The Power of Regrowth:

An assessment of the conservation values of camphor laurel regrowth versus intact native rainforests

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Written for the Woolumbin Land-care and Biodiversity Alliance

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Executive Summary

- Temperatures are increasing all over the world. A major contributor to this warming is the heightened concentration of carbon dioxide (CO_2) in the atmosphere. A notable source of CO_2 emissions is the agricultural industry. Agriculture has historically dominated New South Wales, so the state would have released substantial amounts of CO_2 during the land clearing of farmland.
- The exotic tree camphor laurel can sequester/take up CO_2 in order to build their body structures. Camphor trees have taken over various abandoned farmlands in Tweed Valley, New South Wales. On top of sequestering carbon, they can also help recover rainforests by facilitating the establishment of native rainforest species in the abandoned farmlands' regrowths. Passive restoration (i.e. allowing the camphor tree to naturally sequester carbon and recover rainforests) is advantageous because it does not require significant monetary investment from conservation community groups. However, community groups choose to actively restore (i.e. kill and/or remove camphor trees) camphor regrowth. This is because of the belief that it can prevent other plants from establishing and, by extension, arrest rainforest recovery. Considering how funding is always a major issue for independent community groups, this project recommends that the Wollumbin Land-care and Biodiversity Alliance (WLBA) not utilize active restoration for Tweed Valley's regrowth because camphor trees can sequester carbon and recover the forest at substantially lower costs.
- To convince the WLBA to allow camphor laurel to stay in sites, this project looked at the adult trees, saplings, and seedlings of Tweed Valley's Carool — a site full of camphor regrowth — and Queensland's Lamington National Park — a site full of intact native rainforest. The following key results were found:
    - Some Carool plots have sequestered as much carbon as some Lamington plots despite developing for a shorter amount of time, with much of the sequestered carbon being camphor laurel.
        - Actively killing/removing camphor trees may emit as much CO_2 as clearing an intact native rainforest as the dead trees will decompose.
    - Camphor laurel is not preventing new species from establishing themselves. This is shown by how most sites had multiple species of adult trees, most saplings are non-camphor, and most juvenile trees were able to develop to the sapling stage. Some Carool plots were even able to have as many species as some Lamington plots.
        - Actively killing/removing camphor trees is based on the assumption that camphor laurel will dominate passive restoration sites. This assumption is not valid.
    - Camphor laurel is not preventing the rainforest from recovering, denoted by how most species are native rainforest trees associated with the secondary and mature stage of succession.

        - Actively killing/removing camphor trees is done as camphor trees are feared to arrest rainforest recovery. This reasoning is not valid.
- WLBA should not completely depend on passive restoration because…
    - Some species that were present before agriculture occurred will not return to the site. Assuming Lamington is an accurate representation of Carools' pre-agriculture condition, dozens of species would need to depend on the movements of animals (i.e. a somewhat luck-based process of seed dispersal). New weeds may be dispersed to the regrowth, which was seen in Carool.
    - There is no guarantee that rainforest recovery will happen in a reasonable timeframe. The WLBA may be dissolved by the time recovery happens.
    - Active restoration can address these drawbacks.
- This project recommends a five-part plan that combines passive and active restoration, enhances their advantages, mitigates their disadvantages, and can benefit the WLBA itself. The five components are…
    - Passively keep camphor laurel to reduce and mitigate local CO_2 emissions. Actively removing camphor trees will release substantial amounts of carbon that may be comparable to clearing intact native rainforest.
    - Passively keep camphor laurel to support animal diversity. With camphor regrowth supporting fruit-eating/seed-dispersing animals, preserving their diversity by not actively killing/removing camphor trees will facilitate rainforest recovery at both the regrowth and other sites. If rainforest recovery is allowed to proceed, more carbon can be sequestered.
    - Actively manage weeds to increase the rate of rainforest recovery by reducing competition for establishing native plants.
    - Actively replant rainforest trees that are missing and valued to ensure a return to a condition similar to its pre-agriculture state because not all species will return (e.g. because they must depend on a random factor like wind to disperse their seeds to the regrowth). This component should be kept to a minimum as extensive replanting may inflate the cost of restoration, removing the low-cost aspect of passive restoration.
    - Advertise the carbon-sequestering ability of this strategy to environmentally-conscious companies/people that wish to offset their CO_2 emissions. If enough companies/people pay for the WLBA to preserve camphor trees and compensate for their carbon footprint, the WLBA can make money on top of saving money from not needing to remove camphor laurel. These extra funds can be used to finance this or other restoration projects of the WLBA.
- However, the WLBA is legally required to kill/remove/control camphor laurel regrowth despite all of its values. The WLBA should use Carool as an example for why the law and even other conservationists are not correct as all conservationists should be able to harness the power of the regrowth.

Acknowledgements

Not in order of importance. I would like to thank…

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- James Liu for being a nice normal friend person that helped me see if this report was understandable.

