

The 2017 Tāne Mahuta Public Lecture: The benefits of urban trees: from the intuitive to the surprising

Dr Geoffrey Donovan¹

I'm presenting this lecture as a visitor to both Tauranga and New Zealand. I'm originally from Yorkshire, England, although my parents are from the USA. Since 2002, I've lived in Portland, Oregon, where I've become increasingly interested in the benefits that urban trees provide. The reason for this interest is that the majority of us live in cities, so in our day-to-day lives, we mostly interact with urban trees.

I began my urban-forestry research by looking at the effect of trees on house price. We found that a house in Portland, Oregon, with a street tree in front of it sold for US\$7,130 more than a comparable house without a tree (Donovan and Butry, 2010). Street trees are trees in the grassy median between the road and the sidewalk (Fig. 1).

However, we also found that the benefits of street trees spill over to neighbouring houses. A street tree increased the sale price of homes within 30.5 m by a total of US\$12,828.

This makes trees odd from an economic viewpoint. When we buy most of the things we use in our daily lives – a cup of coffee, for example – we bear all the costs, but we also receive all the benefits. If I sit down next to you and drink a cup of coffee, you won't feel any more alert. Trees are different. If I plant a tree in front of my house, I bear all the costs, but the people around me receive some of the benefits. In this case, the neighbours get almost two thirds of the benefits for free.

From an economic point of view, these spill-over benefits are a problem, because we know that free markets do a poor job of allocating resources to assets with spill-over benefits. Specifically, markets allocate too few resources to things like trees that have these spill-over benefits.

There are a number of possible remedies to this underinvestment in trees including providing a subsidy to plant trees or having city councils take on the cost of tree maintenance.

These solutions imply that trees are community assets: they benefit the entire community, so the community needs to also bear some of the costs. This idea that trees are a community asset is something that I'm going to be returning to throughout this lecture.

I have conducted several other studies on benefits of urban trees. For example, in a study in Sacramento, California, we found that trees to the west and south sides of a house can reduce summertime cooling costs (Donovan and Butry, 2009). Again, we uncovered a spill-over benefit: if you have a large tree in your garden, the shade doesn't stop at your fence line. You pay for your tree, and your neighbour ends up with a cool house. I'm not going to present this study in detail here, because summertime cooling costs are not a major concern in most regions of New Zealand.

Instead, I'm going to discuss more fully a study we conducted investigating the effect of trees on crime (Donovan and Prestemon, 2012). This also marks the point where I started to wander off the mainstream path. Trees and house price makes sense, but trees and crime may seem like an odd thing for an economist like me to study. However, at least crime is interesting. In contrast, electricity use is important but a little dull (nobody writes utilities novels, after all!).

The sample for the trees and crime study was 2,813 single-family homes in Portland. We visited each one and collected data on a wide range of factors including:

- Trees and other vegetation
- Barriers and visibility
- Condition
- Street lights, garages.



Fig. 1 Street trees in Portland, Oregon. Photo: Geoffrey Donovan.

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We found that street trees (those in the public right of way) were generally associated with lower crime rates. However, the relationship between trees in people's gardens and crime was mixed. Taller trees (more than 13 m tall) were also associated with lower crime, because the crown clears the top of the first floor window and does not obstruct views from the ground level. In contrast, smaller trees were associated with higher crime rates. It's easy to see how smaller trees might increase crime through view obstruction. The positive association between small trees and crime was consistent with other study findings. For example, we found that view-obstructing barriers, like tall fences and poor street lighting were also associated with higher crime. Therefore, it is important to avoid planting trees in places that block views and to prune existing trees to minimise view obstruction.

Having completed a study of trees and crime, I decided to wander off the orthodox path even further and look at the relationship between trees and public health. Quantifying the health benefits of trees isn't at all straightforward, or it would have been done a long time ago.

