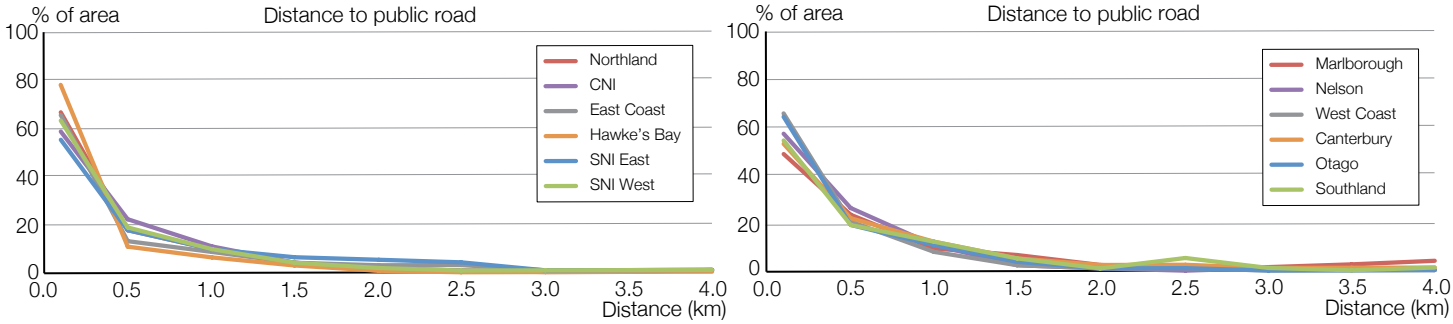

Figure 5: Distribution of distance to public road by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 0.5 km classes (apart from the first class being for distances of 0 to 0.1 km and the second class for 0.1 to 0.5 km) with the distance shown being the maximum of the class

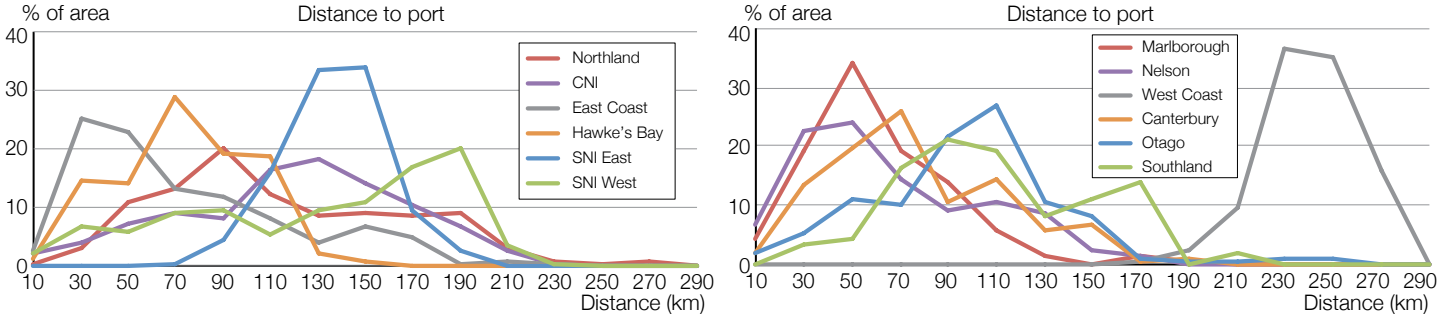

Figure 6: Distribution of distance to port by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 20 km classes with the distance shown being the mid-point of the class

It is evident that, overall, the NEFD over-estimates the area of the small-scale estate, which has implications for a range of applications including wood availability forecasting. Since 2007, the small-scale owner's estate had generally been reduced by 15% for the purpose of wood availability forecasting. This reduction has been applied because small-scale area is often reported on a gross rather than a net stocked area basis. In hindsight, it is apparent that this reduction has been too great for some regions, but too low for others.

The results confirm the need for an accurate spatial database of New Zealand plantations. The case studies undertaken by BForSc students have shown that it is possible to develop an accurate base map of small-scale plantations. Now that this is achieved it is possible to use satellite imagery to update the status of the area, i.e. when it is harvested. With the availability of LiDAR coverage comes the opportunity to estimate stand height.

In Management Case Study in 2021, students are using the canopy height model derived from LiDAR in Northland, in conjunction with the Kimberley et al. (2017) site index layer, to estimate stand age and hence planting year. Using both LiDAR and satellite imagery there is the potential to estimate standing volume (Xu et al., 2018), thus making it possible to forecast the annual wood volumes available from small-scale forests.

Acknowledgements

The basic work reported here was undertaken by final year BForSc students from 2015 to 2021. Their substantial effort and the support of MPI is gratefully acknowledged.

References

Kimberley, M., Watt, M. and Harrison, D. 2017. Characterising Prediction Error as a Function of Scale in Spatial Surfaces of Tree Productivity. *New Zealand Journal of Forestry Science*, 47:19.

Manley, B., Morgenroth, J., Visser, R. and final year BForSc students of 2015 and 2016. 2017. Quantifying the Small-Scale Owners' Estate in Canterbury, Otago and Southland. *New Zealand Journal of Forestry*, 62(3): 24–32.

Manley, B., Morgenroth, J., Xu, C. and final year BForSc students of 2017 and 2018. 2020. Quantifying the Area of the Small-Scale Owners' Estate in East Coast, Hawke's Bay and Southern North Island. *New Zealand Journal of Forestry*, 64(4): 18–26.

Ministry for Primary Industries (MPI). 2016. *Wood Availability Forecasts – New Zealand 2014–2050*. Wellington, NZ: MPI.

Ministry for Primary Industries (MPI). 2020. *National Exotic Forest Description as at 1 April 2020*. Wellington, NZ: MPI.

Xu, C., Manley, B. and Morgenroth, J. 2018. Evaluation of Modelling Approaches in Predicting Forest Volume and Stand Age for Small-Scale Plantation Forests in New Zealand with RapidEye and LiDAR. *International Journal of Applied Earth Observation and Geoinformation*, 73: 386–396.

Bruce Manley is Head of School and Professor of Forest Management at the School of Forestry at the University of Canterbury in Christchurch. Justin Morgenroth is Associate Professor in Geospatial Technologies and Cong (Vega) Xu is WIDE Trust Lecturer in Geospatial Technologies. Corresponding author: bruce.manley@canterbury.ac.nz