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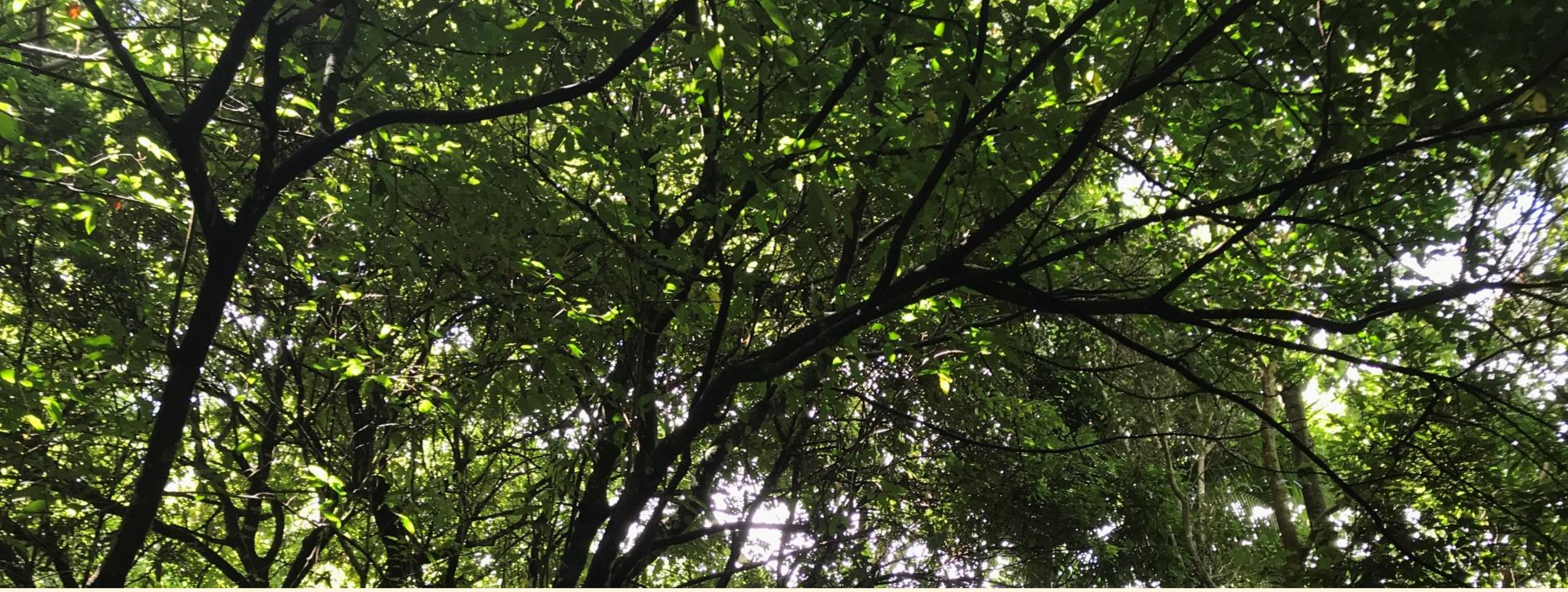
Background Information



Carbon emissions are a global issue

Each year, over 150,000 humans worldwide are estimated to die from factors related to climate change (Patz *et al.*, 2005). Of these factors, one of the most widely-known is the global increase of temperatures, with some studies predicting that the average annual temperature of Australia may rise up to 6.0°C by 2070 (Egan & Mullin, 2012; Hughes, 2003). While this may not seem much, Europe experienced a summer heatwave in 2003 where average temperatures were 3.5°C higher than usual (Patz *et al.*, 2005). Subsequently, 22,000 to 45,000 people died over a period of two weeks from heat stroke or heat stress, demonstrating the need for governments to respond to climate change. With carbon dioxide (CO_2) being a greenhouse gas, and with excess greenhouse gas emissions contributing to global warming, several federal governments have invested effort into curbing CO_2 emissions (Schneider, 1989). Canada, China, and Germany are some of the more prominent governments implementing CO_2 emission reduction schemes, with one major component being the taxation of fossil fuel purchases (Böhringer & Rutherford, 1997; Jotzo & Löschel, 2014; McKitrick, 1997). Yet, while driving cars and other vehicles does pollute the atmosphere, there is another type of activity that contributes even more CO_2: agriculture (FAO, 2016).

Box 1. What is...The Greenhouse Effect?

The sun radiates solar energy that finds its way towards the Earth, providing the planet light. Once there, the planet's surfaces and atmosphere absorb some of the radiation, warming them up. The rest is reflected back to space after bouncing off of the Earth's surfaces, but, along the way, atmosphere absorbs even more energy. This is done namely by greenhouse gases (GHGs) such as carbon dioxide, methane, and fluoride-containing gases. The GHGs subsequently re-emit the energy in various directions. If one such direction is back down to Earth, the planet's surfaces become even warmer. This is the greenhouse effect, and it is not intrinsically problematic. If it were not for this effect, many regions on the planet would be inhospitable. However, if more GHGs are added to the atmosphere via fossil fuel burning and other forms of pollution, more solar energy will be re-emitted back to Earth. This will heat up the planet to a point that is too hot for animal and plant life to survive.

This description is based on Schneider (1989).

Agricultural activity in New South Wales has facilitated an increase in atmospheric CO_2 concentrations

During the agricultural process, there are two major sources of CO_2 emissions: the equipment being utilized and the trees being cleared. For the former, heavy machinery is operated throughout the farming process — from land clearing, to harvesting, and finally to transporting crops (Karjalainen & Asikainen, 1996). For the second source, emissions are based around the fact that carbon is already present inside the body structures of plants (i.e. their biomass) (Fargione *et al.*, 2008). This carbon will be released into the atmosphere as CO_2 if they (and the surrounding soils) are burnt — a popular method for land clearing (Fargione *et al.*, 2008). Even if they are not burnt, there will still be some emission. Once the trees die from being uprooted or directly killed, they will be decomposed by bacteria and fungi in a carbon-releasing process (Fargione *et al.*, 2008).

With over 55.4 millions of hectares of farmland being found in New South Wales, a wide area of rainforests has already been cleared, resulting in high historical CO_2 emissions for the state (ABS, 2018). As such, there is a need for widespread reforestation efforts if conservationists wish to return most of New South Wales' former rainforests to their pre-agriculture state or to even compensate for CO_2 emissions. However, even if a portion of these farms are abandoned, the land may have been too intensively modified for such reforestation. Specifically, farmers may have heavily ploughed the soil and treated it with herbicides, fertilizers, and pesticides (Cramer *et al.*, 2008). As a result, native rainforest plant seeds that find their way to the site may be unable to grow as the soil conditions are too poor (Cramer *et al.*, 2008). However, that does not preclude other tree species from re-colonizing these sites.

Photo 1. A remnant of past farming activity. Such crosses were utilized as a component of pulley systems that made it easier for farmers to transport objects up and down steep slopes.

The exotic camphor laurel has established itself in the Tweed Valley

Camphor laurel (*Cinnamomum camphora*) is an exotic species from China and Japan that has established itself in various cleared sites along the Australian east coast (Biosecurity Queensland, 2016; Head & Muir, 2008). With its high production rate and long viability, camphor laurel seeds have been spread over wide distributions, ensuring that at least some of them find their way to favourable conditions and subsequently establish themselves in new areas (Firth & Ensbey, 2009; Head & Muir, 2008). Such areas would include New South Wales' Tweed Valley. The Valley and the surrounding regions were once full of rainforests before being extensively cleared for mostly dairy farming purposes (Honan, 2017B; Parkes *et al.*, 2012). Eventually, the dairy industry declined, forcing many farmers to abandon their plots and subsequently allowing camphor trees to take over (Honan, 2017A; Parkes *et al.*, 2012). However, despite this dominance, the invasive species can still provide various benefits.

