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ESTIMATING PATTERNS OF LEAF HERBIVORY ALONG AN ALTITUDINAL TRANSECT IN NE QUEENSLAND RAINFORESTS: MIGHT GLOBAL WARMING INCREASE LEAF HERBIVORY IN TROPICAL RAINFORESTS?

En col·laboració amb/in collaboration with:

CSIRO

Memòria del Projecte Fi de Carrera
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presentada per:
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i dirigida per
en **Dr. Jordi Martínez-Vilalta**

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"A 1000 miles journey starts with a single step"

"Those who lose dreaming are lost"

ANCIENT ABORIGINAL PROVERBS

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CONTENTS

1. INTRODUCTION

This study is based on the field work done in the Wet Tropics of Queensland, in Australia. It tries to assess the effects of temperature on the plant-insect interaction, and more specifically, on insect herbivory. Therefore, the introduction has different sections, beginning with climate change, then rainforest and the Wet Tropics and finally the plant-animal interaction.

1.1 Climate Change

Climate change has been a very controversial issue especially over the past 20 years. But ironically, there have been several periods of climate change during the Earth's history. These consist of warm and glacial periods, alternating along millions of years. Therefore, it may seem that the actual global warming period is following the normal pattern of climate changes of the Earth. As we will explain in the following pages, the present global warming episode is not in agreement with the recorded natural changes and is undoubtedly caused by the human activity on the planet.

The Earth's climate is influenced by many factors. In an orbital scale we know that climate is related to the Earth astrophysical variations, such as orbital eccentricity, changes in Earth's axial tilt and rotational axis precession (Ruddiman, 2008).

The Earth's orbit shape has varied in the past becoming at times more elliptical (or eccentric) and at other times more circular than it is today. An ellipse has two main axes called the major (or longer) axis and the minor (or shorter) axis. The eccentricity (or degree of departure) can be described by:

$$\in = \frac{\sqrt{a^2 - b^2}}{a}$$

Where $\in$ is the eccentricity of the ellipse and a and b are the half-lengths of the major and minor axes (also called "semimajor" and "semiminor" axes).

Eccentricity is now 0.0167 but has varied over time between values of 0.005 and 0.0607, so the present status lies toward the lower and more circular end of the range. Orbital eccentricity changes mainly in two cycles, one with a period of approximately 100,000 years and a second one with a period of 413000 years that shows up as alterations of the first cycle. There is a third eccentricity cycle but it's weaker than the two aforementioned ones (Ruddiman, 2008).

The Earth's axis is tilted between a low of 22.2º and a high of 24.5º, and has varied along these values through time. Today, the Earth's tilt is 23.5º, near the middle of this range, and this angle is currently decreasing. Without tilt, there would be no seasonal changes and with a really large angle (90º) the poles would alternate seasons of day long darkness and seasons of day long sunlight. Changes in tilt occur cyclically mainly at a period of 41000 years. These cycles are fairly regular, both in period and in amplitude. These changes amplify or reduce the strength of seasons, especially at higher latitudes. Larger tilt angles increase the amount of solar radiation received and therefore summer is stronger in the summer hemisphere, while winter is stronger in the winter hemisphere. Decreases in tilt have the opposite effect, the strength of seasons is reduced and thus the seasonal amplitude is reduced.

The position of solstices and equinoxes has not always been the same. They have changed with respect to the Earth's eccentric orbit and the perihelion (close-pass) and the aphelion (distant-pass) positions, as a result of what is called axial precession. This is caused mainly by the Sun and Moon gravitational pull on the Earth's slight bulge at the equator. Today, the Earth's axis points at the North Star (Polaris) but during time this axis revolves with a period of 25700 years. There is another precessional motion called precession of the ellipse. In this case, the Earth's elliptical orbit rotates in space, even slower than the axial precession. These two combined movements lead to the precession of the equinoxes. This combined movement describes the absolute motion of the solstices and equinoxes in a universal frame. The average period of the movement is 21700 years but people often refer only to the strong cycle of near 23000 years (Ruddiman, 2008). These astronomical factors influence the amount of solar radiation the Earth has received throughout time, and therefore explain past climatic changes.

Present global warming situation and climate change, is caused undoubtedly by anthropogenic processes. Industrial activity, urban way of life and land use transformation are among the most important causes of the changing climate conditions.

The industrial revolution that took place in the mid 18th century set a starting point for the modern way of life. Industries begun to appear and production models changed towards a quicker, cheaper way of making things. This, however, did not take into account environmental issues, and air, water and soil pollution as well as massive waste and nature exploitation were part of the process. Throughout the years, more and more complex industries appeared, and the environmental problem grew bigger. Until a few years ago, no nature conservation movements appeared. When these did, investigation on environmental and climate issues became important and the first alarms on global warming appeared. Further research showed that human pressure is changing Earth’s climate at non-natural rates.

The greenhouse effect happens when incoming solar radiation is trapped inside the Earth’s atmosphere. Once it reaches the ground, the long wave incoming solar rays are reflected as shortwave rays. Some chemical compounds such as Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) or water vapour don’t allow these rays to leave the Earth and therefore a warming of the planet takes place (IPCC, 2008). This process has happened since the early stages of the Earth and it is absolutely necessary for life to exist. Without it, there would be no habitable environment and the planet would be too cold for life to survive. The problem that we are currently facing is a magnification of the greenhouse effect. The greenhouse effect gases emitted by industry, transportation and farming contain the aforementioned chemical compounds. These, stay in the atmosphere for a long time (long-lived gases) preventing the solar heating radiation to leave the Earth and thus causing the so called global warming (IPCC, 2008).

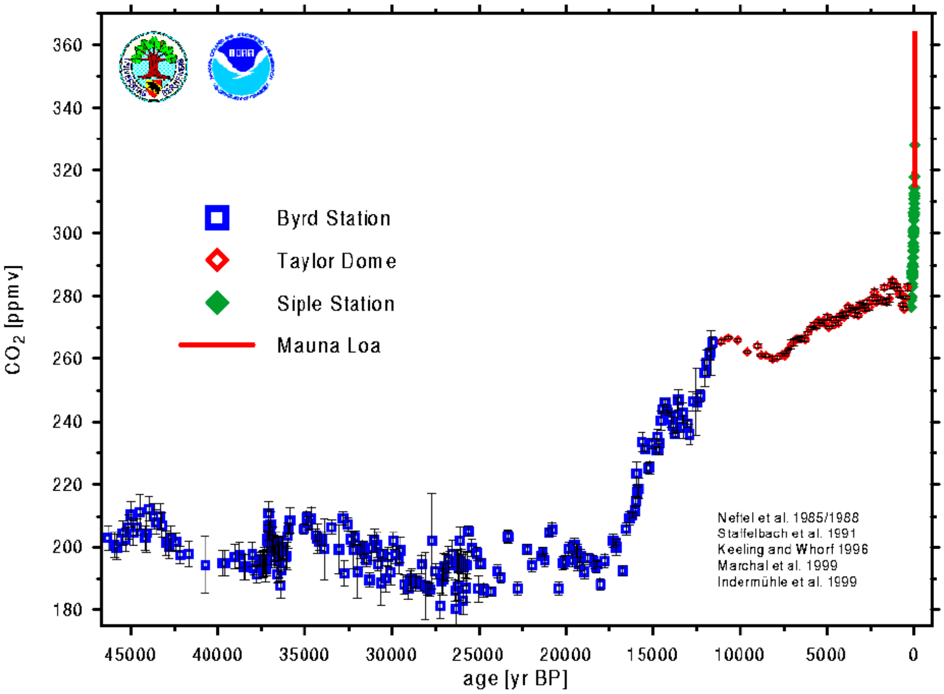
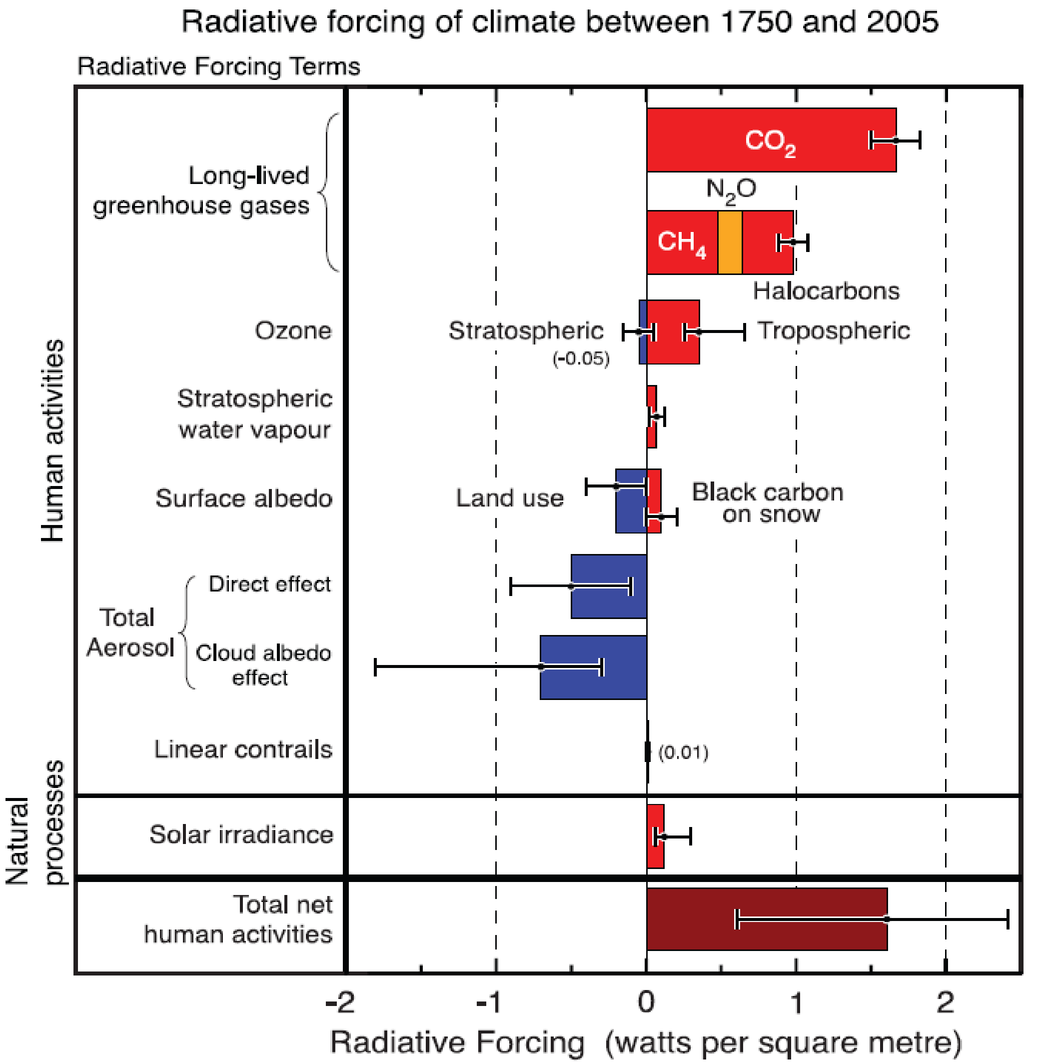


Fig 1: CO2 concentration since 45000y BP. Source: NOAA

In figure 1, we can observe how CO2 concentrations are increasing at an abnormally fast rate in the present years, based on the observations made in 4 climatic stations, either atmospheric (for recent data) or ice sampling (for past data).

In Figure 2, the main causes of radiative forcing are summarized. It shows how human activities are the main components driving global warming, through the emission of greenhouse gases. Tropospheric ozone also contributes to the enhancing of the global change. The aerosols present in the atmosphere provide a negative feedback to the climate change, reflecting rays through the albedo. Natural causes, such as solar irradiance, are a small component of the current climate change, in comparison to the anthropogenic activities.



FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change. All these radiative forcings result from one or more factors that affect climate and are associated with human activities or natural processes as discussed in the text. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value. (Figure adapted from Figure 2.20 of this report.)*

Fig. 2: Principal components of radiative forcing of climate change. Source: IPCC

Nature is the first affected by climate change. And therefore humans will be affected as well, as we depend on nature for resources, climate buffering and health services, just to name a few. In particular, vegetation is an extremely sensitive part of the natural world that would be highly damaged in the worst case scenarios of global warming.

Vegetation would be seriously affected in the predicted cases of global warming. The increasing temperatures would change the habitat for all the species adapted to one particular area. Coastal species would move up to montane environments looking for cooler temperatures while highland species would have serious problems of adaptation to a new and warmer climate. Furthermore, concentrations of carbon dioxide would also increase in the predicted scenarios, and this would also lead to plant changes: Increased CO2 concentrations may result in growth performance and secondary changes in plant phenology due to changes in carbon assimilation (Puhe, 2001). There is also concern about the changes in rainfall patterns in future climate scenarios. While some areas are not predicted to be affected by more intensive dry seasons, such as Amazonia, others are likely to have long periods of drought, possibly due to anthropogenic causes (Mahli and Wright, 2004).

The effect of climate on vegetation is not unidirectional, as vegetation can also influence climate (Raunkiaer, 1934; Holdridge, 1947; in Grime, 1997). Land carbon cycles are the most important contributors to the uncertainty about CO2 emissions in the 21st century after the anthropogenic sources (Meir et al., 2006). Forest loss due to climate change would have several effects on climate at the regional scale (and in a global scale if the forest loss is massive) such as an increasing surface reflectance (almost offsetting cloud effect) (Bala et al, 2007 in Mahli et al. 2007), less water re-circulation (roots absorbing water from the soil and being returned to the atmosphere), and changes in surface roughness (Mahli et al., 2007). It is known that the evaporative surfaces provided by vegetation are driving forces of the atmospheric humidity and rainfall patterns (Grime, 1997). All these effects, would, thus, have important consequences on climate and therefore on human activities, life and survival.

Furthermore, climate alterations could lead to habitat fragmentation (caused by human migrations, changes in land use) reducing the dispersion of late successional species to new areas (Grime, 1997). This can be especially significative when talking about rare or endemic species, where dispersion to new habitats will be a key point for ensuring their survival in the predicted cases of climate change.

Loss of forest masses would mean losing the sink for 45% of the terrestrial carbon in the Earth (Bonan, 2008). In the case of Amazonian forests, the deforestation rate was of 25,000km^{2}year^{-1} during the 1990's (Mahli et al., 2007). This can have a double effect on climate change. First of all, deforestation is a main cause for climate change. Secondly, it will have a positive feedback effect to climate change, enhancing climate change and therefore accelerating loss of larger forest masses. This, however, does not work for the particular case of boreal forests, where the lower surface albedo warms global climate. For temperate forests, the climate forcing is still unknown (Bonan, 2008).

More specifically in the case of rainforests, climate change plays a key role due to the fragile nature of the rainforest environment. Tropical forests cool global climate due to strong evaporative cooling and a high carbon sequestration (Bonan, 2008). Tropical forests are affected by warmer temperatures and drier climate (Mahli et al., 2007). It is known that north Queensland rainforests are highly sensitive to the climate changes expected during the next 20 or 30 years. It is believed that a raise in 1ºC may reduce the rainforest area by 50% (Howden, 2002). In the Wet Tropics bioregion, the expected climate change scenarios may lead to a significantly decrease of the upland rainforest (Hilbert, 2001).

Global warming estimations also predict the intensities of tropical cyclones to increase between 10-20% before the end of the twenty-first century (Turton, 2008). These cyclones inflict high disturbances on the forest structure and dynamics. El Niño Southern Oscillation (ENSO) is responsible for these extreme climatic conditions, and with the increasing number of cyclones and its intensity, tropical forests may be threatened. Although cyclones are necessary for rainforests to develop and to regenerate, an excessive frequency might not allow the ecosystem to recover. ENSO as well regulates the dry-wet season alternation in tropical areas. As mentioned above, some areas will be highly sensitive to climate change, and through affecting the ENSO (less rainfall during the El Niño events [Mahli and Wright, 2004]), tropical areas can be seriously affected by drought.

1.2 Rainforest

Rainforests are highly valuable ecosystems. Charles Darwin (1839) wrote of his initial impressions of tropical rainforest: “In tropical forests, when quietly walking along the shady pathways, and admiring each successive view, I wished to find language to express my ideas”. He could not find the words to express the sensation he felt when experiencing these fabulous ecosystems.

Rainforests can be either tropical or temperate. Most widely known and usually referred to is the tropical rainforest, occurring in South and Central America (neotropics) and in Asia, Australia and Africa (paleotropics). In Canada and United States we find some temperate rainforests.

From now on we will focus on tropical rainforests. They are characterized by high rainfall and high temperature throughout the year. They cover approximately 6 -7 % of the Earth’s surface (Stork et al., 2008) and paradoxically they contain more than 50% (some studies consider up to 90%) of the world’s biodiversity. Rainforests are thus among the most diverse environments on the Earth. Just to illustrate this statement, in Australian rainforests there are more than a 100 (in some cases up to 400) plant species per 0.1 hectare. Furthermore, rainforests are a basic piece of the Earth’s climate regulation: they sequester about 40% of the carbon dioxide that is not taken up by the oceans (Raven, P. H., 2008), which means that after the sea water, tropical forests are the main carbon dioxide sink.

Tropical rainforests usually have a top canopy that seldom exceeds 50m (Longman et al., 1987). This top layer forms the euphotic zone of the forest. There is a middle tree layer that is the boundary between the aforementioned euphotic zone (lit environment) and the oligophotic zone (shaded environment). Below this layer there are two classes of smaller trees: seedlings and saplings that will eventually become top or middle layer trees, and understory or “pigmy” trees that stay permanently in the understory. There is also a shrub layer formed by seedlings, shrubs and pigmy trees from 1 to 5m as well as a herb layer formed by smaller tree seedlings, forbs, graminioid plants, ferns and bryophytes up to 1m (Longman et al., 1987).

These strata are nonetheless, not easy to identify, especially in mixed forests (large number of species). Single-dominant tropical forests show clearly defined strata.

Rainforest soil, despite what may seem, is very poor in nutrients. The high rainfall leads to an important wash out and a fast decomposition rate by the microorganisms in the ground removes available nutrients for plants from the soil. The typical response from rainforest plant species is to capture as quickly as possible the present nutrients in the soil and hold them in their tissues (Richards 1983).

Rainforests have a high economic value. The timber from their trees, the minerals found in the soil, petroleum reservoirs and exotic animals are among the most common assets of the rainforest. One of the most important environmental services that originate in the rainforest is the drugs. Many pharmaceutical companies have research programmes in the rainforest that aim to find chemical compounds that might help in creating commercial drugs for birth control, cancer, AIDS, and many other diseases.