Unfortunately, it's impractical to use a randomised controlled trial (RCT) to investigate the health benefits of trees (RCTs are the standard approach employed by medical researchers to determine whether a new drug works, for example). An RCT involves the following general steps:

- Recruit an appropriate sample – people suffering from a disease, for example
- Randomly split the sample in half
- Give half the group the treatment (the new drug, in this case) and the other half a placebo
- Monitor both groups
- Statistically analyse the results.

It's impractical to recruit a sample of sick people and plant trees outside half these people's houses, as the trees would take too long to grow. If RCT's are impractical for our work, how can we investigate the relationship between trees and health? We can use observational techniques. We don't impose a treatment, as they do in a clinical trial, but we simply look at areas with

more trees and see whether people living there are healthier compared to people living in areas with fewer trees.

Sounds simple enough, right? Let's follow the health of two people for example. One has a tree in their yard and one doesn't. The person without the tree dies, so does that mean trees are good for you? Obviously not, as the people could be different in other important ways, so it's impossible to isolate the impact of the tree. Ideally, we'd look at two identical people, but that's rarely possible. Therefore, we use statistical techniques to control for differences. Observational techniques are more practical for studying the relationship between trees and health than RCT's, but, unlike RCT's, they cannot prove causal relationships.

Let's look at an observational study I did on the relationship between trees and health. Specifically, we quantified the relationship between trees and birth outcomes in my home town of Portland, Oregon (Donovan et al., 2011). In this study, we chose birth outcomes for a number of pragmatic reasons:

- There is a statutory requirement to report births, so the data are reasonably good.
- There is a plausible story linking trees and health. For example, we know that trees can absorb air pollution and reduce people's stress, and we know that air pollution and stress are risk factors for poor birth outcomes.
- Pregnancies last nine months, so with this relatively short time-frame it's easier to quantify a woman's exposure to the natural environment compared to diseases like heart disease or cancer which tend to be longer term.

We sampled all singleton live births in Portland during 2006 and 2007. We restricted our analysis to women living in single-family homes (n = 5,696).

We looked at underweight births (<10th percentile based on gestational age and gender) and preterm births (<37 weeks). Both are major causes of neonatal and infant mortality as well as contributing to health problems in later life.

Demographics were controlled for – controlling means holding these factors constant. We controlled

for previous births, insurance, prenatal care, distance to amenities (public transportation, for example), characteristics of house, crime, and tree cover in 50, 100, and 200 m buffers around the centroid of each house's lot (Fig. 2).

We found that more canopy cover within 50 m of a house and better access to open space were both associated with a reduced chance of an underweight birth but were unrelated to the probability of a preterm birth. This may seem like some statistical oddity, but since we published this paper in 2011, at least 10 other studies have found that exposure to the natural environment is associated with better birth outcomes.

Birth outcomes are obviously very important as they can have a profound effect on costs of medical care, the health trajectory of the baby, and the impacts on the immediate family and wider society.

Despite multiple papers showing a positive association between the natural environment and birth outcomes, all of the studies suffer from the nice-tree-nice-neighbourhood problem: neighbourhoods with more trees tend to be ethnically whiter, wealthier, and better educated, and we know that ethnicity, income, and education are major drivers of health outcomes.

Although I took exhaustive steps to control for these factors, you can never be completely certain that you've captured everything. So, I was fretting about this, and one day (about 5–6 years ago), the anxiety paid off, because I realised that you can flip the question on its head: if trees are good for you, then killing them should be bad for you.

With that in mind, let's imagine a different type of tree experiment. Rather than starting with sick people and planting a tree, let's start with healthy people and cut trees down. This is theoretically a flawless idea, but completely impractical: exactly the type of thing scientists are good at dreaming up. Nobody would volunteer for a study that involved cutting down their healthy trees.

However, what if trees died for other reasons – could we take advantage of that? Possibly, but we'd need a lot of trees to die in a short period of time.