Camphor laurel helps remove CO_2 from the atmosphere at a low cost

When trees are growing, they take out CO_2 from the atmosphere in order to build up their carbon-based body structures/biomass (Nowak & Crane, 2002). This process is called carbon sequestration, and it follows that should conservation community groups in the Tweed Valley want to compensate for historic CO_2 emissions in New South Wales, they can plant new trees and enable this process (Jo & McPherson, 2001). Yet, groups may not have enough resources (both monetary and staff/volunteer-wise) to undertake such projects. Fortunately for them, camphor laurel provides a low-cost opportunity for carbon reduction as it is a secondary rainforest species (i.e. species that occupy rainforest sites that have been modified by humans [Corlett, 1994]). Secondary forest species can establish themselves at a site, start growing, and subsequently sequester carbon all on their own volition (Chazdon *et al.*, 2016). In fact, they are able to reduce atmospheric CO_2 emissions to a higher degree than undisturbed (or "primary") rainforests. This is because the sequestration efforts of primary rainforests are counterbalanced by the amount of decomposition happening due to natural causes (e.g. leaves falling to the forest floor, trees falling from the wind) (Sayer *et al.*, 2011). Thus, when camphor trees colonize new sites and mature, they are actually participating as an important component of global CO_2 removal processes. However, the benefits of camphor laurel are not limited to just that.

Camphor laurel can foster animal diversity and facilitate rainforest recovery

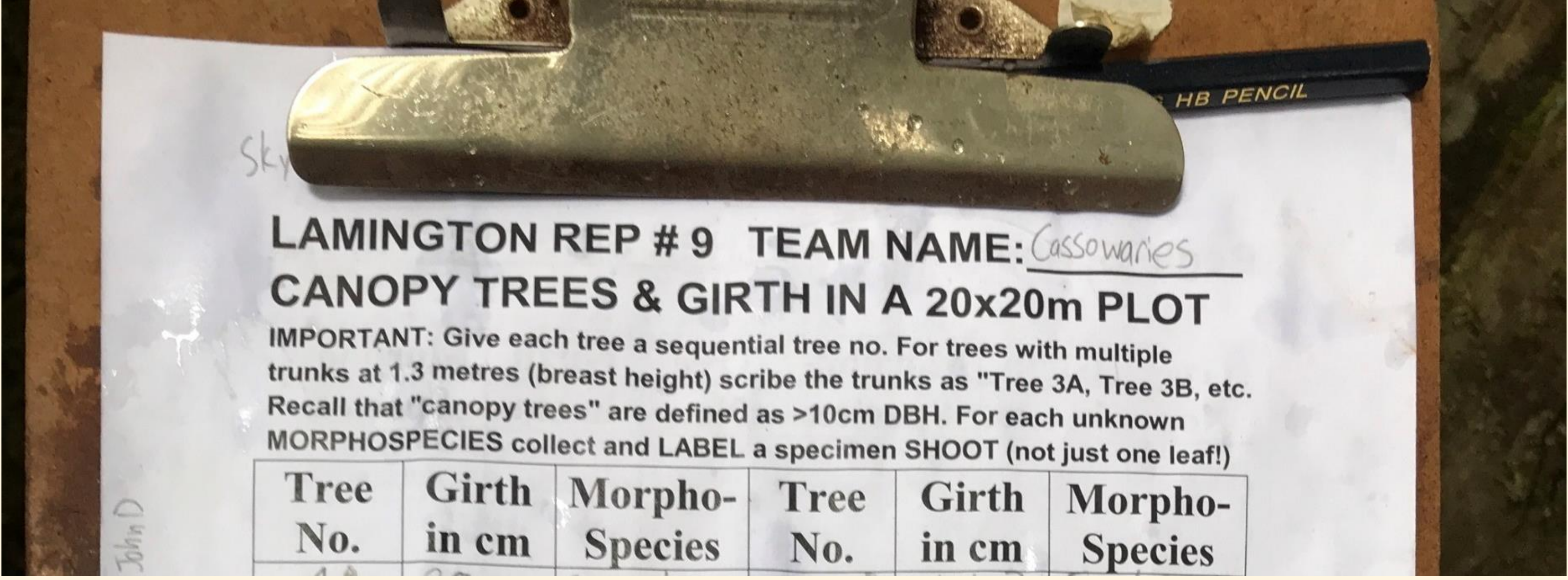
Despite themselves not being native, regrowth dominated by camphor laurel can foster the return of native rainforest plant species (Neilan *et al.*, 2006). Camphor trees are fruit-bearing, and these fruits are eaten by various birds and bats, allowing camphor regrowth to support the animals (Kanowski *et al.*, 2008). Whenever these animals eat a plant's fruit, they also ingest the plant's seeds (Neilan *et al.*, 2006). When they later move to another forest patch, they will defecate these seeds in a process known as seed dispersal (Neilan *et al.*, 2006). As long as a site is able to support these species, they can both receive and be the origin of dispersed seeds (Kanowski *et al.*, 2008; Neilan *et al.*, 2006). Rainforest recovery occurs when an animal consumes the seeds of a native rainforest tree species, the seeds are transported to a site in need of recovery, and the seeds establish themselves in the new site (Neilan *et al.*, 2006). With camphor regrowth being home to several native plant species and a wide variety of bird and bat species that eat the fruits of such plants, it can facilitate rainforest recovery both locally and at other sites (Neilan *et al.*, 2006). However, despite such a role, there is still a stigma attached to camphor laurel.

Photo 2. Despite camphor laurel being an exotic species, native rainforest trees, such as the blue quandong (*Elaeocarpus angustifolia*) depicted here, are still able to establish themselves in camphor-dominated regrowth.