This economical profit from the rainforest is not always “eco-friendly”. Tree-logging, mineral extraction and animal capture create high disturbances and affect the fragile balance of the forest. Tree logging clears large areas of rainforest regardless of the biodiversity living in the area, and the same happens when clearing for agricultural or extraction uses. When the land is cleared, erosion affects the area and the small amount of nutrients that were in the soil is washed out, hampering the recovery of the ecosystem. More frequently, the cleared land is used for logging paths, roads, or even settlements, and thus the rainforest is replaced by other land uses. When companies investigate in the rainforest to find new drugs, then a socio cultural problem raises. Indigenous people living in the rainforest use and take profit of forest services. They do not sell the products they extract from plants and animals, but they use them in their everyday life. Companies, on the other hand, send several scientific expeditions to find new substances for drug design. This affects both the ecosystem, that is perturbed, and the indigenous people, who are being stolen their valuable resources.

1.3. The Wet Tropics of Queensland World Heritage Area

This Wet Tropics area is located in North East Queensland, Australia. Since 1988 the UN declared it World Heritage Area, recognizing its importance due to the high number of endemic species and its high biodiversity. It is therefore known as the Wet Tropics of Queensland World Heritage Area (WTQWHA). The area covers approximately 900,000 ha from Cooktown to Townsville. Its uniqueness in number of endemic species and its ecological significance make it an important and interesting place to study in order to understand and conserve it. The wet tropics are 415 million years old. During this time, many species and a complex ecosystem have formed and evolved until today creating one of the most diverse and unique places on Earth. Many rainforest species originated when Australia was still part of Gondwana (Australian Government, Department of Environment, Water, Heritage and The Arts).

The WTQWHA singular climate conditions are due its latitude, situation (near the winds from the Pacific Ocean) and topography; and all these have created an area with an exclusive rainforest ecosystem. Around 3,000 plant species from 210 families are found in the Wet Tropics. Twelve out of the world's 19 families of primitive flowering plants (angiosperms) grow here and within these families, and 3 are endemic to the Wet Tropics, containing more than 50 endemic species. A third of the mammal species in Australia live in the Wet Tropics and 50 are found nowhere else in the world. A quarter of Australia’s frogs and more than a third of Australia’s freshwater fish also live in the Wet Tropics. And half of the birds in Australia live in the area: more than 370 species.

The Wet Tropics bioregion receives more than 2 million visitors each year (State of the Wet Tropics, 2008) so conservation is a main concern for the Australian Authorities. The management and protection of the area rely on their conservational policies, in order to preserve life and also to increase the tourism and economic benefit of the region.

The WTQWHA is a good example of how nature, human development and tradition meet together in the same area. The aforementioned conservation helps keeping the human footprint small and, sometimes, away from the virgin and unique rainforest habitats. It also helps protecting the aboriginal communities that originally inhabited the area. For these, many parts of the Wet Tropics are sacred places, and their beliefs must be respected. They have been living in the area for thousands of years (50,000 years BP) and their knowledge and respect for its surroundings is to be admired. They have been taking food, medicines, shelter and all kinds of services from the rainforest. They are believed to be the earliest population in Australia. No doubt their knowledge of the area is admirable. An example is how they are able to transform really toxic plants into food or medicines for their own benefit. No questioning why they are called “the rainforest people”. Modern social pressure is invading their spaces, forcing them to retreat and to lose what used to be their homes. New conservation programmes must include the aboriginal people as another vector in the complex eco-socio-economic relationship that characterizes land management, particularly when working in such a fragile ecosystem with all the cultural connections that are involved.

1.4. Plant-animal interaction / Herbivory

Plants and animals interact in many different ways. From frutivorous insects to grazing mammals there are many types of contact between the vegetal and the animal world. Herbivores consume on average, 10-20% of the annual net primary production on terrestrial ecosystems (Hartley, 2007). We will focus on insects for it is the objective of this work, and because herbivory is mainly occasioned by insects in forest ecosystems.

Insects and plants have many kinds of interaction. Insects obtain food, shelter, a safe place for their early reproductive stages (eggs, larvae), and plants in return obtain pollinization, nutrients, chemical defences and seed dispersal. Nonetheless, insects can also have some negative effects on plants. They are not devastating effects (although they could be at some point) but they do not provide any benefit to the plant. We're talking mainly about insect herbivory, which is a very important process in the biological cycles. Herbivory refers to the act of eating the plant, or some of its products (seeds, fruits) totally or partially. We can find generalist or specialist herbivores. The first ones eat many kinds of plants while the second group restricts their diet to particular species or genus of plants.

There are many kinds of insect herbivory in rainforests. The three major types are: phyllode-chewing, sap sucking (both external feeding) and phyllode-mining (internal feeding) (Andrew, 2005). It is known that leaf herbivory occurs more frequently in young leaves than in mature leaves, due to their greater nutritional quality (Coley, 1996) and relatively low leaf toughness (Coley, 1991), although this pattern may change depending on the type of herbivory being considered (Andrew, 2005). Herbivore populations are larger in forest gaps, but have more predator pressure, while in the understory, they are limited by food resources, keeping the damage rates lower (Richards et al., 2007).

It is known that secondary chemicals are more important for plant defence against insect herbivores than their physical defences (Hartley, 2007). Secondary metabolites exist in large numbers and each plant contains several of them, some of them being unique to a certain species. These chemicals affect the insect in different ways, such as toxic effects, growth reduction, digestibility reduction, slow development, etc. (Hartley, 2007). Defence is not the only function of secondary metabolites. Ultraviolet absorption, growth regulation, thermal protection, and attraction of pollinators are some, just to name a few (Hartley, 2007).

Many studies show that insect herbivory of broad-leaved species is significantly more important in tropical than temperate forests (Coley, 1996; Coley, 1991; Coley, 1996). Consequently, this has led plants to develop a wide range of mechanical, phenological and chemical defenses. Herbivores, in turn, have developed resistance to some of these defense methods in order not to starve or get poisoned as a means of survival (Coley, 1996). Generally, tropical forest species have greater resistance to insects than temperate species, though herbivory rates remain high. That leads us to the conclusion that herbivory pressure is higher in tropical forests than in temperate ones. This may give us an explanation for other similar dynamics occurring in the forest, such as tree mortality, which is higher at warmer temperatures (Hilbert, 2009). Crawley (2007) found no clear relationship between herbivory and plant diversity. He found no connection between plant performance and community or population dynamics. What he found is that herbivory can change the identity of the dominant plant species in a community, even though signs of impact may seem rare.

Several studies have studied herbivory along latitudinal gradients (Andrew, 2005; Coley, 1996, Hallam, 2006), but few have investigated the relationship with an altitudinal gradient (e.g.: Scheidel, 2003). Our honours work is one of the first to study the influence of altitude on herbivory in tropical rainforests in the Wet Tropics World Heritage Area. In this area, temperature is the main factor changing along the altitudinal gradient. Several factors influence herbivory rates, including leaf age, leaf toughness, nutritional value and physical defences (Andrew, 2005). However, temperature is widely regarded as the most important abiotic factor influencing herbivory rates (Bale, 2002). Therefore, changes in altitude or longitude might affect herbivory intensity and thus, forest dynamics. Normally, increasing altitude shows a decreasing number of insect species per unit area (Gaston & Williams, 1996). As the influence of rainfall in herbivory is not completely known, some studies consider precipitation as an enhanced mortality factor (e.g. Thacker, 1997; Dixon, 1998). However, other studies find that herbivory rates are higher in the wet season despite several species having outbreaks during periods of drought (Coley, 1998).

1.5. Antecedents and Objectives

There have been many studies about herbivory in tropical forests, especially since the early 80’s (Coley, 1980; Coley, 1982; Coley, 1983). Most of them were situated in the South and Central American region, the Neotopics. More recently, there have been studies relating insect herbivory with a latitudinal gradient (Andrew, 2005; Coley, 1996; Hallam, 2006). Some of them are situated in Australia, but most of them are still focused on the Neotropics. In consequence, there was a need of studying herbivory in the tropical region of Australia, the Wet Tropics of Queensland. Furthermore, there were no studies relating herbivory in tropical forest along a temperature gradient in altitude. The need for this kind of studies was the main reason for starting off this project.

This study tested the hypothesis that **the intensity of insect herbivory is positively correlated with increasing temperature.** We expected the herbivory rates to increase with decreasing altitude, due to higher temperatures at lower stages. It is known that high temperature leads to higher diversity of insect herbivores and higher abundance of them at given latitude –higher metabolic rates, several life cycles in season- (Bale, 2002). This is supported by other studies that have investigated herbivory rates along a latitudinal gradient, with temperature increasing towards the equator (e.g. Andrew, 2005; Coley, 1996). Other similar studies in temperate forests have not found any clear relationship between altitude and herbivory (e.g. Scheidel, 2003).

The objectives were to **assess the extent of leaf herbivory by chewing insects**, at a community (background) level, in the understory of 9 rainforest plots along an altitudinal (and therefore temperature) gradient, and to assess how insect herbivory varies along the same altitudinal gradient for some single, wide-spread species. It is the first study of the altitudinal variation of herbivory in tropical rainforests in NE Queensland. Specific objectives included studying how herbivory variation along temperature can be analogous to climate change scenarios and relating herbivory rates with leaf toughness to look for any effect of this factor on herbivory. This way, we covered some of the most important factors affecting herbivory (temperature and leaf toughness [Suzuki, 2003]).

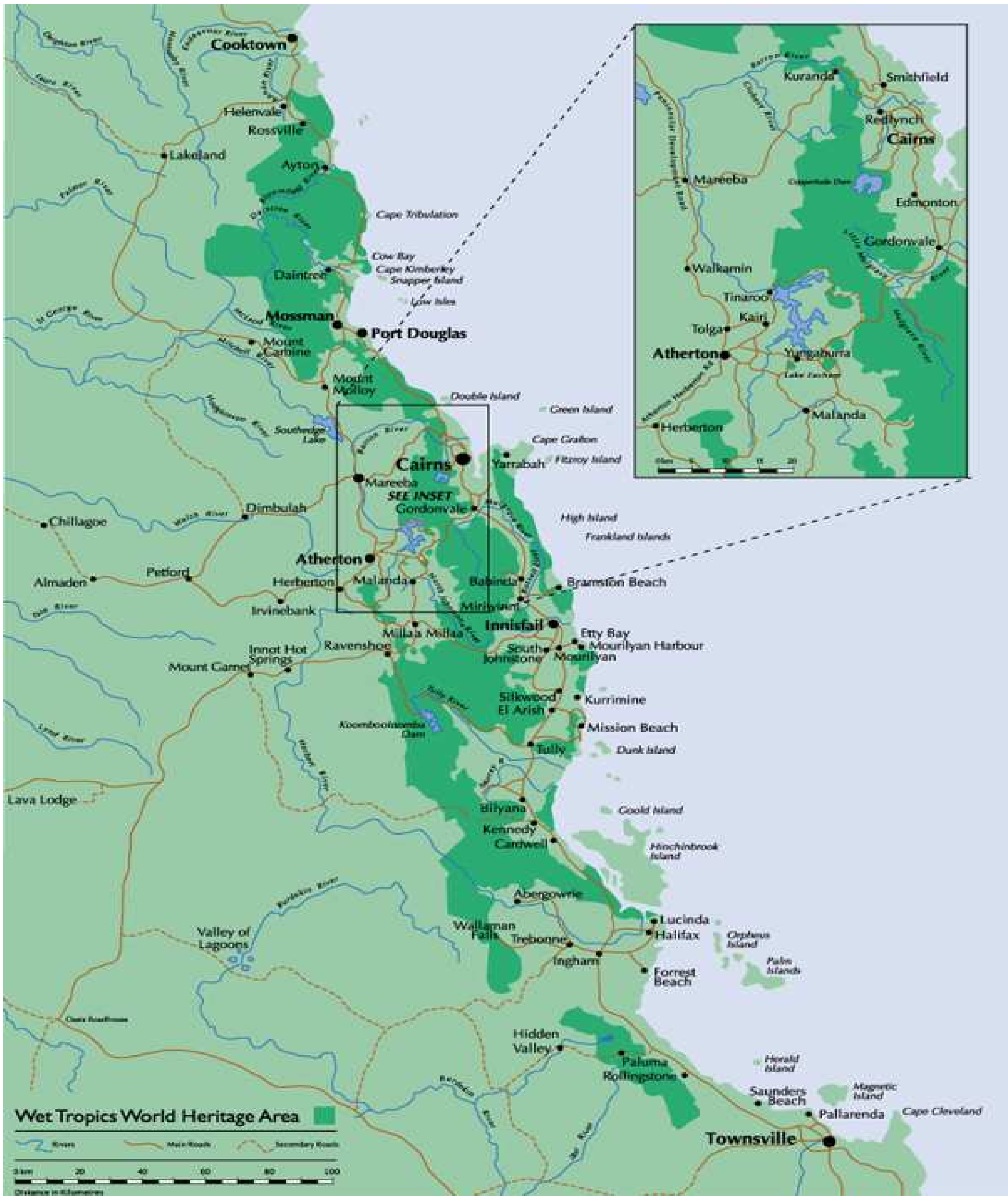
2. MATERIALS AND METHODS

2.1. Study sites

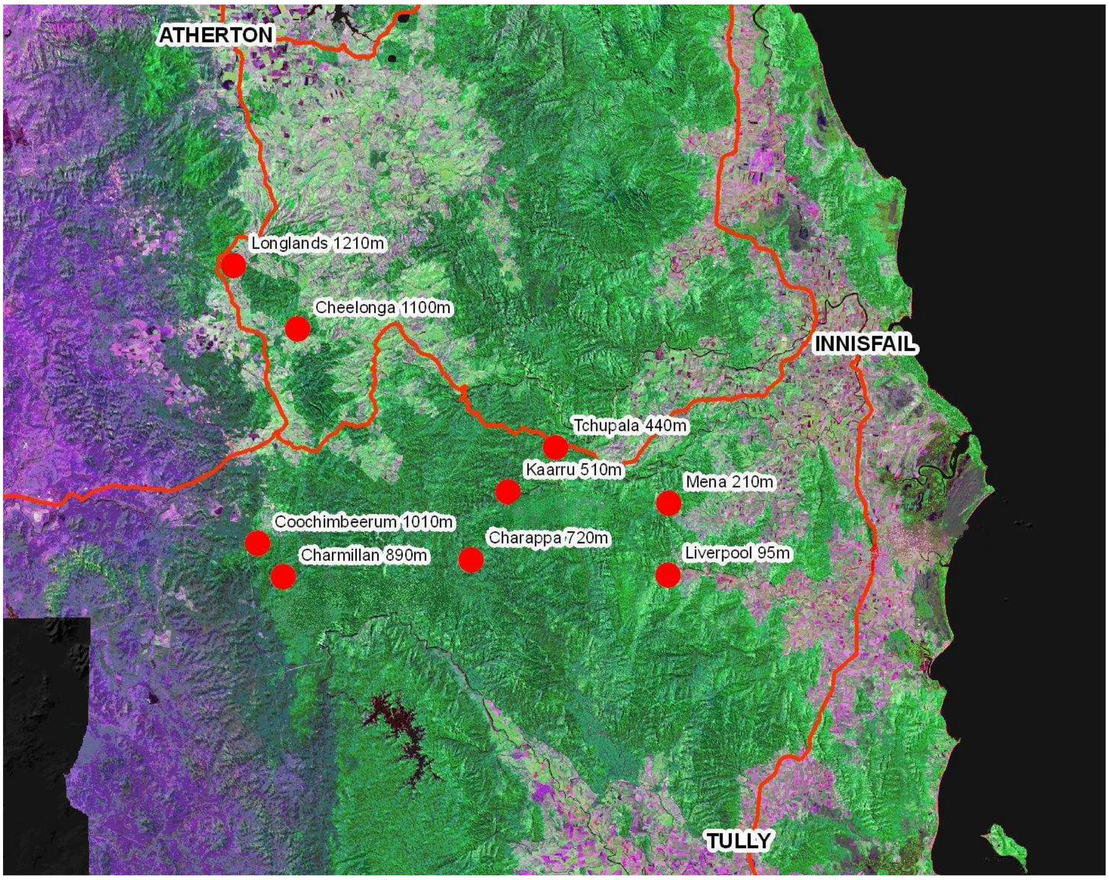
We studied the herbivory patterns in 9 of the 12 climate-change monitoring plots that the CSIRO – Tropical Forest Research Centre (TFRC) has established in the Wet Tropics area. They are set in an altitudinal gradient from 25m to 1210m ASL, with approximately 100m of elevation between each plot. The plots are 50x20m, so each plot has a surface of 0.1ha. Within every plot, all trees of 10cm (dbh) or more were tagged and are permanently marked and all the vascular plants present have been recorded. These plots are used for forest monitoring, weed, disease and mosquito studies. Map 1 shows the Wet Tropics Area in NE Queensland, and Map 2 shows the location of the 9 monitoring plots. In Table 1 there are the most relevant characteristics of the studied sites. 3 of the 12 climate change plots were not sampled due to absence of the study species or the high disturbance caused by cyclone Larry in 2006.

Plot name	Latitude (GDA)	Longitude (GDA)	Altitude (m)	Basal Area	Number of Trees
Liverpool	-17.71	145.86	95	35.71	91
Mena	-17.65	145.86	210	39.01	75
Tchupala	-17.60	145.76	440	46.57	83
Kaarru	-17.64	145.72	510	47.15	93
Charappa	-17.70	145.69	720	58.66	128
Charmillan	-17.71	145.52	890	34.64	87
Coochimbeerum	-17.68	145.50	1010	58.78	71
Cheelonga	-17.50	145.54	1100	50.09	72
Longlands	-17.45	145.48	1210	60.79	80

Table 1: Location, altitude, basal area and number of trees of the 9 monitoring plots. Source: CSIRO



Map 1: The Wet Tropics World Heritage Area Source: www.wetropics.gov.au



Map 2: Location of the 9 plots. Source: CSIRO

2.2. Sampling methods in the field

Sampling methods to determinate the rate of herbivory involved visual estimation of the percentage of leaf removed. In this study, we only considered phyllode-chewing to assess herbivory rates. The following scales was used: 0, <1, 1 – 5, 5 – 10, 10 – 15, 15 – 25, 25 – 50, 50 – 75, 75 – 100%, as done in Grubb et al. (2008). For each plant, we analysed 24 fully expanded leaves from a top, a mid-height and a bottom branch (8 leaves per branch). We sampled 75 random individuals from the understory in a shaded environment along a transect in each plot to obtain an outlook of the herbivory at the community level. We also sampled 10 individuals of the 2 following target species that we selected according to its presence throughout the altitudinal transect: *Mackinlaya confusa* and *Neolitsea dealbata*. For both species, we only sampled individuals from shaded environments and humanreaching size. The objective was to characterize how a single species is affected by altitude and therefore temperature in terms of herbivory.

To estimate the exact number of leaves per plant and the number of individuals that had to be sampled, we used preliminary data to relate confidence intervals to sample size, which showed the minimum number of samples required to achieve the desired confidence interval of 95%.