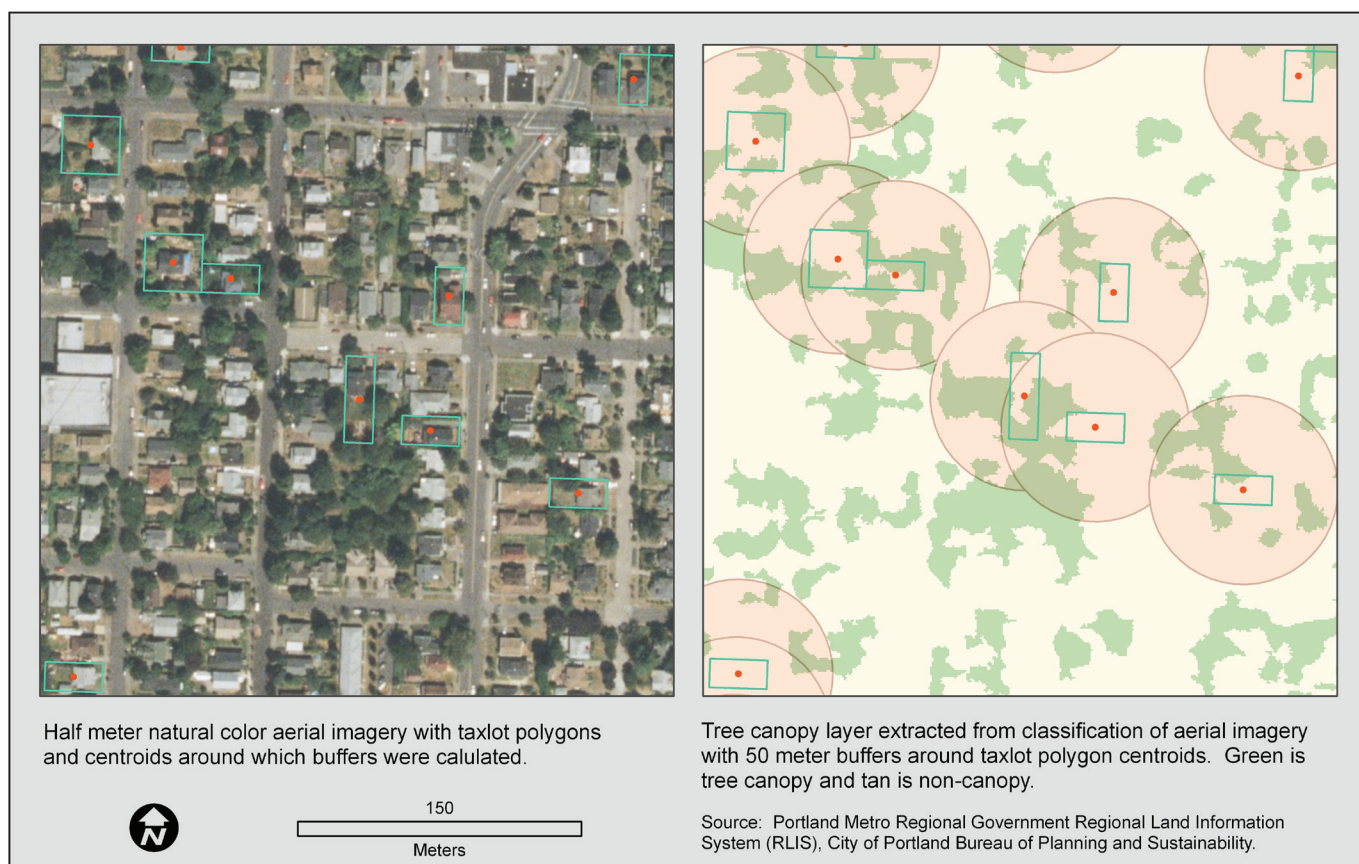


Fig. 2 Left: Half metre natural colour aerial imagery with taxlot polygons and centroids around which buffers were calculated. Right: Tree canopy layer extracted from classification of aerial imagery with 50 m buffers around taxlot polygon centroids. Green represents tree canopy and tan non-canopy. Reproduced from Donovan et al. (2011).