Camphor laurel is seen as a weed; its value must be assessed to show why it is not one

Camphor laurel is treated as a weed by the Queensland and New South Wales state governments, Tweed Shire Council, and various citizens (Biosecurity Queensland, 2016; Firth & Ensbey, 2009; Honan, 2017A; Honan, 2017B; Tweed Shire Council, 2018). This is because it can grow in such a way that it shades out other plant species attempting to establish themselves, and it may even directly inhibit the growth of other plants by releasing oils directly into the soil (Paul *et al.*, 2010). Generally, it is feared that camphor laurel will absolutely dominate regrowth to such an extent that it is the only species in the site, fully arresting rainforest recovery (Firth & Ensbey, 2018). As such, conservation community groups such as the Big Scrub Landcare Group actively kill and/or remove camphor laurels, believing they cannot facilitate rainforest recovery otherwise (Big Scrub Landcare, 2019). More specifically, this active methodology can ensure the establishment of native rainforest trees in a shorter amount of time as it directly removes competition (from both camphor laurel and other weeds) against the native species (Kanowski & Catterall, 2007). However, doing so fails to acknowledge all of the benefits that are provided by camphor regrowth — namely their ability to compensate for CO_2 emissions and their ability to facilitate rainforest recovery both locally and at other sites. Furthermore, if community groups are facing funding crises, camphor regrowth can restore sites at a low cost, while active restoration can cost from 5,000 to 30,000 Australian dollars per hectare of rainforest being recovered (Kanowski & Catterall, 2007). As such, the Wollumbin Land-care and Biodiversity Alliance (WLBA) should choose to allow the regrowth to naturally recover (i.e. passively restore) as opposed to actively restoring the site. However, the WLBA cannot be convinced based off of other literature. Sites used by Neilan *et al.* (2006) may be different enough from the Tweed Valley that passive restoration is not viable. There is a need for projects that assess the camphor regrowth of the Valley and determine whether passive restoration will in fact lead to rainforest recovery. Studying in the Valley's town of Carool, this is one such project.

What We Learned
Results & Discussion



What we did

To determine the merits of camphor laurel, a hillside abandoned farmland in New South Wales' Carool was compared to a portion of Queensland's Lamington National Park, with the two sites respectively representing Tweed Valley's camphor regrowth and an intact native rainforest. The Carool site (hereby referred to as "Carool") was virtually treeless in 1976, so any observed results developed only in a space of 43 years — a length of time incomparable to that of the uninterrupted growth in the Lamington National Park site (hereby referred to as "Lamington") (John Hall, 2016, pers. Comm.).

Box 2. What is...Forest Succession?

Primary forests are generally defined as those that have managed to mature into a stable composition of species, having been relatively untouched by disturbances (Chokkalingam & de Jong, 2001).

In contrast to primary forests, secondary forests have been significantly disturbed, removing many primary forest trees and paving the way for new species to grow in the forest during the process known as succession (Chokkalingam & de Jong, 2001). The first plant species to colonize sites are called pioneers (Smith *et al.*, 2008). They are short-lived, fast-growing species that can only grow in high-light environments such as a clearing (Smith *et al.*, 2008). Eventually, the rainforest becomes full of low-growing pioneers that shade the ground (Smith *et al.*, 2008). The next group of species are able to grow in the shade, grow taller than the pioneers, shade them out instead, and eventually replace them (Smith *et al.*, 2008). They are the secondary species, but eventually, they, too, will be replaced by the last group: the mature species (Smith *et al.*, 2008). Some of these mature species are associated with intact/primary native rainforests (Chazdon *et al.*, 2007). As such, many conservation land managers would like restoration sites to develop back into a state full of mature-stage native species. However, the fear is that camphor trees will prevent such a scenario from happening by dominating the site and growing tall enough to shade out any native plant attempting to establish itself. Should Carool's camphor regrowth foster either secondary or mature trees, this fear will not be valid.

To demonstrate the value of Tweed Valley's camphor laurel, the amount of carbon sequestered inside of them was first determined. To do this, twenty 20 x 20 metre plots were established at Carool and Lamington — ten for each site.

Inside each plot, all adult trees had their diameters at breast height (i.e. 1.3 metres) measured. Subsequently, these values were inputted into equations from Brown (1997), Keith *et al.* (2000), and McPherson *et al.* (2016) that calculated the amount of above-ground biomass present in each tree. Because approximately half of above-ground biomass is carbon, the outputted values were used as a representation for the amount of carbon sequestered inside of each tree (Macías *et al.*, 2017).

To ascertain whether the results seen in Neilan *et al.* (2006) could also be applied to the camphor regrowth of Tweed Valley (i.e. that camphor regrowth facilitates rainforest recovery), the species compositions of both Carool and Lamington were examined. All adult trees surveyed in the twenty 20 x 20 metre plots had their species identified. Furthermore, thirty 2 x 2 metre plots were established at Carool just to survey saplings and seedlings. Sapling species were also identified, while seedlings were only classified as camphor or non-camphor. All identified species were associated with a forest succession stage according to Lismore City Council (2016). Based on the relative abundances of each species or type of species as well as the total number of species found, conclusions were made about how much rainforest development Carool has experienced in the past 43 years.