We also calculated the percentage of damaged leaves (with any level of damage) based on the herbivory data from the field.

2.3. Sampling methods in the laboratory

We also studied leaf toughness for every sampled individual of the target species at every altitude, so that we could compare physiological treats of the species at different altitude as well as compare between species, as leaf toughness may be another factor influencing herbivory rates. To do so, we used two Chatillon Dial Tension Gauge penetrometers, calibrated against an electronic pan balance on April 2005. On of them was a model AG50 measuring 0-50g which read consistently 0.0 to 0.3 below balance value; and the other was a model AG150 measuring 0-150g which read consistently 0.3 to 0.6g below balance value. Both had only marginally detectable deviations from the “true” weight.

2.4 Statistical methods

We performed statistical tests to check the normality of the data, and in all the cases the analysis showed that the studied variables were normally distributed. Thus no data transformation was required. Linear regression analysis and Pearson correlation coefficients were used to quantify association between pairs of continuous variables. Multiple linear regression models were to model the relationship between the two response variables (Percentage of damaged leaves and mean leaf area loss) and explanatory variables, including mean annual temperature (MAT), basal area (BA) and plant diversity (H). Annual rainfall was not included in multiple regression models as it was highly correlated with mean annual temperature, potentially leading to multicollinearity and its associated problems (Gotelli & Ellison, 2004). All analyses were performed with the package SPSS and regressions were made with Excel.

3. RESULTS

In general, we observe significant increases in both mean leaf area loss and percentage of damaged leaves with increasing temperature (Fig. 1 and 2).

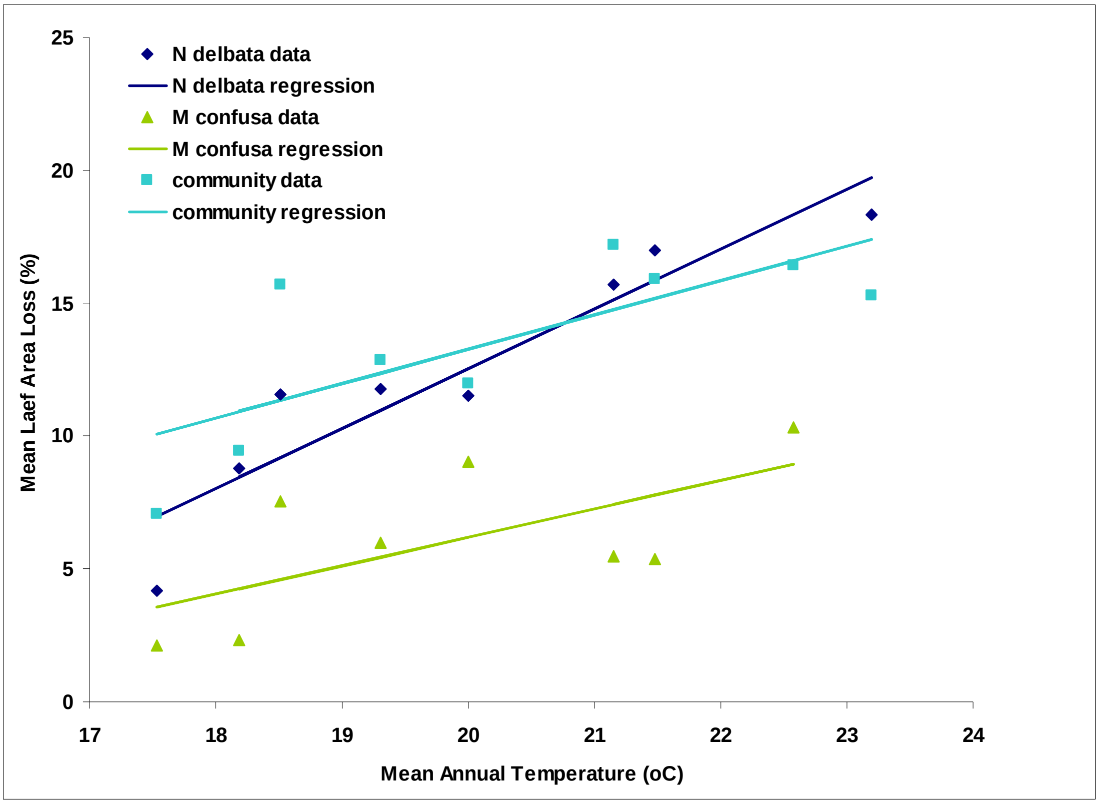


Fig 1: Mean leaf area loss and temperature regression for the community level, *N. dealbata* and *M. confusa*.

As we observe in Fig. 1, the mean leaf area loss for all samples goes from 2% to no more than 20%. In particular, for *Neolitsea dealbata* it increases from 4 to 17% (R^2= 0.87, p=0.0007), for *Mackinlaya confusa* it increases from 2 to 10% (R^2= 0.83, p=0.004), and for the community as a whole it ranges from 7 to 17% (R^2= 0.59, p= 0.015). In all cases the regressions are significant ($p<0.05$). Therefore, both for the overall community and for the two individual species leaf area loss is positively related to temperature.

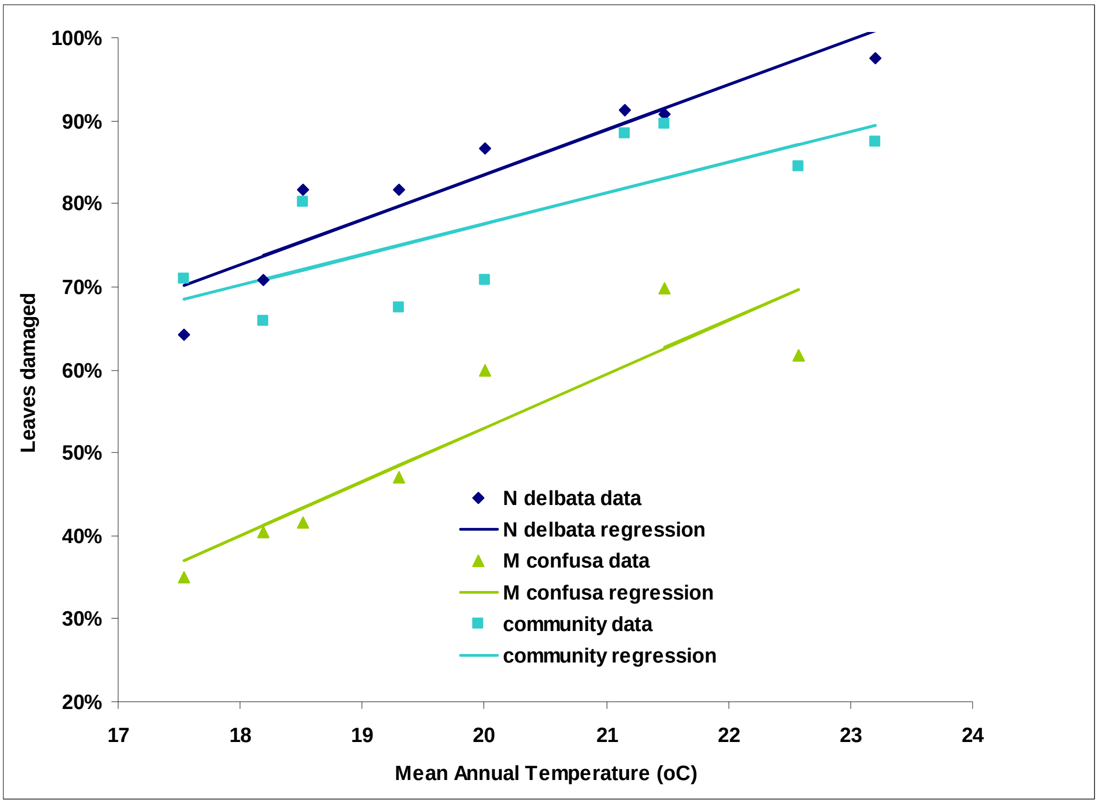


Fig. 2: Damaged leaves and temperature regression for the community level, *N. dealbata* and *M. confusa*.

The percentage of damaged leaves (Fig. 2) also increases as a function of temperature from approximately 65 to 85% for the community sampling (R^2 = 0.59, p=0.015). In this case, the trend is only marginally significant (p>0.01). For *N. dealbata*, the values of damaged leaves increase from 60 to 95% (R^2 = 0.87, p=0.0007), and shows the highest values registered in this study. Finally, *M. confusa* values also increase with temperature, from 35 to 70% (R^2 = 0.83, p=0.004). The regression is highly significant for the two species, showing a significant relationship between mean annual temperature and the percentage of damaged leaves.

A correlation analysis was performed (Table 2) in order to test whether mean leaf area loss and the percentage of damaged leaves were associated with other factors besides temperature. Studied explanatory variables included annual rainfall (AR), basal area (BA) and plant diversity (H), all available for all study plots. The tests were conducted at the community level as well as using data on the two sampled species. For the community level the percentage of leaf area loss showed no significant correlation with the AR, BA or Diversity. The damaged leaves variable showed no significant correlation with the other parameters.

For *M. confusa*, the Leaf Area Loss showed no significant correlation with any of the variables. We found a tendency within the AR correlation (R^2=0.70, p=0.081). No significant correlation was found with the BA or the Diversity.

For *N. dealbata*, both the Leaf Area Loss and the Damaged Leaves showed no significant correlations with the studied variables. In all cases, temperature was significant or showed a positive trend, but the effect of temperature has been already studied with the simple regressions, and it is not showed in this test.

		Annual Rainfall	BA	Site diversity Spp
%Loss Community	Pearson's Correlation	0,327	-0,462	0,531
	Sig. (bilateral)	0,39	0,21	0,142
	N	9	9	9
%Damaged Community	Pearson's Correlation	0,636	-0,292	0,464
	Sig. (bilateral)	0,066	0,447	0,208
	N	9	9	9
% Loss *M. confusa*	Pearson's Correlation	0,272	-0,236	0,345
	Sig. (bilateral)	0,514	0,574	0,402
	N	8	8	8
% Damag. *M. confusa*	Pearson's Correlation	0,699	-0,372	0,466
	Sig. (bilateral)	0,081	0,411	0,292
	N	7	7	7
% Loss *N. dealbata*	Pearson's Correlation	0,542	-0,622	0,654
	Sig. (bilateral)	0,165	0,1	0,079
	N	8	8	8
% Damag *N. dealbata*	Pearson's Correlation	0,543	-0,535	0,595
	Sig. (bilateral)	0,164	0,172	0,12
	N	8	8	8

Table 2: Correlations between herbivory and damage parameters with climate and ecologic variables.

Multiple regression analysis showed that, at the community level, leaf loss was mainly influenced by temperature, but the relationship was not statistically significant (Table 3). Leaf damage showed a better relationship (R^2=0.692, with a significant effect of temperature (p=0.04) (Table 4). Similar results were obtained in the models for *M. confusa* (R^2= 0.517 and R^2=0.978 for leaf loss [Table 5] and leaf damage [Table 6], respectively). Tables 7 and 8 show the results for *N. dealbata*, where the effect of temperature was always significant and the other variables were never significant. The effect of temperature was significant in all leaf damage cases (p<0.05), whereas basal area and diversity were never significant.

Variable	Standardized Coefficients	Degrees of freedom	p
	Beta		
MAT	0,741	3	0,197
BA	0,053	3	0,9
Site diversity Spp	0,054	3	0,899

Table 3: Multiple regression results for the mean leaf area loss at the community level.

Variables	Standardized Coefficients	Degrees of freedom	p
	Beta		
MAT	1,133	3	0,041
BA	0,411	3	0,273
Site diversity Spp	-0,131	3	0,712

Table 4: Multiple regression results for the damaged leaves at the community level.

Variables	Standardized Coefficients	Degrees of freedom	p
	Beta		
MAT	1,035	3	0,148
BA	0,374	3	0,469
Site diversity Spp	-0,2	3	0,693

Table 5: Multiple regression results for the mean leaf area loss of *M. confusa*

Variable	Standardized Coefficients	Degrees of freedom	p
	Beta		
MAT	1,412	3	0,002
BA	0,448	3	0,03
Site diversity Spp	-0,303	3	0,078

Table 6: Multiple regression results for the leaf damage of *M. confusa*

Variables	Standardized Coefficients Beta	Degrees of freedom	p
MAT	0,9	3	0,038
BA	-0,002	3	0,993
Site diversity Spp	0,048	3	0,852

Table 7: Multiple regression results for the mean leaf area loss of *N. dealbata*

Variable	Standardized Coefficients Beta	Degrees of freedom	p
MAT	1,091	3	0,017
BA	0,164	3	0,507
Site diversity Spp	-0,072	3	0,766

Table 8: Multiple regression results for the leaf damage of *N. dealbata*

The effect of leaf toughness on herbivory was studied on the two target species (not at the community level) using linear regression (Fig. 3 and 4). Our results showed no significant effect of toughness on either mean leaf area loss (Fig. 3) and percentage of damaged leaves (Fig. 4).

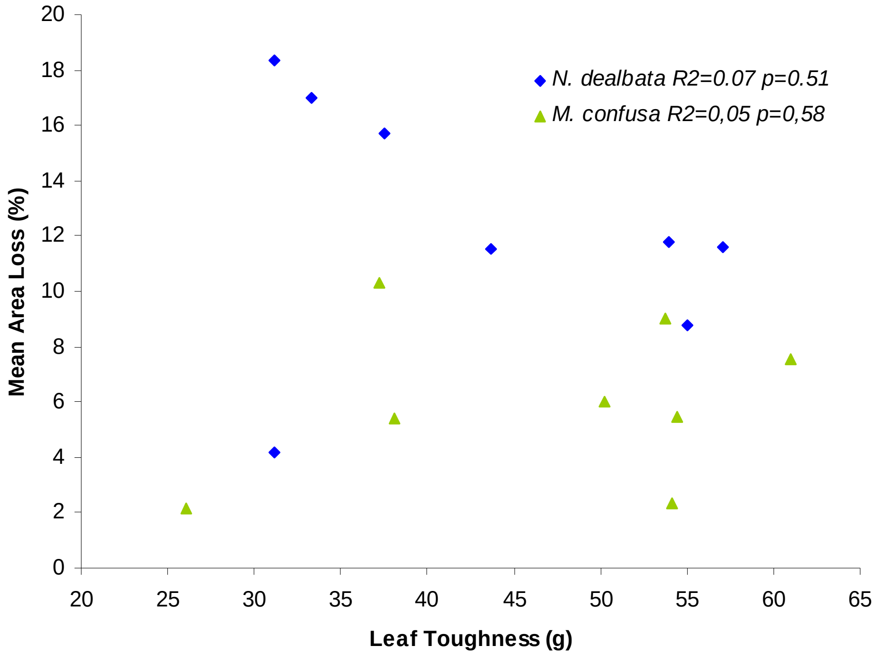


Fig. 3: Mean Leaf Area Loss and Leaf Toughness regression for *N. dealbata* and *M. confusa*.

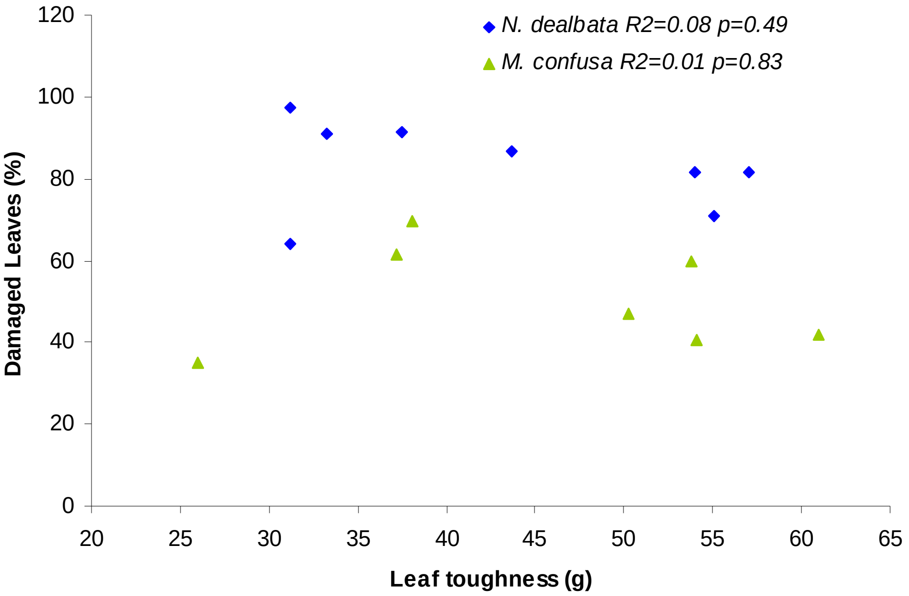


Fig. 4: Damaged Leaves and Leaf Toughness regression for *N. dealbata* and *M. confusa*.

4. DISCUSSION

The main observation made from this study is that the levels of insect damage (either leaf area removed or damaged leaves) increase along with temperature. At the community level, the observed rates of herbivory increased 1.3% $^{o}C^{-1}$ for the Mean Leaf Area Loss and 3.7% $^{o}C^{-1}$ for the Damaged Leaves. If we assume that current differences in temperature among sites are analogous to future temperature changes within a site, the previous values can be translated into predictions under climate change scenarios. Thus, if air temperature raises 3.5 degrees in the area, as predicted by some scenarios (Suppiah et al., 2009), the leaf area loss would increase 4.6% and the damaged leaves would increase 13%. These are expected results if we expect insect activity to increase along a positive temperature gradient (Bale, 2002), and knowing that increasing temperature shows higher herbivore attacks (Andrew, 2005; Coley, 1996). These results are, nevertheless, not enough to fully understand the response from tropical forests to global warming. Although it's clear that there will be changes (more damage) and alterations, further research is needed in order to achieve more accurate conclusions. The obtained results are based on a temperature change along an altitudinal gradient, but given the prediction of increasing temperature in the future due to global warming, the present results are interpreted as an analogy of future global warming scenarios, so that they provide useful information for understanding the response of the ecosystem to the expected temperature changes. This is the main goal of a study of this kind and the same approach has been used by many other studies (Dunne et al. 2004).

The statistical tests that were performed suggest that the percentage of damaged leaves has a higher sensitivity to temperature than the mean leaf area loss (due to more significant results). Also, it is more influenced by temperature in the multiple regressions, so it might be a more suitable parameter to detect the effect of temperature changes than the amount of leaf area removed.

More specifically, the regressions from the two species show higher coefficients of determination (R^2) than the community ones. This is an expected result as the community level shows the response to herbivory from many plant species whereas the targes species focus on the selected species and results are more accurate. At the community level different species may respond in different ways, compensating each other.