In the USA, an invasive insect pest, the emerald ash borer (*Agrilus planipennis*; Fig. 3) is doing just that.



Fig. 3 The emerald ash borer (*Agrilus planipennis*). Image courtesy of emerald ash borer information network, www.emeraldashborer.info.

Since 2002, the emerald ash borer (EAB) is spreading and has killed hundreds of millions of ash trees in North America (Fig. 4). Trees typically die in 2–5 years (Fig. 5A–B).

We took advantage of EAB by examining the relationship between people's health and the loss of trees (Donovan et al., 2013). This isn't a true Randomised Controlled Trial, as the treatment wasn't under our control (we didn't pick which trees died; the insect did). It's called a natural experiment, and provides stronger evidence of causality than a conventional observational study.

We know that trees are correlated with other drivers of health. However, in the case of EAB, we're no longer looking at the presence of trees at one point in time; we're looking at the loss of trees over time. This is a crucial difference, as the pattern and speed of EAB's spread is far less likely to be correlated with changes in other drivers of health.

Drivers of health such as ethnicity, education, and income don't have similar patterns of change. They don't change that quickly or follow the same pattern of spread. The unique way in which EAB is spread is partly driven by accidental transport. For example, EAB can be transported hundreds of miles in firewood in a matter of hours.

What health outcomes could be affected by the loss of trees? Cardiovascular and lower-respiratory disease (CLRD) were two candidates through mechanisms including reduced air quality and increased stress.

We chose to examine mortality because of good reporting (>99% of deaths in the USA are reported), and collected county-mortality data from

1990–2007 (the most recent National Center for Health Statistics data). We controlled for a wide range of demographics.

We found that EAB was associated with increased mortality, and this effect increased in size and significance as an infestation progressed – so there was a dose-response relationship between tree loss and mortality.

The magnitude of this effect was also greater as infestation progressed and in counties with above-average median household income. This may be because people in wealthier counties have greater access to ash trees, so the death of these trees has a greater impact on them, or that trees provide different benefits in wealthier areas.

Across the 15 states in the study area, EAB was associated with an additional 15,080 cardiovascular-related deaths and 6,113 deaths related to illness of the lower respiratory system.

I'd now like to share with you some of the difficulties I encounter communicating my trees-and-health research to a wider audience.