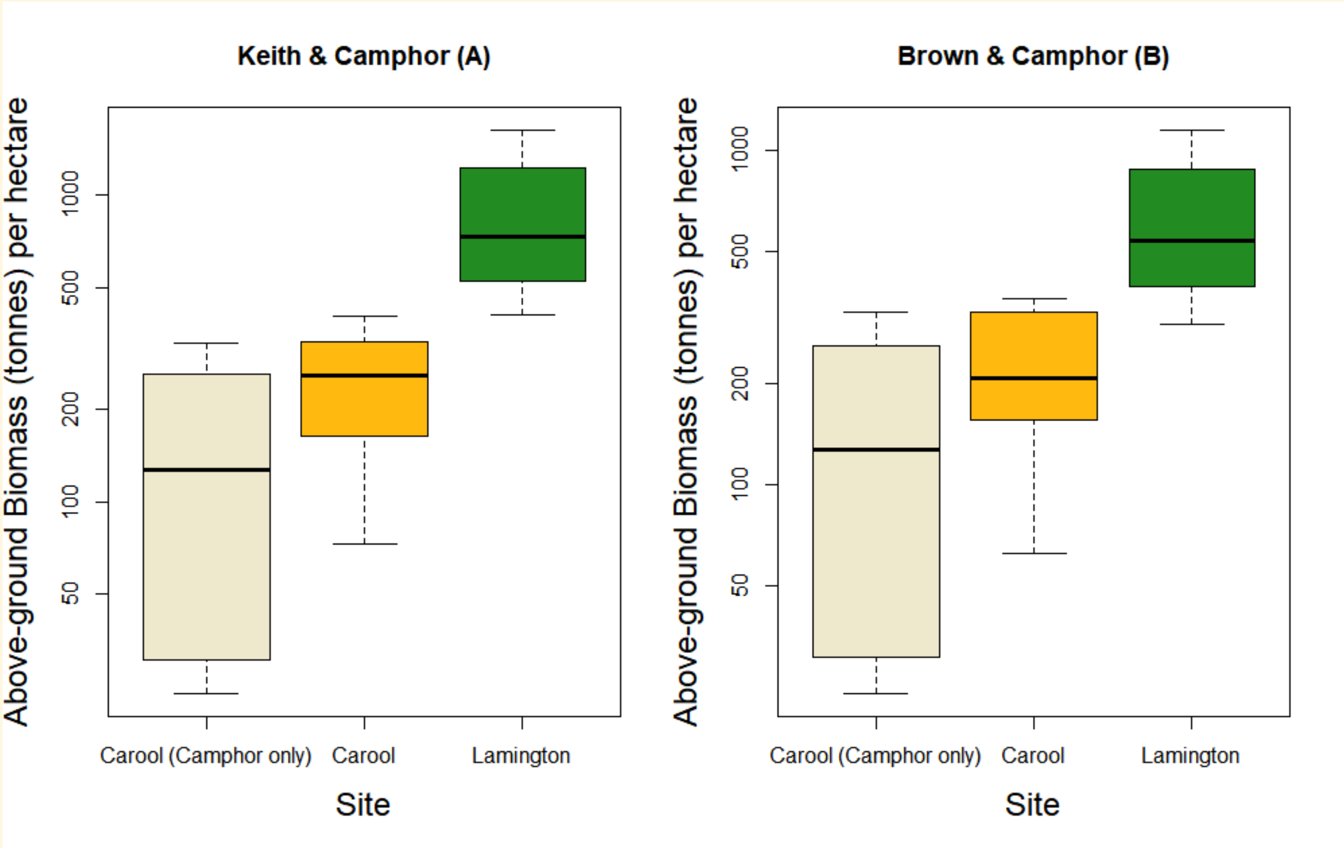


Figure 1. Box-and-whiskers plots charting the above-ground-biomass in tonnes per hectare of adult trees at a camphor laurel regrowth that has only been developing for 43 years (New South Wales' Carool) and an intact native rainforest (Queensland's Lamington National Park). To calculate the biomass of non-camphor trees, equations from Keith *et al.* (2000) [A] or Brown (1997) [B] were utilized. An equation from McPherson *et al.* (2016) was used for calculating camphor tree biomass. All biomass values were calculated from each tree's diameter at breast height (1.3 metres), but regardless of the equation used, Lamington has a higher average biomass. Each site's biomass value is based on 10 plots. Adult trees are defined as trees taller than 50 centimetres and with a diameter at breast height greater than 10 centimetres. Top whiskers, bottom whiskers, boxes, and horizontal lines inside the boxes represent the highest 25%, lowest 25%, middle 50%, and median of each site's biomass values respectively.

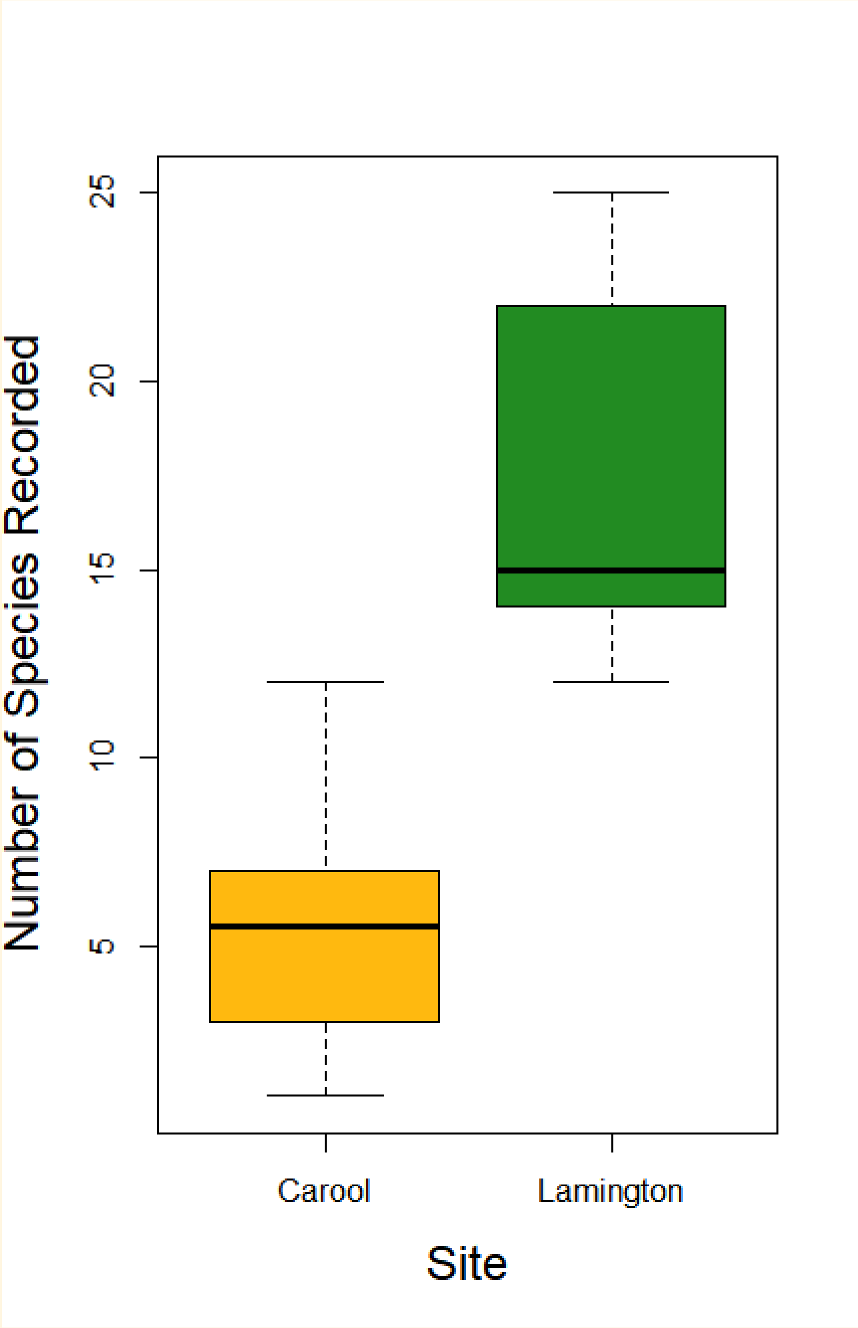


Figure 2. A box-and-whiskers plot charting the species richness of the adult trees at a camphor laurel regrowth that has only been developing for 43 years (New South Wales' Carool) and an intact native rainforest (Queensland's Lamington National Park). Higher species richness values are denoted by higher numbers of species recorded, and Lamington has more of them on average. Each site's species richness value is based on 10 plots. Adult trees are defined as trees taller than 50 centimetres and with a diameter at breast height (1.3 metres) greater than 10 centimetres. Top whiskers, bottom whiskers, boxes, and horizontal lines inside the boxes represent the highest 25%, lowest 25%, middle 50%, and median of each site's species richness values respectively.