We also observe how *M. confusa* has less damage level in both regression analyses. This could be due to stronger physical or chemical defences. According to our leaf toughness results, no correlation is found between insect attacks and leaf toughness, either within or between the two studied species, and therefore we suggest that *M. confusa* has stronger chemical defences than *N. dealbata*. This is also corroborated by the studies made by Hartley, (2007), who found that secondary chemical metabolites are more important against herbivory than physical defences.

Climate predictions for the next decades show that the global temperature of the world will increase up to 6 degrees by 2070 (IPCC, 2008), and up to 5 degrees in the Wet Tropics. This fact, combined with the results obtained in this study, leads to the conclusion that global warming is going to increase insect herbivory in the Wet Tropics rainforest. However, there are many factors that have not been taken into account in this study, such as changes in plant physiology and morphology under raising temperature, rainfall and CO_2 concentration changes due to climate change and unknown insect responses to these changes, to name a few. There are, nevertheless, several studies showing how in the past, during the Paleocene-Eocene Thermal Maximum, herbivory increased during a global warming episode (Currano, 2008; Wilf, 1999). More recently, De Lucía (2008) found that in the event of a combined increase of temperature and carbon dioxide, herbivore insects would increase their damage rate. Together with the present study, these results are alarming for the conservation of the Wet Tropics Area. It is thus possible that global warming increases herbivory in the Wet Tropics bioregion.

Considering that NE Queensland rainforests are expected to be highly sensitive to global warming (Hilbert, 2001), the expected temperature increments could put a real threat to one of the most diverse and unique ecosystems of the world.

5. CONCLUSIONS

The present study shows that temperature affects insect herbivory on tropical forests in NE Queensland. Both the community and the target species showed the same trends of increasing damage with increasing temperature along an altitudinal gradient. This is interpreted as analogous to the response of the forest to expected global warming. Although this study is partial in that it only looks at the effect of temperature on leaf herbivory, its results suggest that important changes at the community level are to be expected in tropical forests as a result of climate change. Given the foreseen climate predictions and along with the Paleocene-Eocene warming episode data it is important to continue studying the effects of temperature on insect herbivory in the Wet Tropics, because the fast changes that climate is experiencing might not leave nature enough time to evolve, reducing plant dispersal or altering plant-insect relationships (Coley, 1999)

It is essential to carry out larger studies (or experiments) and also look at other response variables such as rainfall, CO_2, diversity, predation etc. as well as to investigate on insect response to climate change to predict the effects of changed insect herbivory on other components of the ecosystem and, more generally, how global warming is going to affect tropical forests. Similar experiments carried out with different methods (leaf scanning, photography) and more sampling sites for a same altitude would provide more accurate results and they would be very useful in order to compare and decide the best way of developing these studies.

Moreover, a multidisciplinary approach is needed in order to manage the scientific, cultural and economical aspects of climate change in the area, in order to preserve all the important values associated with a forested area such as the Wet Tropics of Queensland.

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7. BUDGET

DIRECT EXPENSES	
HUMAN RESOURCES	
Research and Project elaboration	
Item	Subtotal (hours)
Experimental design and reference research	480
Meetings	20
Meetings with Supervisors	15
Field Work	100
Writing	350
Total (hours)	965
Cost = 20€/hour	**Subtotal (€)**
	19,300 €
Travelling	
Item	Distance (Km)
5 meetings with the Project Supervisor (Bellaterra)	150
12 Field trips	1500
1 Overseas Trip	1600 € (not accounted in distance)
Total distance (Km)	2150
Cost (fuel price) = 0,19 €/km	**Subtotal (€)**
	1913 €
TOTAL HUMAN RESOURCES	**21,213 €**

MATERIAL RESOURCES			
Item	Qty	Item/price (€)	Subtotal (€)
Printing	80	0,04	3.2
Copies	3	2	6
CD copies	4	0,5	2
Binding	4	2	8
TOTAL MATERIAL RESOURCES			**19.2 €**
TOTAL DIRECT EXPENSES			**21,232 €**

INDIRECT EXPENSES	
Equipments and facilities	**Total (€)**
20% of the direct expenses	**4,246 €**

Total direct expenses	21,232 €
Total indirect expenses	4,246 €
Basic Budget	25,478 €
IVA (VAT) (16%)	4,077 €
TOTAL BUDGET	**29,555€**

8. TIMELINE

Task	September				October				November				December				January				June				July				August				September			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Project election and paperwork	■	■																																		
Reference and bibliography research			■	■	■	■	■	■	■	■																										
Experimental design					■	■	■	■	■	■	■																									
Interviews and meetings			■	■		■		■			■																									
Fieldwork					■				■				■	■	■	■	■	■																		
Project Writing										■	■	■							■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Meetings with supervisors	■			■		■			■			■	■		■						■			■		■		■								
Project hand-in																																	■			
Oral defense preparation																																	■	■	■	
Oral defense																																			■	

9. VALORACIÓ FINAL

Arribats a aquest punt, i després de tantes pàgines escrites en anglès, em permetré la llicència d'escriure aquest apartat en català, la meva llengua materna. No hi ha millor manera d'expressar les opinions, les experiències i els sentiments que en la llengua pròpia.

La idea d'aquest projecte, va començar a gestar-se des del primer any de carrera. No pel que fa al tema, sinó pel que fa a la seva realització a l'estranger. La fascinació per viatjar i per Austràlia en concret han marcat indubtablement les decisions que vaig prendre per tal de poder marxar a l'altra punta del món a fer el projecte. I han valgut la pena. Pel que fa al tema del projecte, es va anar despertant dins meu l'interés per la ecologia i els boscos durant la carerra, a ran de diverses assignatures cursades, així com pel tant famós canvi climàtic, i de la voluntat d'unir aquests dos temes en va sorgir aquest estudi.

Aquest projecte es va dissenyar amb la idea d'obtindre'n un article científic publicable. Gran va ser la decepció al saber que el format d'entrega no podia ser aquest. Fins aleshores, estava dissenyat per tenir extensió reduïda i publicable. No obstant, no ha estat la fi del món, sinó ben al contrari: ha estat interessant el fet d'haver d'ampliar la recerca a àmbits més diversos, arribant a incorporar a la introducció aspectes multidisciplinaris com el turisme, la cultura i la ciència. La reestructuració del projecte ha significat una ampliació de les mires d'aquest estudi. Tal i com hem desenvolupat durant la Llicenciatura, els aspectes que afecten al medi natural són molts i diversos, i en última (i a vegades primera) instància, cal integrar-los tots. Per arribar a aquesta integració cal estudiar en profunditat tots els vectors que hi intervenen, i aquesta és la principal contribució a les Ciències Ambientals d'aquest projecte: L'estudi científic d'una zona d'alt interès natural, social i econòmic que pot ajudar en un futur, a prevenir, conservar, o remeiar allò que la amenaça, en aquest cas, el canvi climàtic.

Com a continuïtat amb aquest projecte, i fidel a la idea original (i a les expectatives dels científics d'Austràlia que van ajudar-me en aquest projecte), està pensada la publicació d’un article científic sobre el tema. Els bons resultats obtinguts i la exclusivitat en el tema, gairebé asseguren l’interés d’alguna revista científica per publicar-lo, segons paraules textuals del tutor de projecte a Austràlia. Segons el meu parer, seria la culminació d’una feina portada a terme amb interès i il·lusió, ja que una publicació és el punt màxim on pot arribar una investigació d’aquestes característiques.

El camí recorregut ha estat a vegades dur, ja que les diferències lingüístiques hi influeixen, així com la distància de les persones conegudes, les dificultats trobades a certes fases del projecte que porten al desànim, la dura feina de camp a la selva; i sobre aquest últim apartat es podria fer un article sencer: Les paparres, sangoneres, serps, aranyes, els terrenys relliscosos, les dificultats d’accés, les plantes urticants, punxegudes, enganxoses, la calor asfixiant i la humitat exagerada, els avisos d’huracà... tots han fet que la feina de camp sigui dura fins a extrems insospitats. Tot plegat ara ja forma part de l’essència del projecte i fan que la feina feta i recollida dins d’aquest document gairebé conclòs, sigui gratificant.

A part de la feina relacionada amb aquest projecte, durant la estada Austràlia, també vaig tenir la oportunitat de treballar en altres projectes que es duien a terme al centre de recerca on treballava. Projectes de monitorització i interacció entre espècies protegides (Cassowaries) i l’ésser humà i el turisme, de vectors de malalties a través dels ocells i mosquits, de dispersió de llavors, entre d’altres, han contribuït a la meva formació acadèmico-científica multidisciplinar i a agafar el rigor necessari per la feina ben feta.

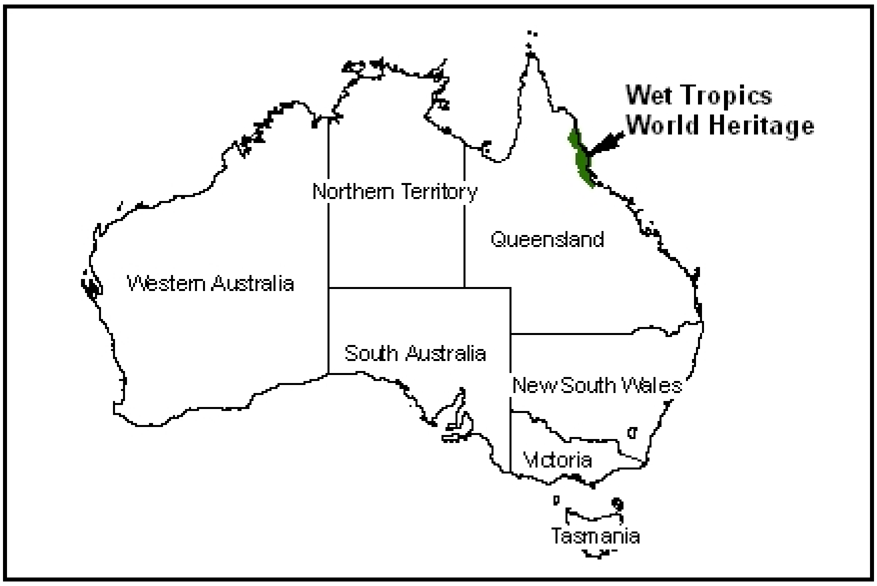
Aquest projecte, ha estat una experiència única, i gairebé podria qualificar-se d’aventura. Un país-continent, Austràlia, una regió selvàtica inèdita a la meva vida mediterrània, una presa de contacte de luxe amb la ciència. Tot ha estat meravellós, tant en el sentit personal com en l’acadèmic. Sens dubte, és una experiència recomanable per a qualsevol estudiant de la Ciències Ambientals que tingui afany de viatjar, de conèixer una nova cultura, de treballar en un centre d’alt nivell, amb científics de renom i amb nivells d’exigència elevats, molt útils per a introduir-se a la vessant més professional del món de la ciència.

8. ANNEXES

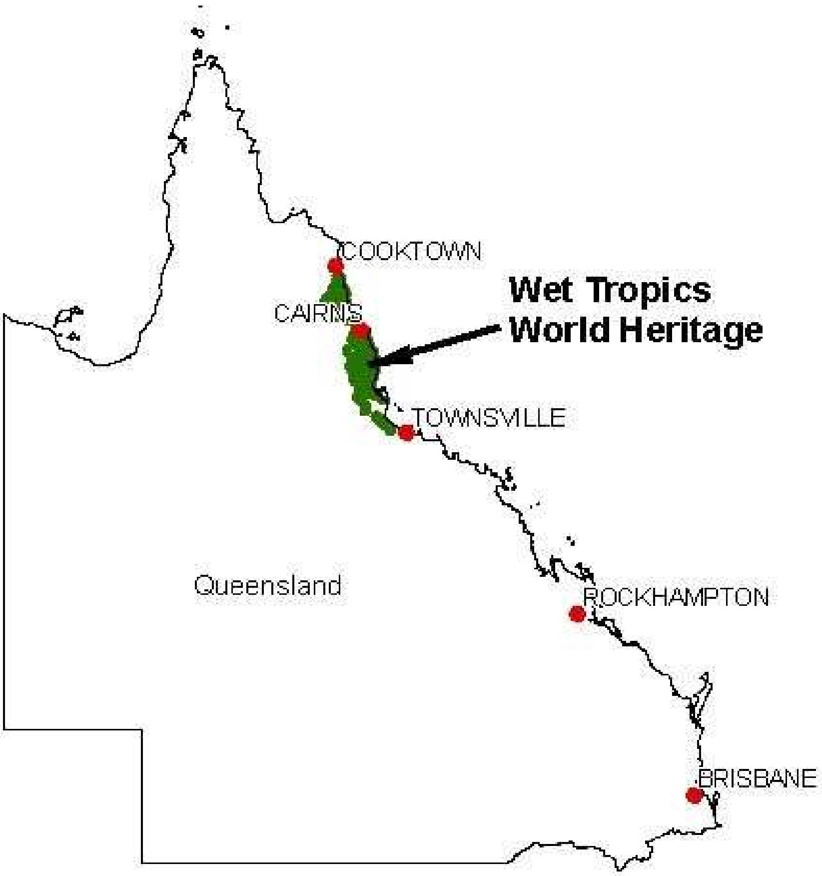
A – Maps of the Wet Tropics
B – Climate Change Figures
C – Studied Species
D – Climate Change Plots Characteristics
E – Recorded vascular plants in the Climate Change Plots
F – Field Data (in CD)

ANNEX A:

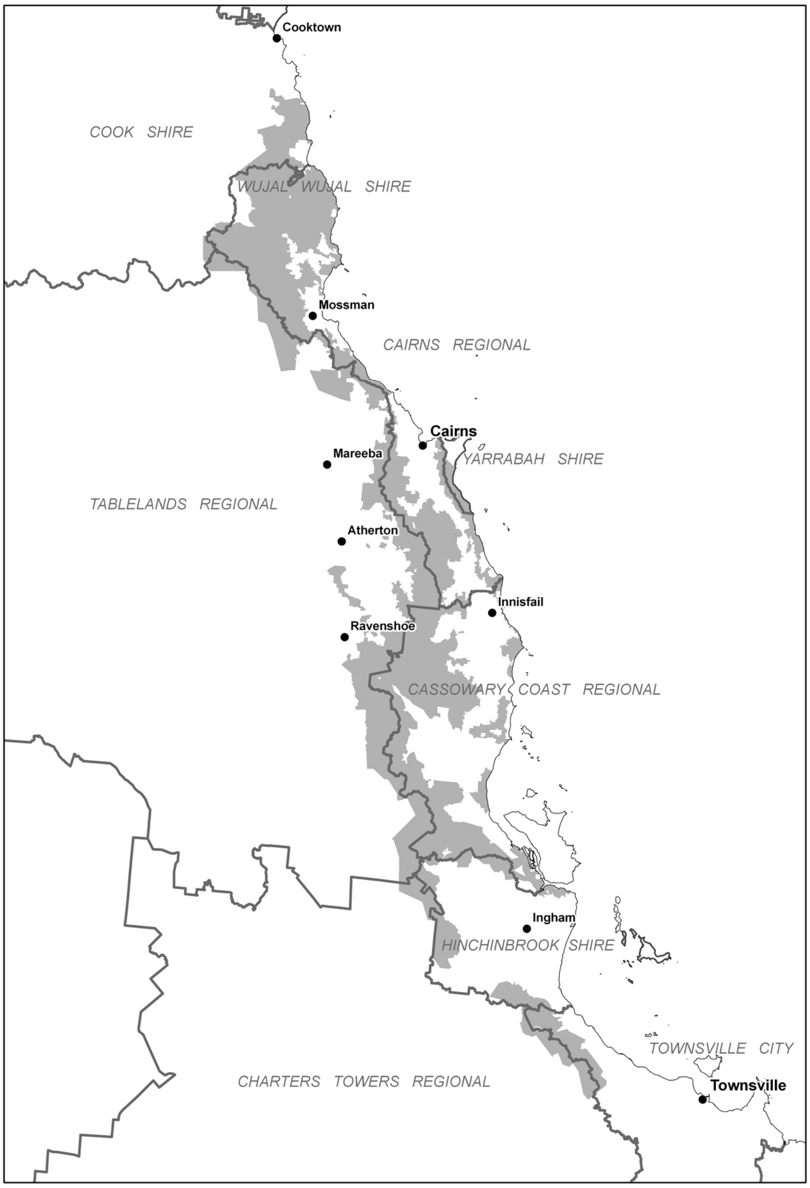
Maps of the Wet Tropics



Map A1: General situation of the Wet Tropics of Queensland in Australia.
Source: Wet Tropics Management Authority

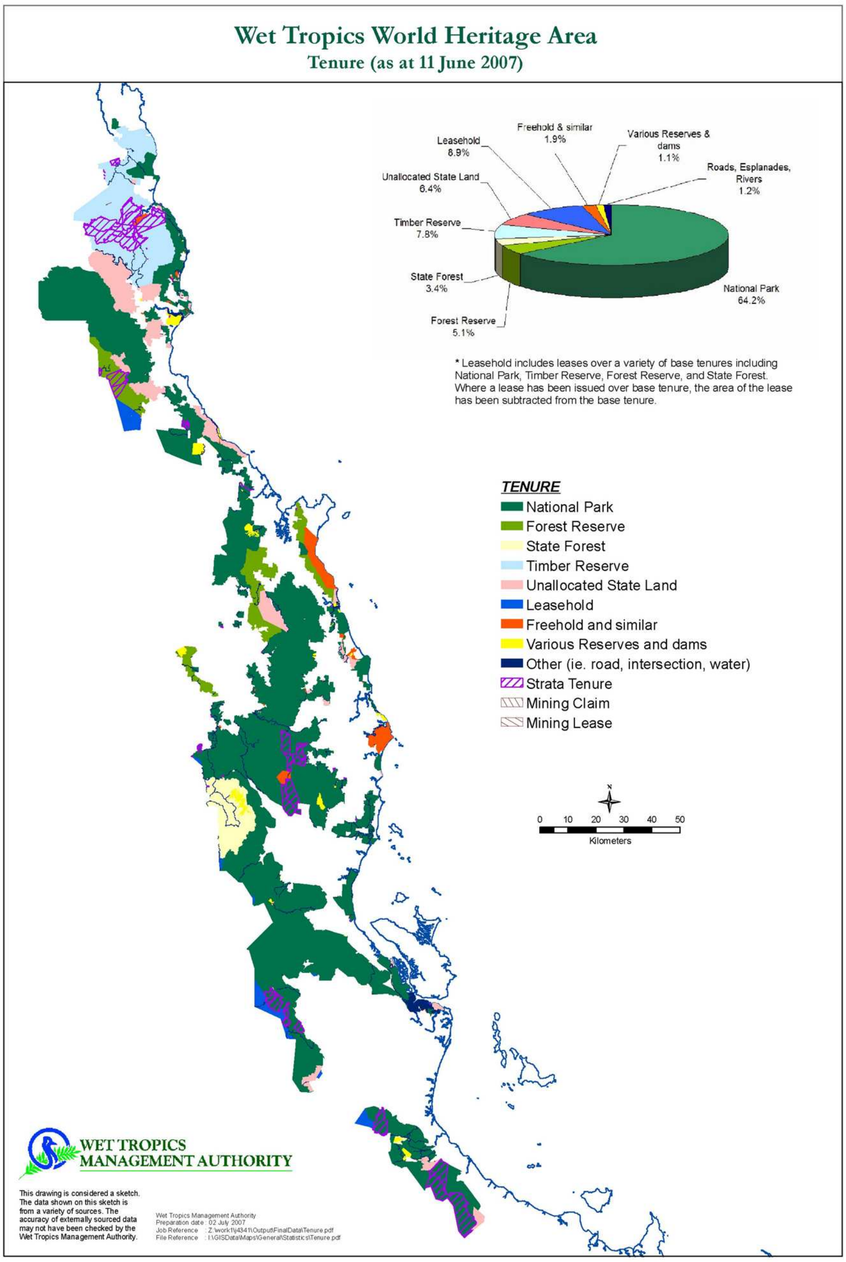


Map A2: Situation of the Wet Tropics World Heritage Area in Queensland.
Source: Wet Tropics Management Authority