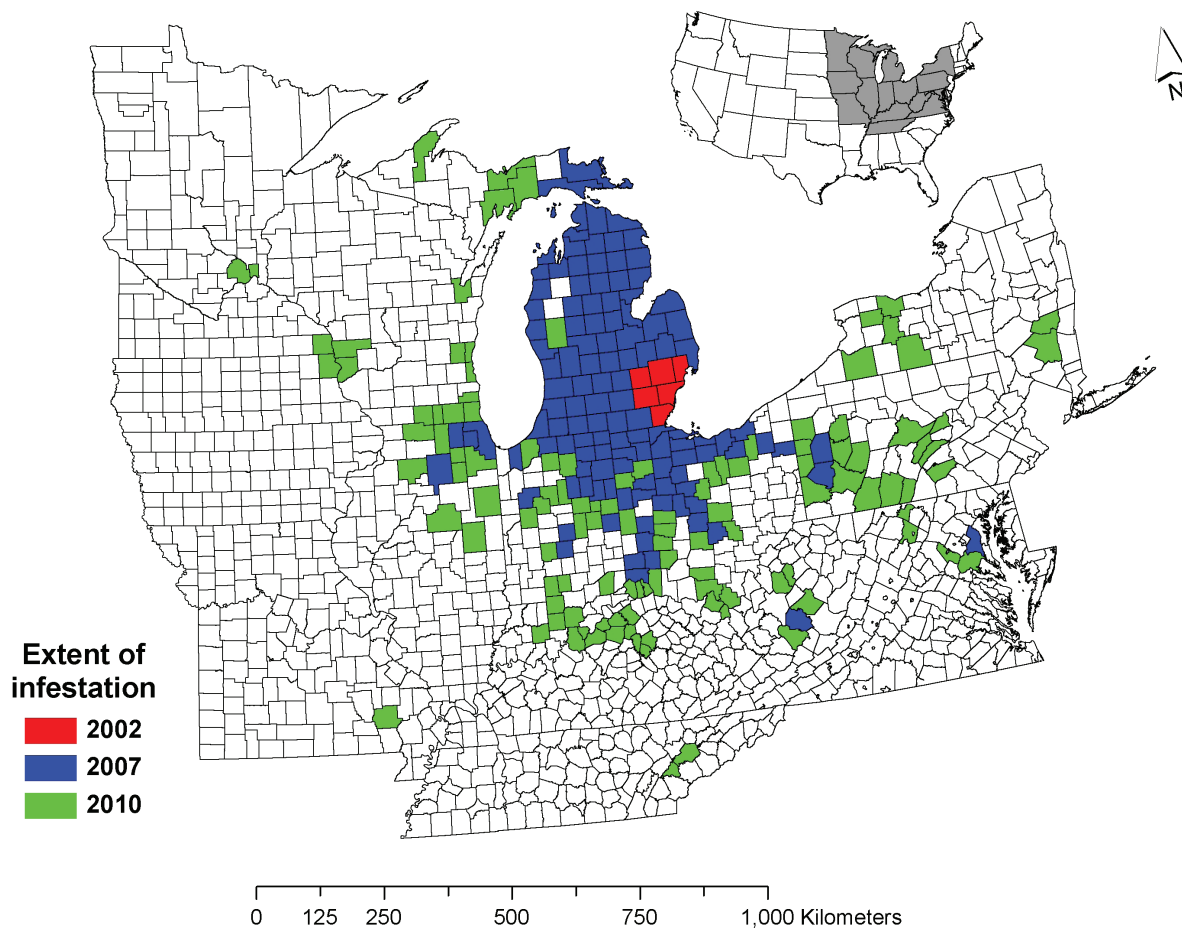


Fig. 4 Detections of emerald ash borer in the USA. Reproduced from Donovan et al. (2013, p. 140).



Fig. 5 The devastating effects of emerald ash borer. **A**, healthy trees, June 2006. **B**, dead and dying trees three years later, in June 2009. Photos: Dan Herms, Ohio State University.

Earlier this year (2017), I was contacted by a reporter from *Wired* magazine, who wanted to interview me about a new invasive insect that was just starting to impact California. This insect is the polyphagous shot-hole borer (*Euwallacea fornicatus*; Fig. 6). It's a beetle that drills into trees and brings with it a pathogenic fungus (*Fusarium euwallacea*), as well as other fungal species that the beetle larvae feed on. This beetle is a serious pest that may kill up to 40% of the urban trees in parts of Southern California.



Fig. 6 Polyphagous shot-hole borer (*Euwallacea fornicatus*). Photo: 'thatkinson' CC BY-NC, <http://xyleborini.myspecies.info/taxonomy/term/483/>

The reporter wanted to know about the likely public-health impacts of the polyphagous shot-hole borer. The reporter was surprisingly well informed – he had actually read my paper on the relationship between trees and human health (Donovan et al., 2013), which is almost unheard of, and was scientifically literate. I spent a long time explaining the nuances of my research, and he seemed to be really getting it.