Table 1. The relative abundances of non-camphor-laurel saplings and seedlings recorded in the camphor laurel regrowth of New South Wales' Carool[a]

Plant development stage	Total # of plants found	Mean # of plants found (± S.E.)[d]	Total # of non-camphor plants found	Mean # of plants found (± S.E.)[d]	% of non-camphor plants collected
Seedling[b]	1273	42.4 ± 17.8	112	3.7 ± 17.1	8.8
Sapling[c]	168	5.6 ± 2.0	158	5.3 ± 1.9	94.0

[a] *Values are based off of thirty quadrats.*

[b] *Seedlings = juvenile trees that are less developed than saplings; they are shorter than 50 centimetres and have less than 10 centimetres diameter at breast height (1.3 metres).*

[c] *Saplings = juvenile trees taller than 50 centimetres but with less than 10 centimetres diameter at breast height (1.3 metres).*

[d] *S.E. = Standard Error; it denotes the uncertainty present in an estimate of the actual mean value of a studied group of entities (in this case camphor and non-camphor seedlings and saplings) (Barde & Barde, 2012).*

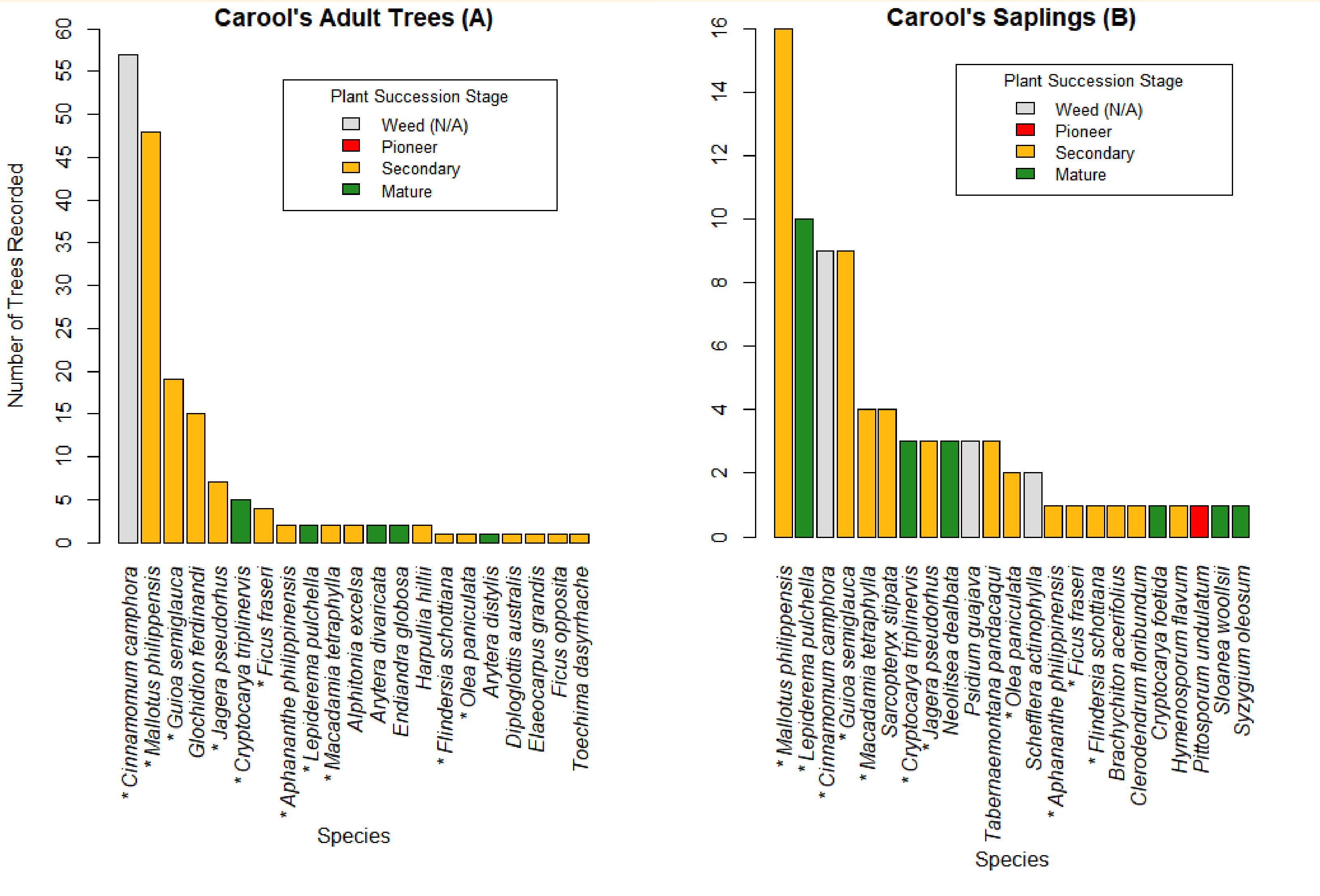


Figure 3. The abundances of the species identified as adult trees (A) and saplings (B) in the camphor laurel regrowth of New South Wales' Carool, ranked in descending order and categorized according to their associated rainforest succession stage (as suggested by Lismore City Council [2016]). The camphor regrowth has only been developing for 43 years. Asterisks denote species found as adult trees and saplings. Both adult trees and saplings are taller than 50 centimetres, but the former is distinguished by having a diameter at breast height (1.3 metres) greater than 10 centimetres. Abundance values are based on data recorded at 10 plots for adult trees and 30 quadrats for saplings.

Figure 4. A Venn diagram listing the species of all adult trees and saplings identified in the camphor regrowth of Carool and the rainforests of Lamington National Park. Across both sites, 91 species were identified. In Carool, 33 species were recorded compared to Lamington's 65. Seven species were common between the two sites. The camphor regrowth has only been developing for 43 years. Listed species are based on results of surveys for adult trees at twenty plots (ten for each site) and for saplings at thirty quadrats (only done at Carool).