Map A3: The Wet Tropics World Heritage Area and shires. Source: Wet Tropics Management Authority

Map A4: The Wet Tropics World Heritage Area and the road network and main rivers. Source: Wet Tropics Management Authority



Map A5: Land Tenure in the Wet Tropics World Heritage Area. Source: Wet Tropics Management Authority

ANNEX B:

Climate Change Figures

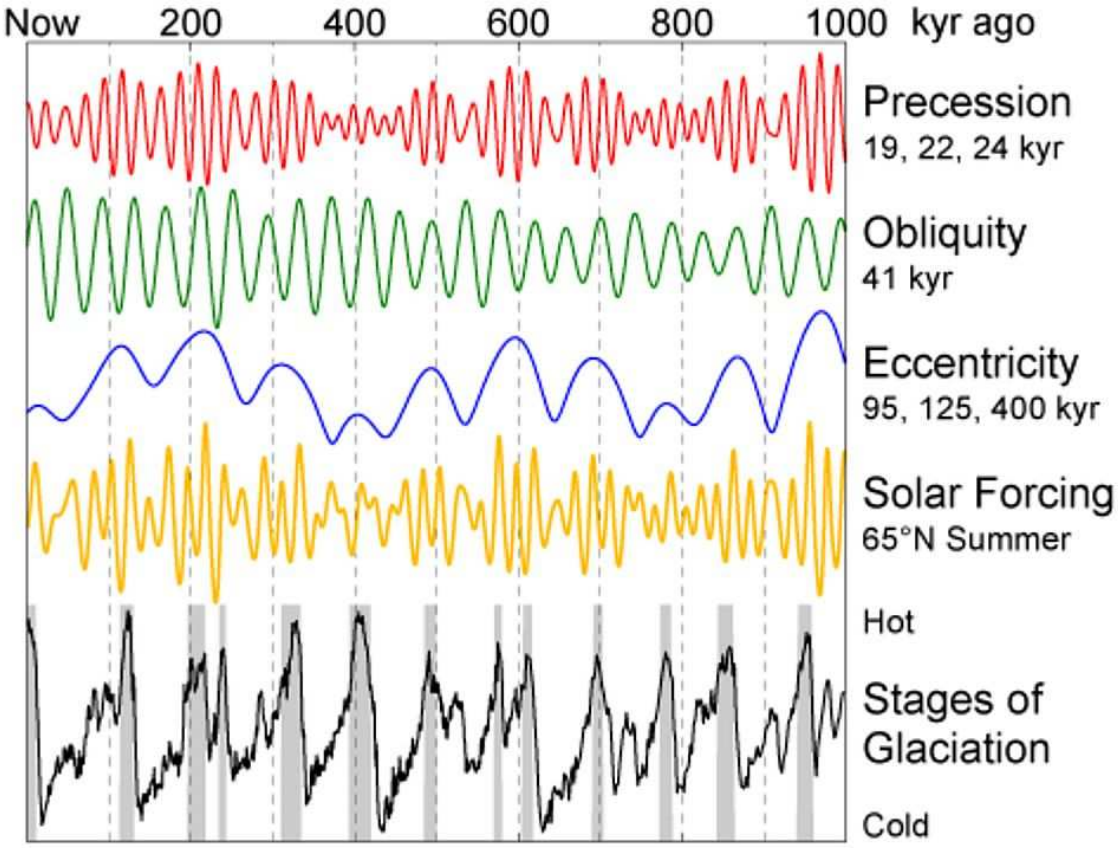


Figure B1: Variations of the parameters driving natural climate changes. Source: Adapted from the Pollution Chemistry course material.

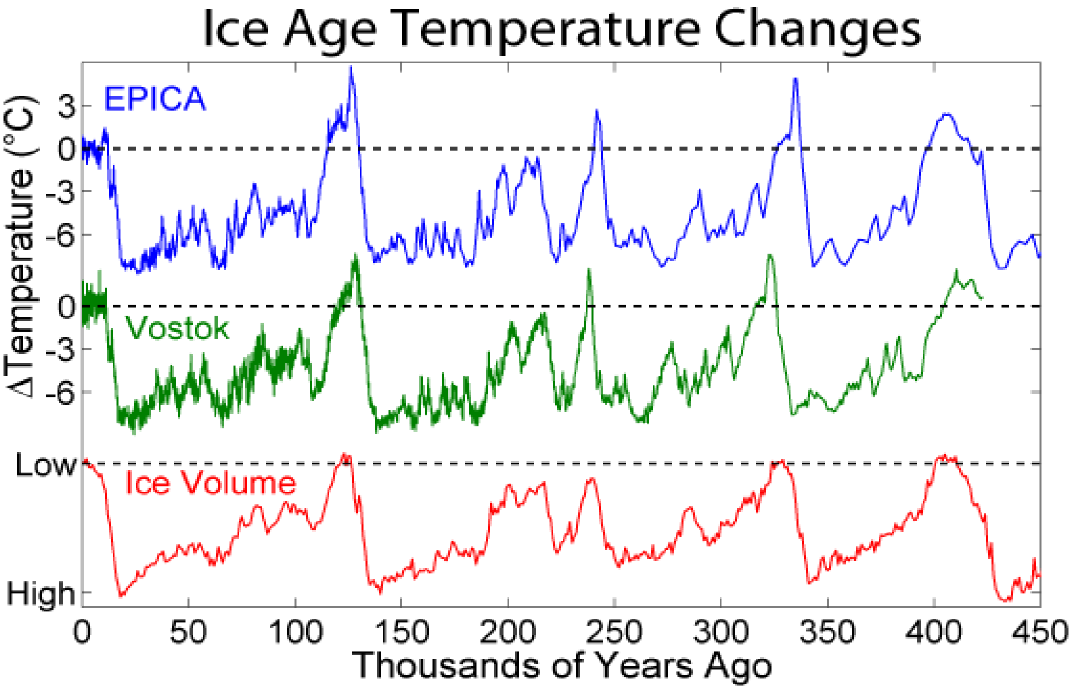
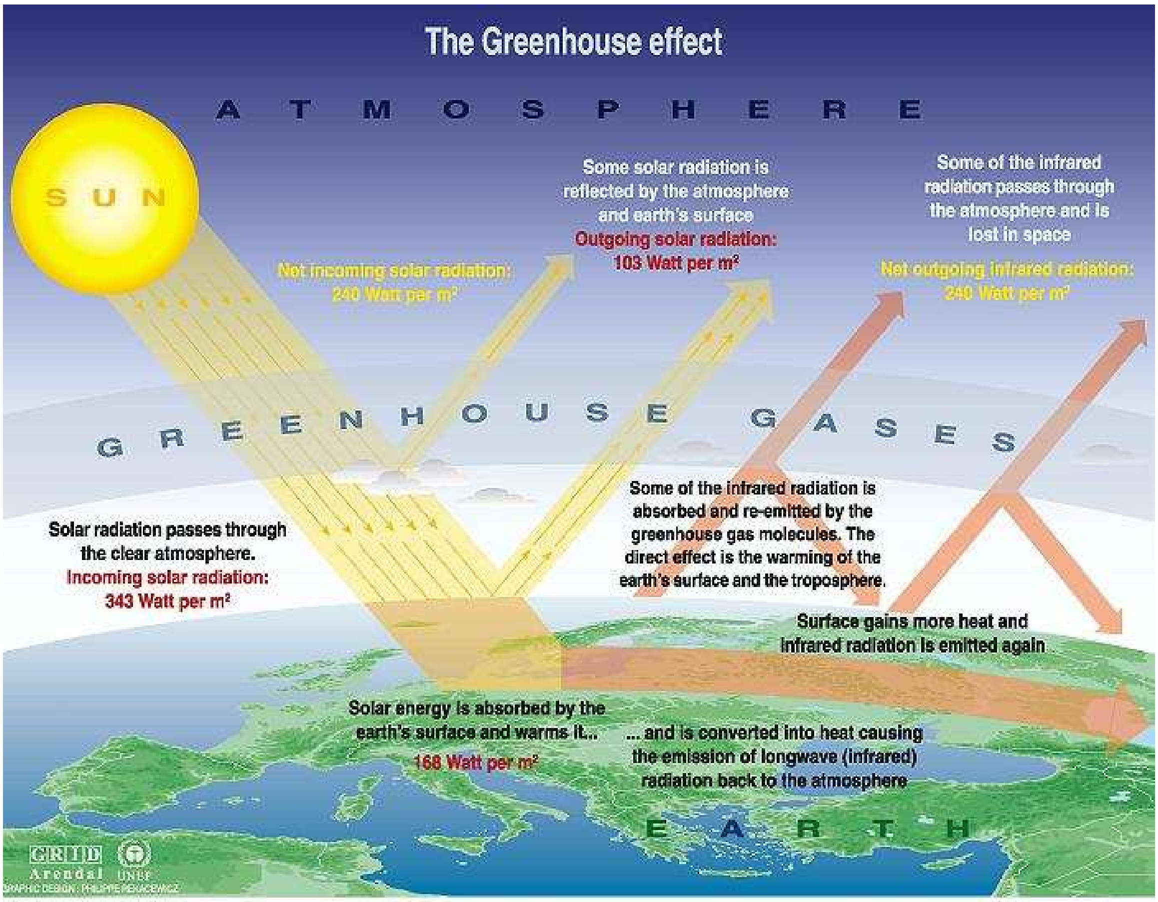
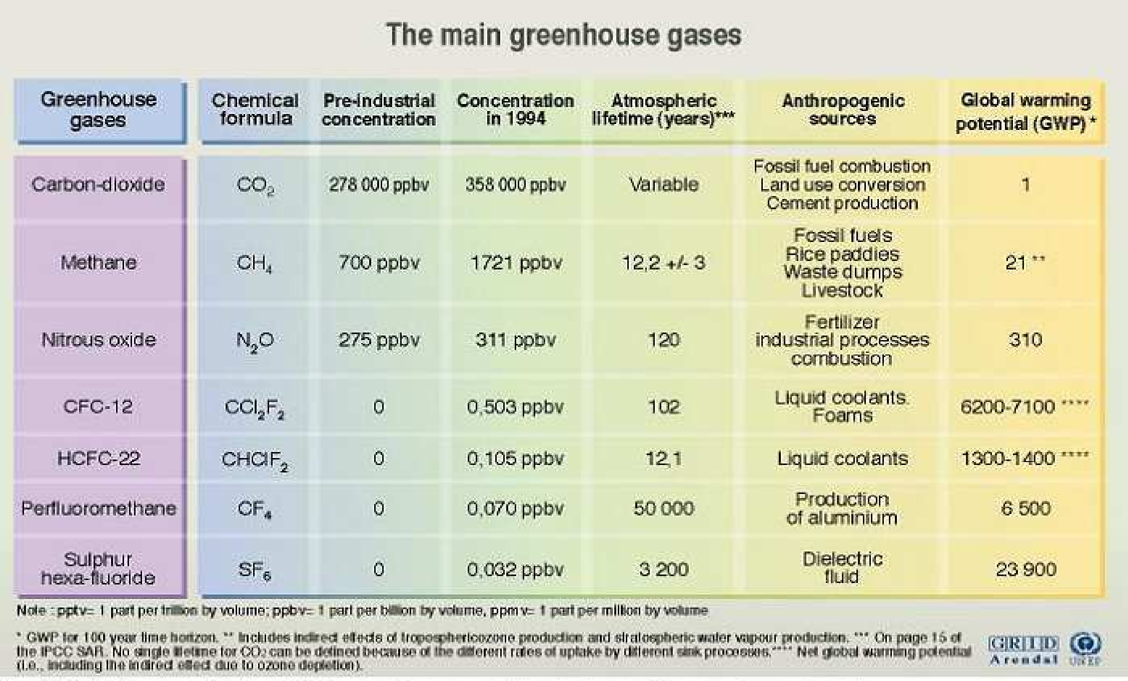


Figure B2: Ice Age temperature changes in different data records. Source: Adapted from the Meteorology course material.



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Figure B3: Greenhouse effect diagram. Source: Adapted from the Pollution Chemistry course material.



The main greenhouse gases

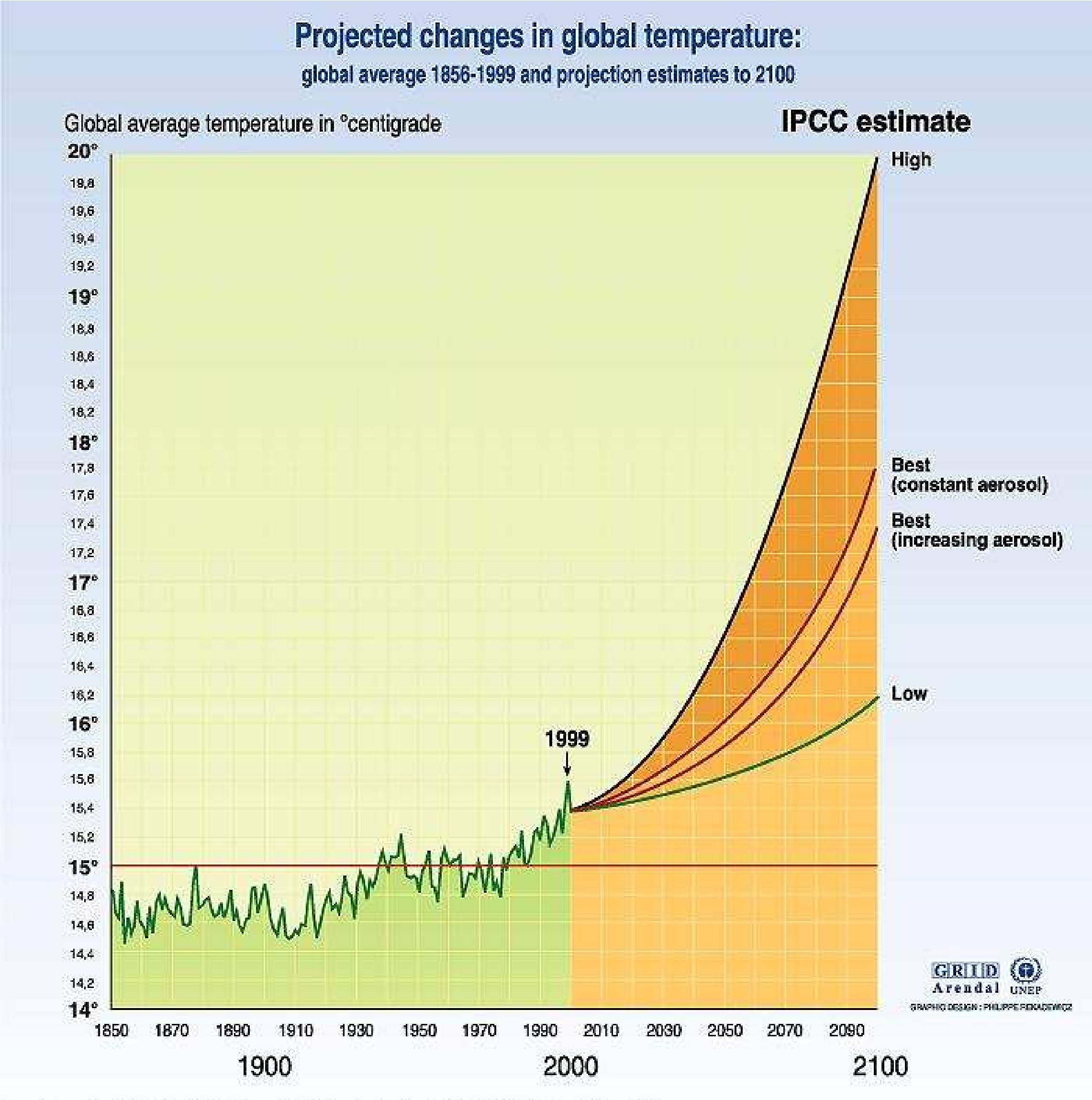
Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)***	Anthropogenic sources	Global warming potential (GWP)*
Carbon-dioxide	CO_2	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production	1
Methane	CH_4	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock	21 **
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion	310
CFC-12	CCl_2F_2	0	0,503 ppbv	102	Liquid coolants. Foams	6200-7100 ****
HCFC-22	$CHClF_2$	0	0,105 ppbv	12,1	Liquid coolants	1300-1400 ****
Perfluoromethane	CF_4	0	0,070 ppbv	50 000	Production of aluminium	6 500
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3 200	Dielectric fluid	23 900

Note : pptv= 1 part per trillion by volume; ppbv= 1 part per billion by volume, ppm v= 1 part per million by volume

* GWP for 100 year time horizon. ** Includes indirect effects of tropospheric ozone production and stratospheric water vapour production. *** On page 15 of the IPCC SAR. No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes.**** Net global warming potential (i.e., including the indirect effect due to ozone depletion).