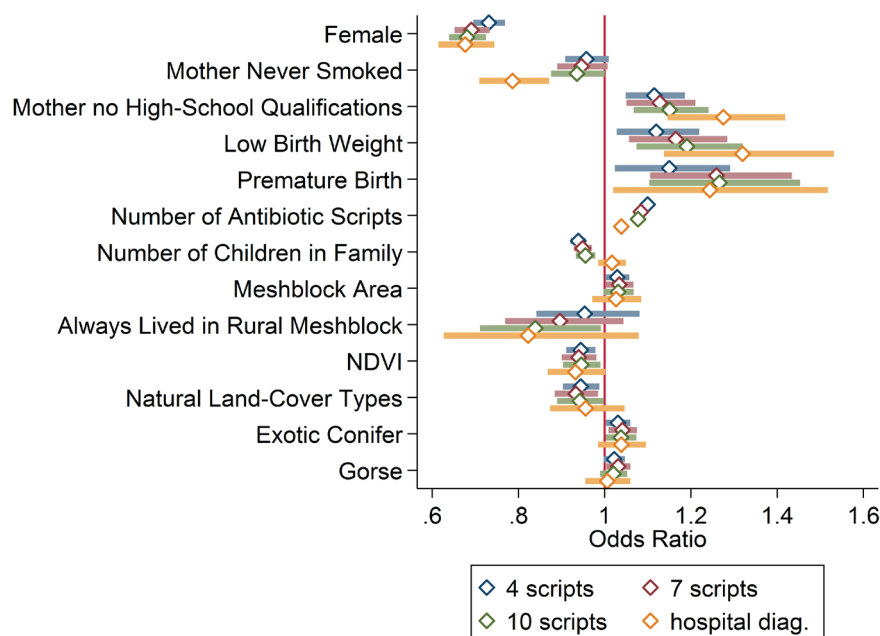


Fig. 7 Odds ratio plots of asthma prevalence among children born in New Zealand in 1998 (n = 39,108). Reproduced from Donovan et al. (2018).

Therefore, when the story came out, I was interested to see what he had to say. The sensationalist headline read “All the trees will die, and then so will you”! My wife, who’s a science writer, laughed uncontrollably for about 10 minutes when she saw it.

So far, all the studies I’ve discussed were conducted in the USA.

However, I have completed some research in New Zealand, which was recently published (Donovan et al., 2018).

This study examined the relationship between the natural environment and childhood asthma. I used data from Statistics New Zealand’s Integrated Data Infrastructure (IDI). This is a huge database of individual-level data on health, births and deaths, education, criminal justice, and immigration. For privacy reasons, you have to access the IDI from a secure data lab within New Zealand, which is the main reason why I have visited this country².

I decided to look at all children born in New Zealand in 1998. The graph I produced (Fig. 7), shows how a range of factors influence the probability that a child develops asthma.

Although this graph may look complicated, there are a few main points to note. If the diamond symbols lie to the left of the vertical red line, then that factor makes it less likely that a child develops asthma. If these four little diamonds are to the right of the red line, then a factor makes it more likely that a child develops asthma.

For example, the graph shows us that girls are less likely to develop asthma than boys (the four diamonds represent four different definitions of asthma, which isn’t important for this explanation). If the horizontal error bars projecting from the diamond symbols don’t touch the red line, then a relationship is statistically significant. In the case of gender, the error bars don’t come close to the red line, so we know that girls are less likely to get asthma than boys, and the relationship is highly statistically significant.

Unsurprisingly, we also see that children with mothers who never smoked are less likely to get asthma. In contrast, children whose mothers have no high-school qualifications are more likely to get asthma, as are those who are born prematurely or underweight.

The next set of results can be interpreted in the context of the hygiene hypothesis. Simply put, the hygiene hypothesis postulates that if we’re kept too clean early in life, then our immune systems don’t develop properly.

With the hygiene hypothesis in mind, let’s look at a series of variables that are related to children’s exposures to allergens and biodiversity.

First, children who receive more antibiotic prescriptions are more likely to get asthma. How could antibiotics be related to the hygiene hypothesis? It’s well established that antibiotics reduce our gut biodiversity.

Conversely, children with more siblings are less likely to get asthma – I don’t think that I need to convince anyone that more kids means more dirt! Living in a rural area is also associated with less asthma, although this was not always statistically significant. Rural areas are certainly more biodiverse.