Camphor regrowth can sequester substantial amounts of carbon

Carool's camphor regrowth was able to accumulate a large amount of biomass and, by extension, sequester substantial amounts of carbon in the past 43 years. While less carbon was sequestered in Carool, this was expected considering how Lamington was able to develop for a longer period of time. What was not expected was how some of the Carool plots were able to sequester as much carbon as some Lamington plots. Using Brown (1997), there is even overlap in carbon sequestration values between the two sites (**Figure 1B**). With the majority of Carool's biomass being camphor laurel, actively restoring camphor laurel regrowths would not be recommended for conservation community groups. The resulting decomposition of all the killed/removed camphor trees could release emissions on a similar scale to the clearing of intact native rainforest.

Camphor regrowth are not necessarily absolutely dominated by camphor trees

Despite being stigmatized as a weed that can absolutely dominate sites (Firth & Ensbey, 2018), the median adult tree species richness for the Carool plots was six species (**Figure 2**). Looking at raw values, only one plot was absolutely dominated by camphor laurel. Furthermore, one Carool site contained 12 species — a figure comparable to the five Lamington plots that had between 12 and 14 species. As such, camphor laurel's negative reputation is brought into question.

However, species richness may not tell the whole story; camphor laurel may end up dominating the site again if the trees of the future (i.e. saplings and seedlings) are mostly camphor. At Carool, such was the case for seedlings (**Table 1**), but this result was expected due to the exotic species' high seed production rate (Head & Muir, 2008). On the other hand, most observed saplings were non-camphor (**Table 1**), indicating that most camphor seedlings were unable to mature/survive past their initial state. Combined with how 158 of the 270 recorded juvenile non-camphor trees had managed to develop into the sapling stage, the future of Carool's regrowth will probably not be one completely dominated by camphor trees.

Looking at these results, community groups should not undertake active restoration projects based solely on the assumption that camphor trees will prevent other plants from establishing; camphor regrowth may actually support as many species as a native rainforest.

Camphor regrowth can facilitate rainforest recovery

If camphor trees did prevent other plants from establishing, it follows that camphor laurel would completely stop forest succession (and rainforest recovery by extension), but this is not the case in Carool's regrowth (**Figure 3**). Most adult trees and saplings are associated with the secondary stage of succession, with some even being mature tree species (**Figure 3**). Furthermore, some secondary and mature species are found as only saplings (**Figure 3B**), indicating that camphor trees are not preventing new species from maturing. In fact, with Carool supporting animals identified by Neilan *et al.* (2006) to be seed dispersers (**Box 3**), the regrowth may actually be facilitating the entrance of the new plant species, most of which are native rainforest ones. As such, community groups should not remove and kill camphor trees based on the incorrect belief that native rainforest plants are unable to establish themselves in camphor regrowth.

Box 3. The Animals of Carool and Lamington

The following are animal species that have been observed in Carool (John Hall, 2016, pers. Comm.). All species — with the exception of the two marked by an asterisk — have also been recorded in Lamington (Department of Environment and Science, n.d.). While all listed birds can disperse seeds, underlined species have been distinguished by Neilan *et al.* (2006) as having high seed-dispersal potential. They ingest a wide range of seeds and/or frequently consume fruits.

- Mammals
  - Long-nosed Bandicoot (*Perameles nasuta*)
  - *Mountain Brushtail Possum (*Trichosurus cunninghami*)
  - Swamp Wallaby (*Wallabia bicolor*)
- Birds
  - Australian Brush Turkey (*Alectura lathami*)
  - Brown Cuckoo-dove (*Macropygia phasianella*)
  - <u>Channel-billed Cuckoo (*Scythrops novaehollandiae*)</u>
  - <u>*Figbird (*Sphecotheres viridis*)</u>
  - <u>Topknot Pigeon (*Lopholaimus antarcticus*)</u>
  - White-headed Pigeon (*Columba leucomela*)
  - Wonga Pigeon (*Leucosarcia melanoleuca*)
  - Yellow-tailed Black Cockatoo (*Calyptorhynchus funereus*)

Camphor regrowth has some caveats

Before the WLBA prepares to undertake a strictly passive restoration project, there are major caveats associated with depending on camphor regrowth. First, like with other secondary rainforests, some species that were present before agriculture occurred will not be able to re-establish (Barlow *et al.*, 2007). At this point in time, there are only seven species that were found in both Carool and Lamington (**Figure 4**). Carool would need over 55 specific species to re-establish in order for the regrowth to resemble Lamington. For this to occur, the seed-dispersing animals must somehow find the fruits/seeds of each missing species and subsequently defecate them onto an area in the regrowth that has optimal conditions for growing and establishing the plant. This process is somewhat based on luck and may never happen (Montoya *et al.*, 2008; Neilan *et al.*, 2006). Furthermore, the animals may even bring back the seeds of weeds and other exotic species, which may proceed to outcompete the native ones (Kanowski & Catterall, 2007; Neilan *et al.*, 2006). In fact, seeds of two non-camphor weed species have already grown to become saplings in Carool (**Figure 3B**).

Even if the remaining Lamington species return to Carool, there is no guarantee that they will re-establish in a reasonable timeframe (Neilan *et al.*, 2006). Should it take another 40 years (or even longer) for Carool to return to a pre-agriculture state, the WLBA may have already dissolved due to a lack of funding or a lack of new recruits/staff/volunteers. Furthermore, during those years, governments may believe that the land is still in poor condition and subsequently allow construction developers to come in as they interpret its lack of rainforest as not having any ecological worth. Decades worth of rainforest recovery will be subsequently erased. However, with active restoration, the drawbacks of camphor regrowth are addressed.

Active restoration entails the control of two things: competition from other weeds that inhibit native plant re-establishment and the composition of species that re-establish (Kanowski & Catterall, 2007). As such, even though the camphor regrowth can facilitate rainforest recovery and sequester carbon all on its own volition and at a low cost to conservation managers, the WLBA needs to acknowledge that active restoration can ensure rainforest recovery occurs in a reasonable timeframe. Following from this, the WLBA's Tweed Valley regrowth restoration efforts must encompass the advantages of both active and passive restoration.