Source: IPCC radiative forcing report ; Climate change 1995, The science of climate change, contribution of working groupe 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Figure B4: Main greenhouse gases in the atmosphere. Source: IPCC



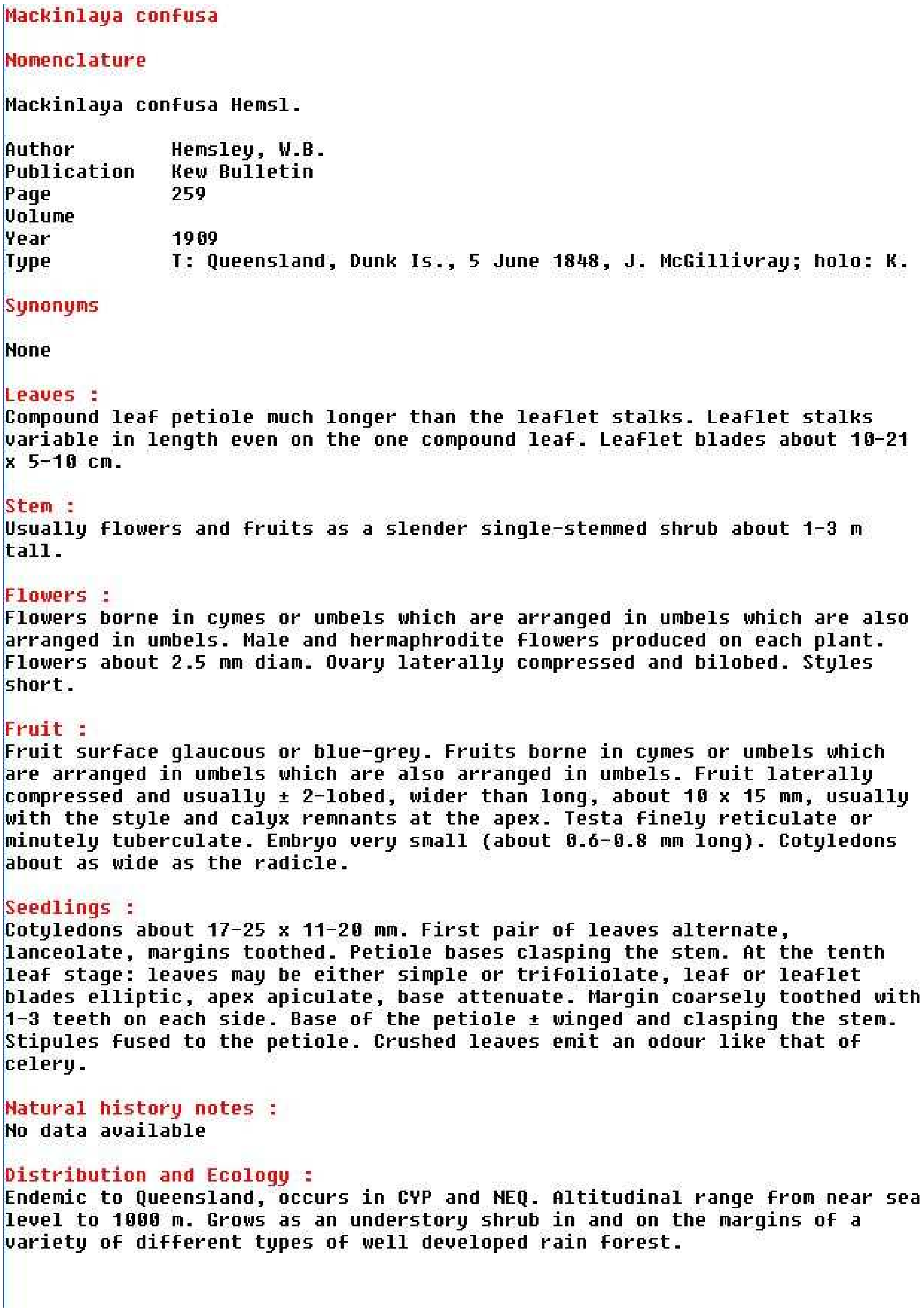
Source : Temperatures 1856 - 1999: Climatic Research Unit, University at East Anglia, Norwich UK. Projections: IPCC report 95.

Figure B5: Climate change projections. Source: Adapted from the Pollution Chemistry course material.

ANNEX C:

Studied Species

Mackinlaya confusa



Mackinlaya confusa

Nomenclature

Mackinlaya confusa Hemsl.

Author	Hemsley, W.B.
Publication	Kew Bulletin
Page	259
Volume	
Year	1909
Type	T: Queensland, Dunk Is., 5 June 1848, J. McGillivray; holo: K.

Synonyms

None

Leaves :
Compound leaf petiole much longer than the leaflet stalks. Leaflet stalks variable in length even on the one compound leaf. Leaflet blades about 10-21 x 5-10 cm.

Stem :
Usually flowers and fruits as a slender single-stemmed shrub about 1-3 m tall.

Flowers :
Flowers borne in cymes or umbels which are arranged in umbels which are also arranged in umbels. Male and hermaphrodite flowers produced on each plant. Flowers about 2.5 mm diam. Ovary laterally compressed and bilobed. Styles short.

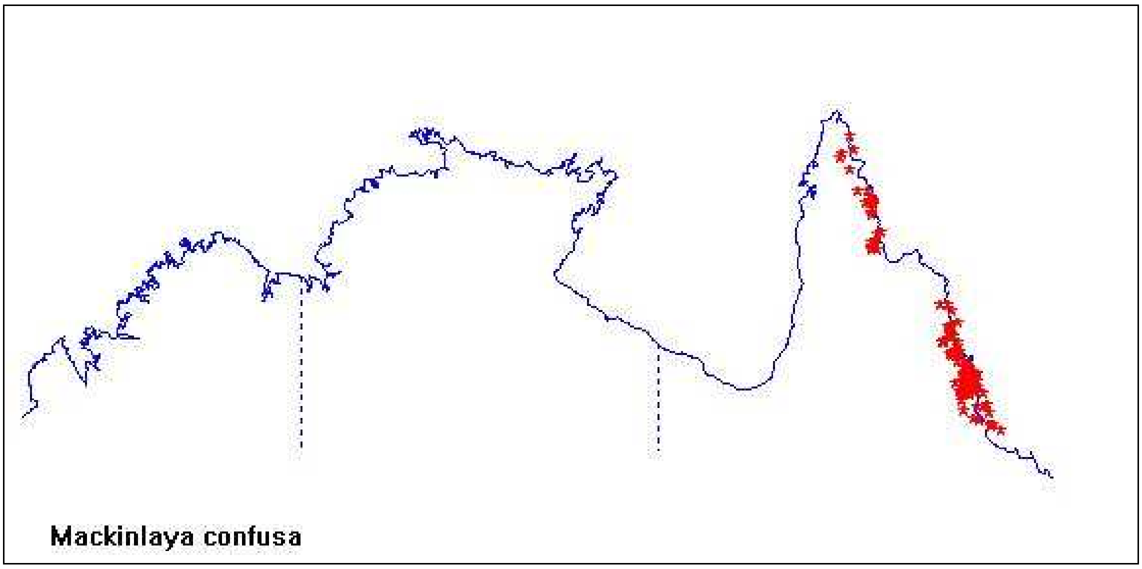
Fruit :
Fruit surface glaucous or blue-grey. Fruits borne in cymes or umbels which are arranged in umbels which are also arranged in umbels. Fruit laterally compressed and usually ± 2-lobed, wider than long, about 10 x 15 mm, usually with the style and calyx remnants at the apex. Testa finely reticulate or minutely tuberculate. Embryo very small (about 0.6-0.8 mm long). Cotyledons about as wide as the radicle.

Seedlings :
Cotyledons about 17-25 x 11-20 mm. First pair of leaves alternate, lanceolate, margins toothed. Petiole bases clasping the stem. At the tenth leaf stage: leaves may be either simple or trifoliolate, leaf or leaflet blades elliptic, apex apiculate, base attenuate. Margin coarsely toothed with 1-3 teeth on each side. Base of the petiole ± winged and clasping the stem. Stipules fused to the petiole. Crushed leaves emit an odour like that of celery.

Natural history notes :
No data available

Distribution and Ecology :
Endemic to Queensland, occurs in CYP and NEQ. Altitudinal range from near sea level to 1000 m. Grows as an understory shrub in and on the margins of a variety of different types of well developed rain forest.

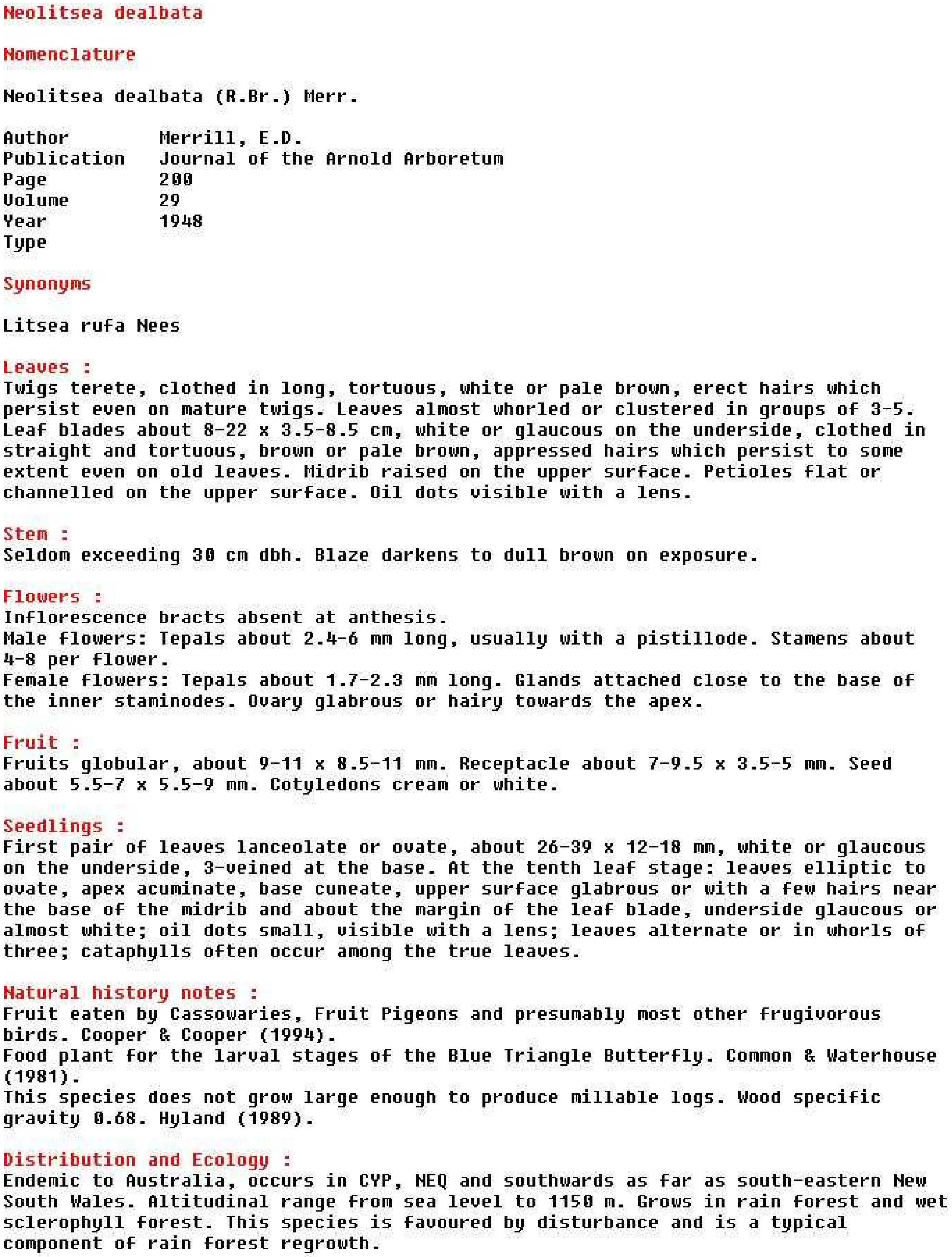
Sheet C1: *Mackinlaya confusa* information. Source: Australian Tropical Forest Plants Key



Map C1: Distribution map for *M. confusa*. Source: Australian Tropical Forest Plants Key

Image C1: *M. confusa* tenth leaf stage. Source: Australian Tropical Forest Plants Key

Neolitsea dealbata



Neolitsea dealbata

Nomenclature

Neolitsea dealbata (R.Br.) Merr.

Author	Merrill, E.D.
Publication	Journal of the Arnold Arboretum
Page	200
Volume	29
Year	1948
Type	

Synonyms

Litsea rufa Nees

Leaves :
Twigs terete, clothed in long, tortuous, white or pale brown, erect hairs which persist even on mature twigs. Leaves almost whorled or clustered in groups of 3-5. Leaf blades about 8-22 x 3.5-8.5 cm, white or glaucous on the underside, clothed in straight and tortuous, brown or pale brown, appressed hairs which persist to some extent even on old leaves. Midrib raised on the upper surface. Petioles flat or channelled on the upper surface. Oil dots visible with a lens.

Stem :
Seldom exceeding 30 cm dbh. Blaze darkens to dull brown on exposure.

Flowers :
Inflorescence bracts absent at anthesis.
Male flowers: Tepals about 2.4-6 mm long, usually with a pistillode. Stamens about 4-8 per flower.
Female flowers: Tepals about 1.7-2.3 mm long. Glands attached close to the base of the inner staminodes. Ovary glabrous or hairy towards the apex.

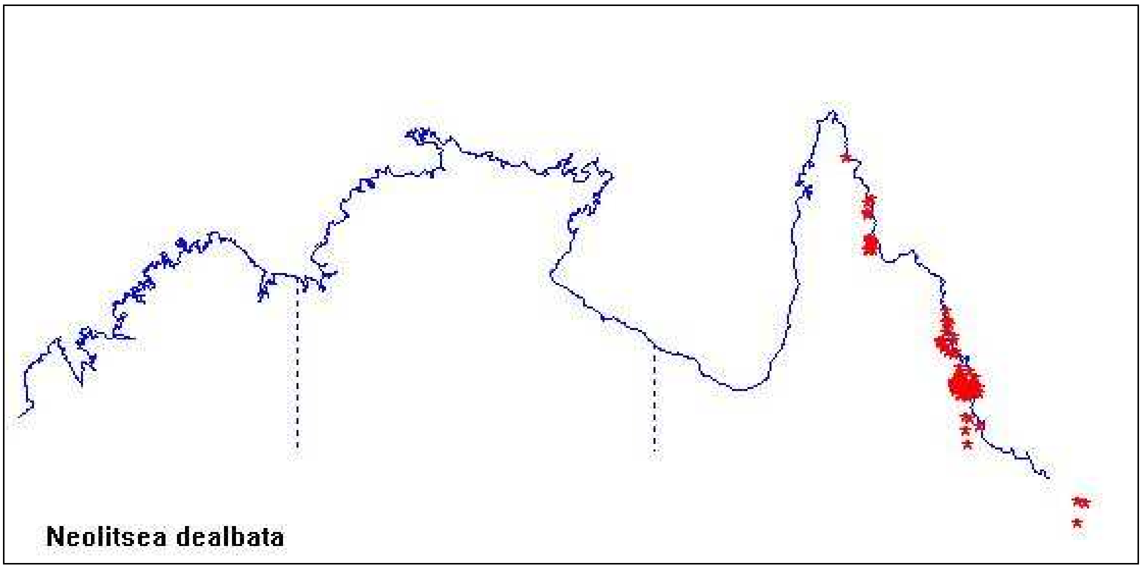
Fruit :
Fruits globular, about 9-11 x 8.5-11 mm. Receptacle about 7-9.5 x 3.5-5 mm. Seed about 5.5-7 x 5.5-9 mm. Cotyledons cream or white.

Seedlings :
First pair of leaves lanceolate or ovate, about 26-39 x 12-18 mm, white or glaucous on the underside, 3-veined at the base. At the tenth leaf stage: leaves elliptic to ovate, apex acuminate, base cuneate, upper surface glabrous or with a few hairs near the base of the midrib and about the margin of the leaf blade, underside glaucous or almost white; oil dots small, visible with a lens; leaves alternate or in whorls of three; cataphylls often occur among the true leaves.

Natural history notes :
Fruit eaten by Cassowaries, Fruit Pigeons and presumably most other frugivorous birds. Cooper & Cooper (1994).
Food plant for the larval stages of the Blue Triangle Butterfly. Common & Waterhouse (1981).
This species does not grow large enough to produce millable logs. Wood specific gravity 0.68. Hyland (1989).

Distribution and Ecology :
Endemic to Australia, occurs in CYP, NEQ and southwards as far as south-eastern New South Wales. Altitudinal range from sea level to 1150 m. Grows in rain forest and wet sclerophyll forest. This species is favoured by disturbance and is a typical component of rain forest regrowth.