Finally, children living in greener areas are less likely to get asthma. I measured greenness using a satellite-derived measure called the Normalised Difference Vegetation Index, hence the label NDVI on the graph.

It is interesting to see from these results, that there is further evidence suggesting that people living in greener areas are indeed healthier.

Thank you for your time. I appreciate your willingness to hear about my research and to host me in Tauranga.

References

- Donovan, G.H. (2017). Including public-health benefits of trees in urban-forestry decision making. *Urban Forestry & Urban Greening* 22: 120–123. Available at <https://doi.org/10.1016/j.ufug.2017.02.010>
- Donovan, G.H. and Butry, D.T. (2009). The value of shade: Estimating the effect of urban trees on summertime electricity use. *Energy and Buildings* 41: 662–668. Available at <https://pubag.nal.usda.gov/download/31642/PDF>

² A disclaimer on the use of this data: “Access to the data presented was managed by Statistics New Zealand under strict micro-data access protocols and in accordance with the security and confidentiality provisions of the Statistics Act 1975. The findings are not Official Statistics. The opinions, findings, recommendations, and conclusions expressed are those of the researchers, not Statistics NZ.”

- Donovan, G.H. and Butry, D.T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning* 94: 77–83. Available at www.fs.fed.us/pnw/pubs/journals/pnw_2010_donovan001.pdf
- Donovan, G.H. and Butry, D.T. (2011). The effect of urban trees on the rental price of single-family homes in Portland, Oregon. *Urban Forestry & Urban Greening* 10: 163–168.
- Donovan, G.H.; Butry, D.T.; Michael, Y.L.; Prestemon, J.P.; Liebhold, A.M.; Gatzolis, D.; Mao, M.Y. (2013). The relationship between trees and human health: Evidence from the spread of the emerald ash borer. *American Journal of Preventative Medicine* 44(2): 139–145. Available at www.srs.fs.usda.gov/pubs/ja/2013/ja_2013_donovan_001.pdf
- Donovan, G.; Gatzolis, D.; Longley, I.; Douwes, J. (2018). Vegetation diversity protects against childhood asthma: Results from a large New Zealand birth cohort. *Nature Plants*. DOI: 10.1038/s41477-018-0151-8.
- Donovan, G. and Kirkland, J. (2011). Growing quality of life: Urban trees, birth weight, and crime. Science Findings 137. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 6 p.
- Donovan, G.H.; Michael, Y.L.; Butry, D.T.; Sullivan, A.D.; Chase, J.M. (2011). Urban trees and the risk of poor birth outcomes. *Health & Place* 17: 390–393. Available at www.fs.fed.us/pnw/pubs/journals/pnw_2011_donovan001.pdf
- Donovan, G. and Oliver, M. (2014). Exploring connections between trees and human health. Science Findings 158. Portland OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 6 p.
- Donovan, G.H. and Prestemon, J.P. (2012). The effect of trees on crime in Portland, Oregon. *Environment and Behavior* 44(1): 3–30. Available at www.srs.fs.fed.us/pubs/ja/2012/ja_2012_donovan_001.pdf
- Kondo, M.C.; Han, S-H; Donovan, G.H.; MacDonald, J.M. (2017). The association between urban trees and crime: Evidence from the spread of the emerald ash borer in Cincinnati. *Landscape and Urban Planning* 157: 193–199.
- Wells, G. and Donovan, G. (2010). Calculating the green in green: What's an urban tree worth? Science Findings 126. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 5 p.

Geoffrey Donovan delivered the Tāne Mahuta Public Lecture on 26th October 2017, at the Trinity Wharf Conference Venue in Tauranga.

The Tāne Mahuta Public Lecture Series was first introduced in 2009 by the NZ Notable Trees Trust and the NZ Arboricultural Association (NZArb).

The lectures are named after the most significant tree in New Zealand – the giant Tāne Mahuta (Lord of the Forest) kauri in the Waipoua Forest of Northland.