What We Recommend
A Five-part Plan

Passively keep camphor laurel to reduce and mitigate local CO_2 emissions

With camphor laurel being shown to sequester large amounts of carbon, they should not be actively killed or removed. When dead, they will decompose and release substantial amounts of carbon (Fargione *et al.*, 2008). Emissions will be exacerbated by pollution originating from the heavy machinery utilized for this restoration method, further adding onto total emissions (Kanowski & Catterall, 2007; Melanta *et al.*, 2013). However, during the active restoration process, camphor laurel will be replaced by trees from primary native rainforests. The average primary tree species grows taller than camphor trees and, by extension, will require more carbon to be sequestered inside of them to build up larger body structures (Drake *et al.*, 2002). As such, the amount of carbon released during active restoration will be exceeded by the amount being taken in by the new primary trees. Yet, this net increase will only come into fruition after years of primary tree growth. In the meantime, the restoration site will remain in a state with fewer adult trees, presenting another issue (Kanowski & Catterall, 2007).

Passively keep camphor laurel to support animal diversity, and, by extension, rainforest recovery

A variety of animals call camphor regrowth home and depend on their trees, so turning the sites into something without these structures will leave the animals without a habitat or food source (John Hall, 2016, pers. Comm.; Neilan *et al.*, 2006). As such, fewer fruit-eating animals may travel to the sites because it cannot support them, decreasing the number of native rainforest seeds dispersed there (Montoya *et al.*, 2008). Furthermore, other animals that utilize the sites as stop-overs along the way to other rainforests may find their route blocked off, interrupting the flow of native rainforest seeds to their final destination (Runge *et al.*, 2014). The sites will also be unable to act as origins of dispersed seeds due to lack of fruit-eaters. As such, active restoration may actually decrease the number of native rainforest plants that are able to establish themselves both locally and at other sites in need of restoration, impeding rainforest recovery. If sites are forced to remain with secondary regrowth trees instead of the taller primary forest trees, they will not amass as much biomass and sequester as much carbon as they would if plant establishment was not inhibited. Based on this information, community groups may choose to passively restore sites, but it should be noted that seed dispersal can also help exotic species establish.

Actively manage weeds to increase the rate of rainforest recovery

In Carool, some weeds were able to survive in the regrowth and mature as saplings. In general, if weeds are left unmanaged — as they would in passive restoration — they may outcompete native rainforest plants attempting to establish themselves, resulting in the arrest of rainforest recovery (Kanowski & Catterall, 2007; Guevara *et al.*, 2004). As such, active weed control (but not of camphor trees) is required to reduce their influence on native species. Doing so will accelerate the rate at which new plant species establish as they are able to easily obtain resources, while ensuring that rainforest recovery in the regrowth and other sites can still be facilitated by camphor trees (Kanowski & Catterall, 2007). However, even if there was absolutely no competition inhibiting native rainforest plant growth, not all species will return.

Actively replant trees to ensure a return to a condition similar to its pre-agriculture state

Plants that were found before a rainforest became farmland may never return, even if the WLBA recovers as much rainforest as possible via passive restoration (Barlow *et al.*, 2007). For example, the non-removal of camphor trees may facilitate the recovery of native rainforest plants that are dispersed by animals, but it does not address those dispersed via another method: wind (Montoya *et al.*, 2008). This process is even more random than animal-mediated seed dispersal. Rainforest recovery would require the seeds to be blown in a specific direction towards sites that need to be restored and that also have suitable conditions for their establishment (Montoya *et al.*, 2008). Such a luck-based process may not occur frequently enough for some wind-dispersed species to establish themselves (Montoya *et al.*, 2008). As such, wind-dispersed species — as well as other native rainforest species that are missing and valued by the community groups — should be actively planted and have their growth monitored. This will ensure that the regrowth can develop into a site similar to what it was before agriculture or, at the very least, one valued by the conservation managers. Furthermore, the addition of new trees to the site will mean even more biomass being developed and carbon being sequestered away. However, more new trees will also mean increased costs in order to pay for staff and supplies. This will essentially remove one key advantage of using camphor laurel to sequester carbon: its low cost. As such, tree-planting (and even weed control) should be kept to a minimum. Still, the WLBA may require a source of funding for this recommended passive-active hybrid strategy to be put into place.

Advertise the carbon-sequestering ability of this strategy to the environmentally-conscious

The main advantage of passively restoring camphor laurel is that they are able to provide so many ecological benefits at a low cost. Leaning too heavily into the active components of this project's recommended hybrid strategy will lead the WLBA away from this advantage, but there may still be years where funding for this strategy (and for other projects being undertaken) will need to be supplemented regardless of active efforts. Fortunately, carbon sequestration is marketable. Projects are available catering to environmentally-conscious companies and individuals who recognize that their business or lifestyle emits carbon. Conservation organizations are paid money by these parties to plant new trees, increasing the amount of CO_2 being taken up from the atmosphere (Clark, 2011; David Suzuki Foundation; 2017; Smith, 2018). Thus, for the final component of this hybrid strategy, the WLBA should advertise its camphor regrowth restoration efforts and present it as an option for compensating for one's own carbon emissions. On top of saving money from not needing to remove camphor laurel, the WLBA will even be able to make money if enough people pay them for offsetting their emissions. All of this can be done while still recovering the rainforest and ensuring it sequesters as much carbon as possible. Thus, there is a win-win-win scenario for the client, the WLBA, and, most importantly, the rainforest.

Final Remarks

All over eastern Australia, camphor laurel is stigmatized by citizens and conservationists alike. They are treated as weeds that dominate the rainforest and prevent further development, but such a reputation is not valid. Camphor regrowth can support a diverse set of plant and animal species, help rainforests recover, and, most importantly, mitigate the human-mediated global increase in atmospheric CO_2 concentration. What is remarkable about camphor regrowth is that all of this comes about without requiring much human intervention. In the face of such opposition, the WLBA should break away from other landcare community groups and subscribe to a methodology that can harness the values of camphor laurel while bolstering them using some elements of active restoration. However, the WLBA will face a major barrier: the law. Both Queensland and New South Wales legally require land managers/owners to remove and prevent the growth of camphor laurel (Biosecurity Queensland, 2016; Firth & Ensbey, 2018). Thus, to mitigate CO_2 emissions and restore the rainforest at an efficient cost, perhaps the WLBA's first order of business is to use Carool as an example of how the camphor laurel's reputation has inaccurately preceded it. Conservationists should be able to harness the power of the regrowth no matter what the law or even other conservationists say.

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