Sheet C2: *Neolitsea dealbata* information. Source: Australian Tropical Forest Plants Key



Map C2: Distribution map for *N. dealbata*. Source: Australian Tropical Forest Plants Key

Image C2: *N. dealbata* tenth leaf stage. Source: Australian Tropical Forest Plants Key

ANNEX D:

Climate Change Plots Characteristics

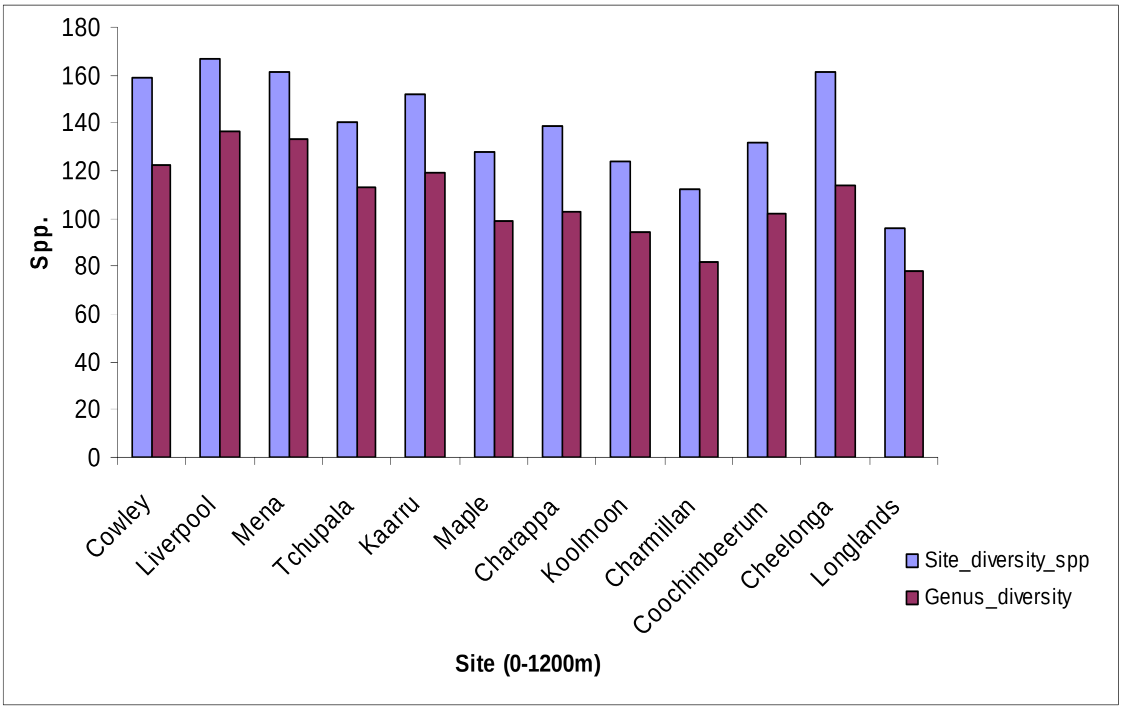


Figure D1: Species diversity and genus diversity in the Climate Change Plots. Data: CSIRO

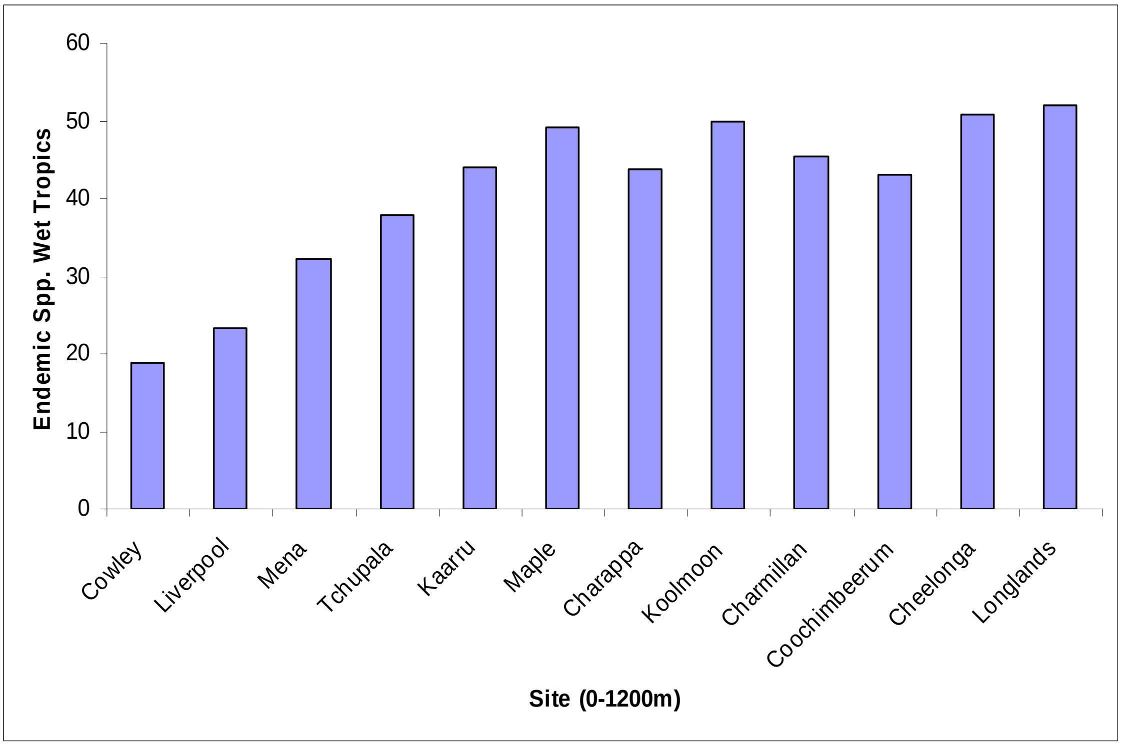


Figure D2: Endemic species to the Wet Tropics in the Climate Change Plots. Data: CSIRO

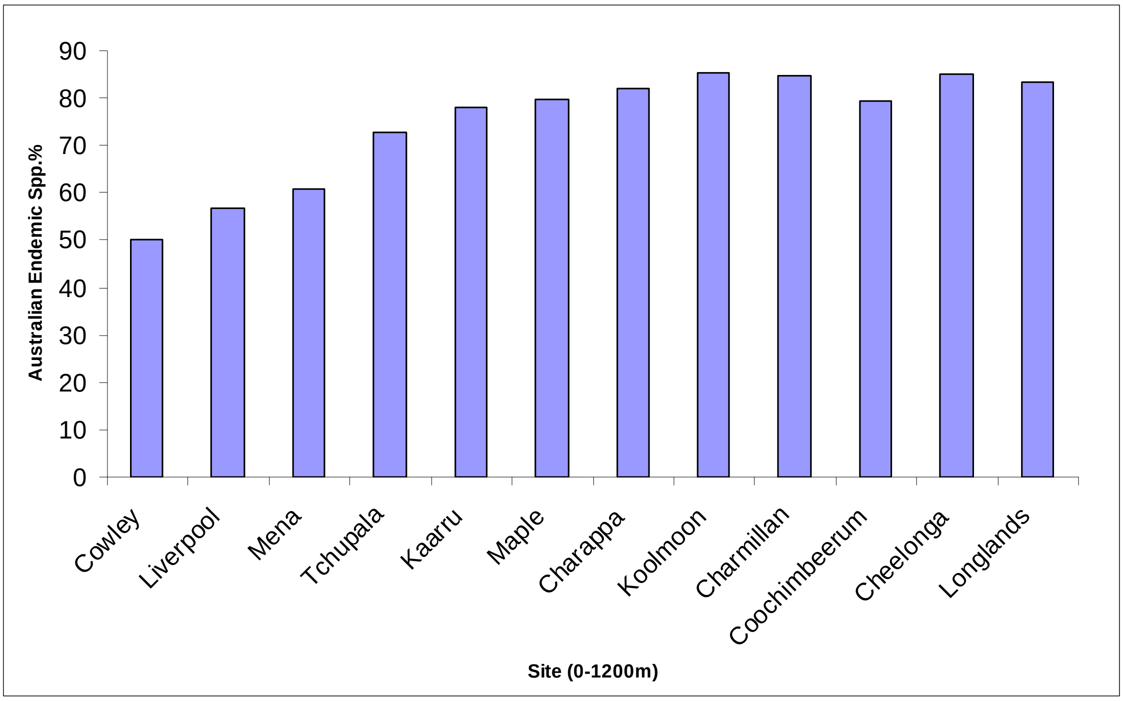


Figure D3: Percentage of Australian endemic species in the Climate Change Plots. Data: CSIRO

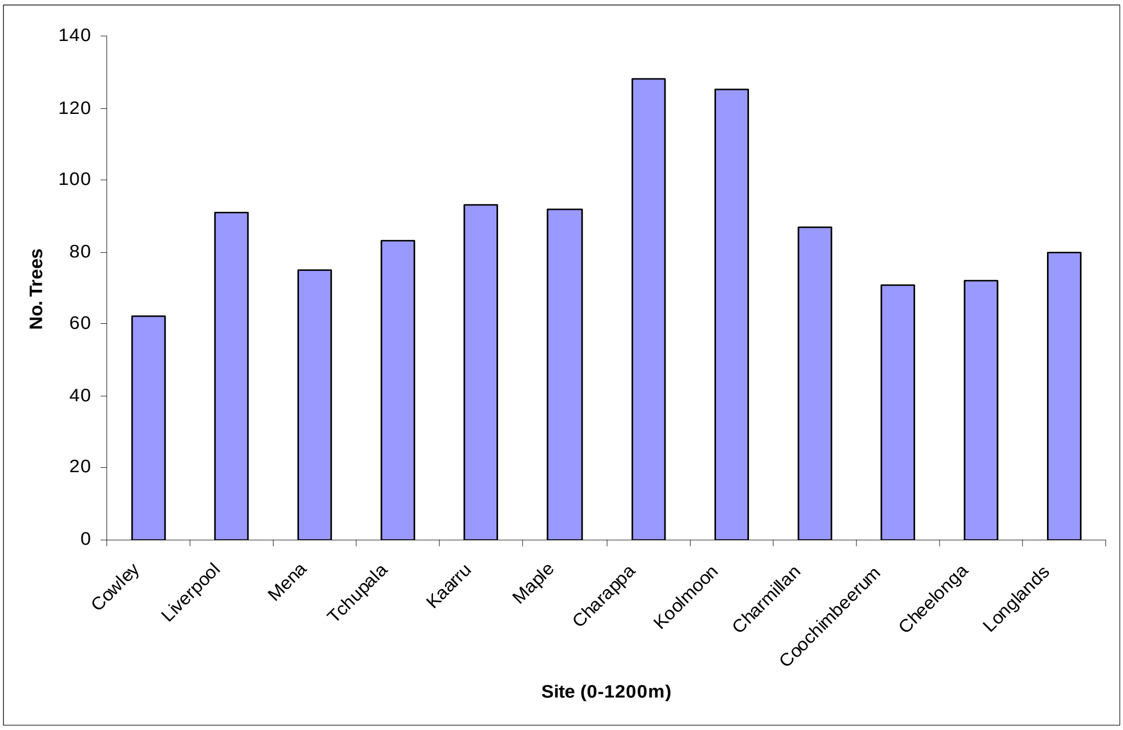


Figure D4: Number of trees (>10cm dbh) in the Climate Change plots. Data: CSIRO

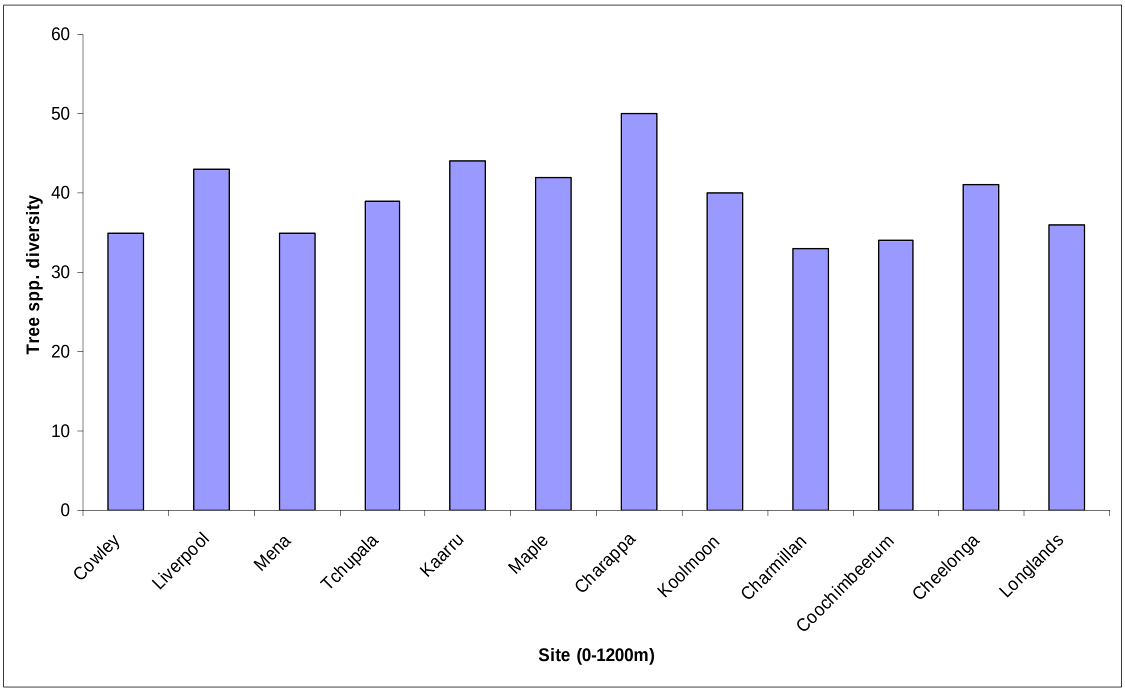


Figure D5: Tree species diversity in the Climate Change Plots. Data: CSIRO

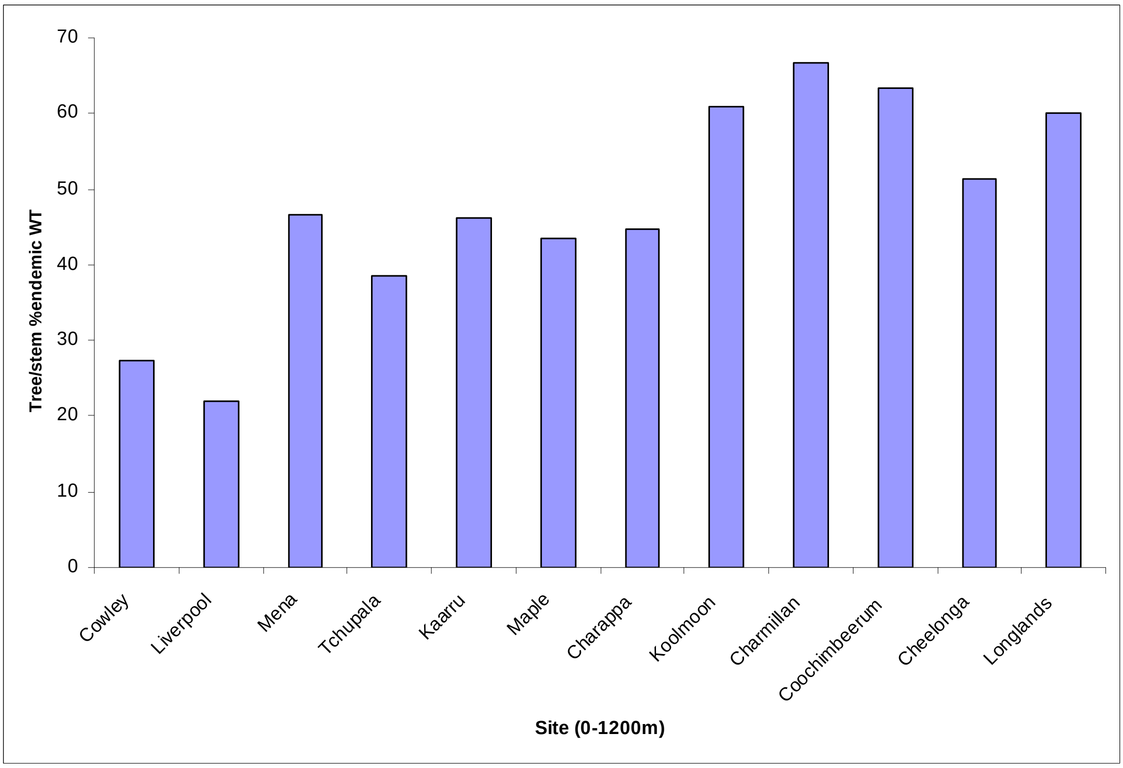


Figure D6: Tree – stem ratio of Wet Tropics endemic species in the Climate Change Plots. Data: CSIRO

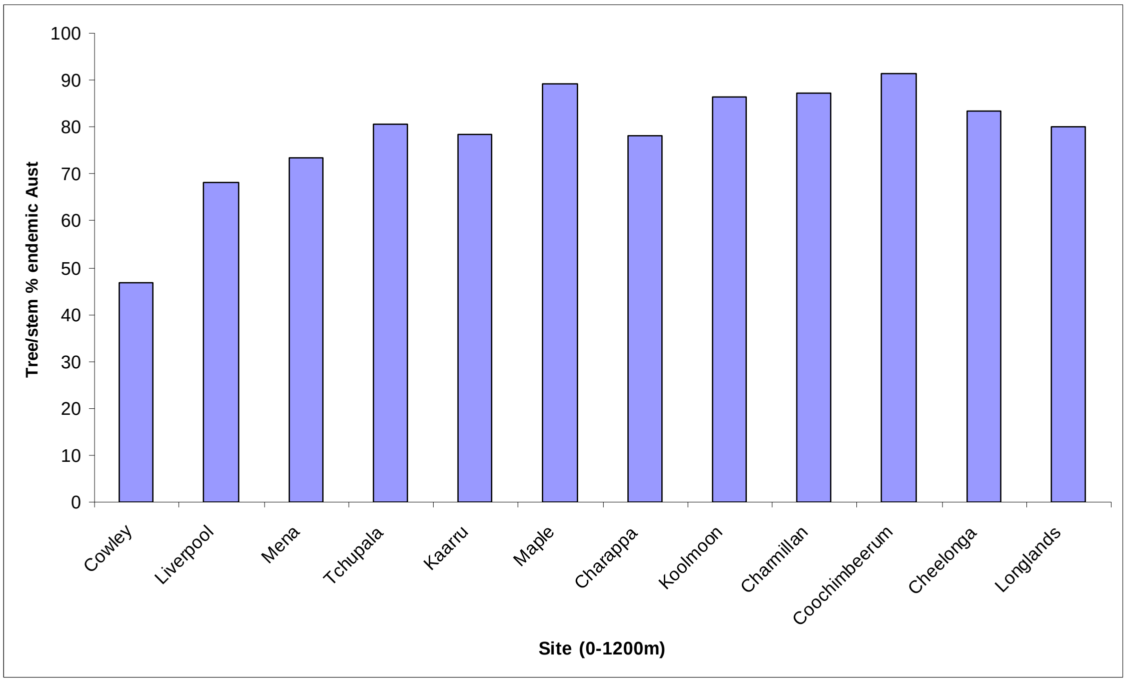


Figure D7: Tree – stem ratio percentage of Australian endemic species. Data: CSIRO

ANNEX E:

Recorded Vascular Plants in the Studied Plots

Abrophyllum ornans (F.Muell.) Hook.f. ex Benth.
Acacia celsa Tindale
Aceratium concinnum (S.Moore) C.T.White
Aceratium doggrellii C.T.White
Aceratium megalospermum (F.Muell.) Balgooy
Acmena divaricata Merr. & L.M.Perry
Acmena graveolens (F.M.Bailey) L.S.Sm.
Acmena resa B.Hyland
Acmenosperma claviflorum (Roxb.) Kausel
Acronychia acidula F.Muell.
Acronychia crassipetala T.G.Hartley
Acronychia parviflora C.T.White
Acronychia vestita F.Muell.
Adenanthera pavonina L.
Adiantum silvaticum Tindale
Aglaia meridionalis Pannell
Aglaia sapindina (F.Muell.) Harms
Aglaia tomentosa Teijsm. & Binn.
Alangium villosum subsp. polyosmoides (F.Muell.) Bloemb.
Aleurites rockinghamensis (Baill.) P.I.Forst.
Alocasia brisbanensis (F.M.Bailey) Domin
Alphitonia petriei Braid & C.T.White
Alphitonia whitei Braid
Alpinia arctiflora (F.Muell.) Benth.
Alpinia modesta F.Muell. ex K.Schum.
Alstonia muelleriana Domin
Alstonia scholaris (L.) R.Br.
Alyxia grandis P.I.Forst.
Antidesma erostre F.Muell. ex Benth.
Antirhea sp. (Mt Lewis BG 5733)
Antirhea tenuiflora F.Muell. ex Benth.
Apodytes brachystylis F.Muell.
Archidendron ramiflorum (F.Muell.) Kosterm.
Archidendron vaillantii (F.Muell.) F.Muell.
Archidendron whitei I.C.Nielsen
Archirhodomyrtus beckleri (F.Muell.) A.J.Scott
Archontophoenix alexandrae (F.Muell.) H.Wendl. & Drude
Ardisia brevipedata F.Muell.
Argyrodendron peralatum (F.M.Bailey) Edlin ex Boas
Argyrodendron trifoliolatum F.Muell.
Arthropteris palisotii (Desv.) Alston
Arthropteris submarginalis Domin
Arytera pauciflora S.T.Reynolds
Asplenium australasicum (J.Sm.) Hook.
Asplenium nidus L.
Asplenium simplicifrons F.Muell.
Atractocarpus fitzalanii subsp. tenuipes Puttock
Atractocarpus hirtus (F.Muell.) Puttock
Atractocarpus merikin (F.M.Bailey) Puttock
Austrobaileya scandens C.T.White
Austromatthaea elegans L.S.Sm.
Austrosteenisia stipularis (C.T.White) Jessup
Balanops australiana F.Muell.
Barringtonia calyptrata (R.Br. ex Miers) R.Br. ex F.M.Bailey
Beilschmiedia bancroftii (F.M.Bailey) C.T.White
Beilschmiedia brunnea B.Hyland
Beilschmiedia collina B.Hyland
Beilschmiedia recurva B.Hyland
Beilschmiedia tooram (F.M.Bailey) B.Hyland
Belvisia mucronata (Fee) Copel. var. mucronata
Blechnum cartilagineum Sw.
Bobea myrtoides (F.Muell.) Valeton
Bowenia spectabilis Hook. ex Hook.f.
Brachychiton acerifolius (A.Cunn. ex G.Don) Macarthur
Brackenridgea australiana F.Muell.
Bridelia insulana Hance
Brombya platynema F.Muell.
Bubbia semecarpoides (F.Muell.) B.L.Burtt
Buckinghamia celsissima F.Muell.
Bulbophyllum johnsonii T.E.Hunt
Bulbophyllum radicans F.M.Bailey
Calamus australis Mart.
Calamus caryotoides A.Cunn.
Calamus moti F.M.Bailey
Caldcluvia australiensis (Schltr.) Hoogland
Callicarpa longifolia Lam.
Calophyllum costatum F.M.Bailey
Cananga odorata (Lam.) Hook.f. & Thomson
Canarium australasicum (F.M.Bailey) Leenh.
Guioa acutifolia Radlk.
Guioa lasioneura Radlk.
Guioa montana C.T.White
Gymnostachys anceps R.Br.
Gynochthodes oresbia Halford & A.J.Ford
Halfordia kendack (Montrouz.) Guillaumin
Haplostichanthus rufescens Jessup
Haplostichanthus submontanus ssp. sessiliflorus Jessup
Harpullia frutescens F.M.Bailey
Harpullia rhyticarpa C.T.White & W.D.Francis
Hedycarya loxocarya (Benth.) W.D.Francis
Hedyotis auricularia var. melanesica Fosberg
Helicia lamingtoniana (F.M.Bailey) C.T.White ex L.S.Sm.
Helicia nortoniana (F.M.Bailey) F.M.Bailey
Hernandia albiflora (C.T.White) Kubitzki
Hibbertia scandens (Willd.) Gilg
Hippocratea barbata F.Muell.
Homalanthus novoguineensis (Warb.) K.Schum.
Hornstedtia scottiana (F.Muell.) K.Schum.
Hoya pottsii Traill
Huperzia phlegmaria (L.) Rothm.
Hydriastele wendlandiana (F.Muell.) H.Wendl. & Drude
Hydrocotyle miranda A.R.Bean & Henwood
Hylandia dockrillii Airy Shaw
Hypolepis glandulifera Brownsey & Chinnock
Hypolytrum nemorum (Vahl) Spreng.
Hypserpa decumbens (Benth.) Diels
Hypserpa laurina (F.Muell.) Diels
Hypserpa smilacifolia Diels
Hypsophila dielsiana Loes.
Ichnocarpus frutescens (L.) W.T.Aiton
Ilex sp. (Gadgarra B.P.Hyland RFK2011)
Irvingbaileya australis (C.T.White) R.A.Howard
Ixora baileyana Bridson & L.G.Adams
Ixora oreogena S.T.Reynolds & P.I.Forst.
Jagera pseudorhus var. integerrima S.T.Reynolds
Jasminum didymum G.Forst. subsp. didymum
Jasminum kajewskii C.T.White
Lasianthus strigosus Wight
Lastreopsis wurunuran (Domin) Tindale
Leea indica (Burm.f.) Merr.
Lepiderema ixiocarpa S.T.Reynolds
Lepiderema sericolignis (F.M.Bailey) Radlk.
Levieria acuminata (F.Muell.) J.R.Perkins
Lindsaea brachypoda (Baker) Salomon
Linospadix minor (W.Hill ex F.Muell.) F.Muell.
Liparis nugentiae F.M.Bailey
Litsea bindoniana (F.Muell.) F.Muell.
Litsea connorsii B.Hyland
Litsea leefeana (F.Muell.) Merr.
Lomatia fraxinifolia F.Muell. ex Benth.
Lygodium flexuosum (L.) Sw.
Lygodium reticulatum Schkuhr
Macadamia whelanii (F.M.Bailey) F.M.Bailey
Macaranga involucrata var. mallotoides (F.Muell.) L.M.Perry
Mackinlaya confusa Hemsl.
Maclura cochinchinensis (Lour.) Corner
Maesa dependens F.Muell. var. dependens
Maesa dependens var. pubescens F.Muell.
Mallotus paniculatus (Lam.) Muell.Arg.
Mallotus polyadenos F.Muell.
Marattia oreades Domin
Marsdenia jensenii P.I.Forst.
Medicosma fareana (F.Muell.) T.G.Hartley
Medinilla balls-headleyi F.Muell.
Melastoma cyanoides
Melicope bonwickii (F.Muell.) T.G. Hartley
Melicope broadbentiana F.M.Bailey
Melicope elleryana (F.Muell.) T.G.Hartley
Melicope jonesii T.G. Hartley
Melicope vitiflora (F.Muell.) T.G.Hartley
Melicope xanthoxyloides (F.Muell.) T.G.Hartley
Melodinus australis (F.Muell.) Pierre
Melodinus bacellianus (F.Muell.) S.T.Blake
Melodorum leichhardtii F.Muell.
Melodorum uhrii F.Muell.
Merremia peltata (L.) Merr.
Microsorum australiense (F.M.Bailey) Bostock
Mischarytera lautereriana (F.M.Bailey) H.Turner

Canarium muelleri F.M.Bailey
Cardwellia sublimis F.Muell.
Carnarvonia araliifolia F.Muell. var. araliifolia
Carnarvonia araliifolia var. montana B.Hyland
Carronia pedicellata Forman
Carronia protensa (F.Muell.) Diels
Casearia costulata Jessup
Casearia grayi Jessup
Castanospermum australe A.Cunn. & Fraser ex Hook.
Castanospora alphandii (F.Muell.) F.Muell.
Cayratia japonica (Thunb.) Gagnep.
Cayratia saponaria (Seem. ex Benth.) Domin
Celastrus subspicata Hook.
Chionanthus axillaris R.Br.
Chionanthus ramiflora Roxb.
Cinnamomum laubatii F.Muell.
Cissus hypoglauca A.Gray
Cissus penninervis (F.Muell.) Planch.
Cissus sterculiifolia (F.Muell. ex Benth.) Planch.
Cissus vinosa Jackes
Citronella moorei (F.Muell. ex Benth.) R.A.Howard
Citronella smythii (F.Muell.) R.A.Howard
Claoxylon tenerifolium (Baill.) F.Muell.
Clerodendrum grayi Munir
Clerodendrum tracyanum (F.Muell.) F.Muell. ex Benth.
Cnesmocarpon dasyantha (Radlk.) Adema
Colysis ampla (F.Muell. ex Benth.) Copel.
Colysis sayeri (F.Muell. & Baker) Copel.
Connarus conchocarpus F.Muell. subsp. conchocarpus
Cordia subcordata Lam.
Cordyline cannifolia R.Br.
Corynocarpus cribbianus (F.M.Bailey) L.S.Sm.
Crepidomanes barnardianum (F.M.Bailey) Tindale subsp. barnardianum
Crepidomanes kurzii (Bedd.) Tagawa & K.Iwats.
Crepidomanes saxifragoides (C.Presl) P.S.Green
Croton triacros F.Muell.
Cryptocarya angulata C.T.White
Cryptocarya cocosoides B.Hyland
Cryptocarya corrugata C.T.White & W.D.Francis
Cryptocarya cunninghamii Meisn.
Cryptocarya densiflora Blume
Cryptocarya grandis B.Hyland
Cryptocarya hypospodia F.Muell.
Cryptocarya laevigata Blume
Cryptocarya leucophylla B.Hyland
Cryptocarya lividula B.Hyland
Cryptocarya mackinnoniana F.Muell.
Cryptocarya melanocarpa B.Hyland
Cryptocarya murrayi F.Muell.
Cryptocarya oblata F.M.Bailey
Cryptocarya pleurosperma C.T.White & W.D.Francis
Cryptocarya putida B.Hyland
Cryptocarya saccharata B.Hyland
Cryptocarya smaragdina B.Hyland
Ctenopteris gordonii S.B.Andrews
Cupaniopsis dallachyi S.T.Reynolds
Cupaniopsis flagelliformis (F.M.Bailey) Radlk. var. flagelliformis
Cupaniopsis papillosa P.I.Forst.
Cyathea celebica Blume
Cyathea cooperi (Hook. ex F.Muell.) Domin
Cyathea rebeccae (F.Muell.) Domin
Cyclophyllum multiflorum S.T.Reynolds & R.F.J.Hend.
Daphnandra repandula (F.Muell.) F.Muell.
Darlingia darlingiana (F.Muell.) L.A.S.Johnson
Darlingia ferruginea J.F.Bailey
Davidsonia pruriens F.Muell. var. pruriens
Decaspermum humile (G.Don) A.J.Scott
Delarbrea michieana (F.Muell.) F.Muell.
Dendrobium adae F.M.Bailey
Dendrobium discolor Lindl. var. discolor
Dendrocnide cordifolia (L.S.Sm.) Jackes & M.Hurley
Dendrocnide moroides (Wedd.) Chew
Dendrotrophe varians (Blume) Miq.
Derris sp. (Daintree D.E.Boyland+ 469)
Desmos goezeanus (F.Muell.) Jessup
Dichapetalum papuanum (Becc.) Boerl.
Dictymia brownii (Wikstr.) Copel.
Dienia montana (Sm.) M.A.Clem. & D.L.Jones
Dioclea hexandra (Ralph) Mabb.
Dioscorea bulbifera L. var. bulbifera
Diospyros cupulosa (F.Muell.) F.Muell.

Mischocarpus grandissimus (F.Muell.) Radlk.
Mischocarpus lachnocarpus (F.Muell.) Radlk.
Mischocarpus macrocarpus S.T.Reynolds
Mischocarpus pyriformis (F.Muell.) Radlk. subsp. pyriformis
Mobilabium hamatum Rupp
Morinda jasminoides A.Cunn. ex Hook.
Morinda umbellata L.
Muehlenbeckia rhyticarya F.Muell.
Musa banksii F.Muell.
Musgravea heterophylla L.S.Sm.
Musgravea stenostachya F.Muell.
Myristica globosa subsp. muelleri (Warb.) W.J.de Wilde
Myrsine achradifolia F.Muell.
Myrsine porosa (F.Muell.)
Myrsine subsessilis ssp. cryptostemon Jackes
Neisosperma poweri (F.M.Bailey) Fosberg & Sachet
Neoalsomitra clavigera (Wall.) Hutch.
Neolitsea dealbata (R.Br.) Merr.
Neosepicaea jucunda (F.Muell.) Steenis
Niemeyera prunifera (F.Muell.) F.Muell.
Octarrhena pusilla (F.M.Bailey) M.A.Clem. & D.L.Jones
Ophioglossum pendulum L.
Opisthiolepis heterophylla L.S.Sm.
Ostrearia australiana Baill.
Palaquium galactoxylon (F.Muell.) H.J.Lam
Palmeria scandens F.Muell.
Pandanus monticola F.Muell.
Pandorea pandorana (Andrews) Steenis
Parapachygone longifolia (F.M.Bailey) Forman
Pararistolochia australopithecurus Michael J.Parsons
Pararistolochia deltantha (F.Muell.) Michael J.Parsons
Parsonsia densivestita C.T.White
Parsonsia grayana J.B.Williams
Parsonsia langiana F.Muell.
Parsonsia latifolia (Benth.) S.T.Blake
Passiflora subpeltata Ortega
Perrottetia arborescens (F.Muell.) Loes.
Phaleria clerodendron (F.Muell.) Benth.
Pilidiostigma tetramerum L.S.Sm.
Pilidiostigma tropicum L.S.Sm.
Piper caninum Blume
Piper hederaceum (Miq.) C.DC. var. hederaceum
Pitaviaster haplophyllus (F.Muell.) T.G.Hartley
Pittosporum rubiginosum A.Cunn.
Platycerium hillii T.Moore
Pleuranthodium racemigerum (F.Muell.) R.M.Sm.
Podocarpus dispermus C.T.White
Podocarpus grayae de Laub.
Polyalthia michaelii C.T.White
Polyalthia patinata Jessup
Polyosma alangiacea F.Muell.
Polyosma hirsuta C.T.White
Polyosma rhytophloia C.T.White & W.D.Francis
Polyscias australiana (F.Muell.) Philipson
Polyscias elegans (C.Moore & F.Muell.) Harms
Polyscias mollis (Benth.) Harms
Polyscias murrayi (F.Muell.) Harms
Polyscias purpurea C.T.White
Pothos longipes Schott
Pouteria brownlessiana (F.Muell.) Baehni
Pouteria castanosperma (C.T.White) Baehni
Pouteria chartacea (F.Muell. ex Benth.) Baehni
Pouteria euphlebia (F.Muell.) Baehni
Pouteria myrsinodendron (F.Muell.) Jessup
Pouteria pohlmaniana (F.Muell.) Baehni
Pouteria xerocarpa (F.Muell. ex Benth.) Baehni
Prunus turneriana (F.M.Bailey) Kalkman
Pseuderanthemum variabile (R.Br.) Radlk.
Pseudoweinmannia lachnocarpa (F.Muell.) Engl.
Pseuduvaria villosa Jessup
Psilotum nudum (L.) P.Beauv.
Psychotria nematopoda F.Muell.
Psychotria sp. (Danbulla S.T.Blake 15262)
Psychotria sp. (Mt Lewis V.K.Moriarty 2445)
Psychotria sp. (Utchee Creek H.Flecker NQNC5313)
Psydrax laxiflorens S.T.Reynolds & R.F.J.Hend.
Psydrax tropica S.T.Reynolds & R.F.J.Hend.
Pteridoblechnum neglectum (F.M.Bailey) Hennipman
Pullea stutzeri (F.Muell.) Gibbs
Pyrrosia longifolia (Burm.f.) C.V.Morton
Randia tuberculosa F.M.Bailey

Diospyros sp. (Millaa Millaa L.W.Jessup 515)
Diospyros sp. (Mt Lewis L.S.Smith 10107)
Diploglottis pedleyi S.T.Reynolds
Diploglottis smithii S.T.Reynolds
Dockrillia teretifolia (R.Br.) Brieger
Doryphora aromatica (F.M.Bailey) L.S.Sm.
Drynaria rigidula (Sw.) Bedd.
Drypetes acuminata P.I.Forst.
Duboisia myoporoides R.Br.
Dysoxylum alliaceum (Blume) Blume
Dysoxylum arborescens (Blume) Miq.
Dysoxylum klanderi F.Muell.
Dysoxylum mollissimum subsp. molle (Miq.) Mabb.
Dysoxylum oppositifolium F.Muell.
Dysoxylum papuanum (Merr. & L.M.Perry) Mabb.
Dysoxylum parasiticum (Osbeck) Kosterm.
Dysoxylum pettigrewianum F.M.Bailey
Elaeocarpus elliffii B.Hyland & Coode
Elaeocarpus eumundi F.M.Bailey
Elaeocarpus ferruginiflorus C.T.White
Elaeocarpus foveolatus F.Muell.
Elaeocarpus grandis F.Muell.
Elaeocarpus largiflorens C.T.White subsp. largiflorens
Elaeocarpus ruminatus F.Muell.
Elaeocarpus sericopetalus F.Muell.
Elaeocarpus sp. (Mt Bellenden Ker L.J.Brass 18336)
Elaeocarpus stellaris L.S.Sm.
Elaphoglossum queenslandicum S.B.Andrews
Embelia caulialata S.T.Reynolds
Embelia grayi S.T.Reynolds
Endiandra acuminata C.T.White & W.D.Francis
Endiandra bessaphila B.Hyland
Endiandra compressa C.T.White
Endiandra cowleyana F.M.Bailey
Endiandra dichrophylla F.Muell.
Endiandra dielsiana Teschner
Endiandra globosa Maiden & Betche
Endiandra hypotephra F.Muell.
Endiandra insignis (F.M.Bailey) F.M.Bailey
Endiandra leptodendron B.Hyland
Endiandra monothyra B.Hyland subsp. monothyra
Endiandra montana C.T.White
Endiandra palmerstonii (F.M.Bailey) C.T.White & W.D.Francis
Endiandra sankeyana F.M.Bailey
Endiandra sideroxylon B.Hyland
Endiandra wolfei B.Hyland
Endospermum myrmecophilum L.S.Sm.
Endressia wardellii (F.Muell.) Whiffin
Entada phaseoloides (L.) Merr.
Epipremnum pinnatum (L.) Engl.
Erechtites valerianifolia (Wolf) DC. forma valerianifolia
Erycibe coccinea (F.M.Bailey) Hoogland
Erythroxylum sp. (Brewer LA B.Hyland 13373
Eupomatia barbata Jessup
Eupomatia laurina R.Br.
Eustrephus latifolius R.Br. ex Ker Gawl.
Fagraea fagraeacea (F.Muell.) Druce
Faradaya splendida F.Muell.
Ficus copiosa Steud.
Ficus crassipes F.M.Bailey
Ficus destruens F.Muell. ex C.T.White
Ficus leptoclada Benth.
Ficus pantoniana King var. pantoniana
Ficus pleurocarpa F.Muell.
Ficus septica Burm.f.
Ficus variegata Blume var. variegata
Ficus virens Aiton var. virens
Ficus virgata Reinw. ex Blume var. virgata
Flagellaria indica L.
Flindersia bourjotiana F.Muell.
Flindersia brayleyana F.Muell.
Flindersia pimenteliana F.Muell. forma pimenteliana
Franciscodendron laurifolium (F.Muell.) B.Hyland & Steenis
Freycinetia excelsa F.Muell.
Gahnia sieberiana Kunth
Galbulimima baccata F.M.Bailey
Garcinia sp. (Davies Creek J.G.Tracey 14745)
Gardenia ovularis F.M.Bailey
Geissois biagiana (F.Muell.) F.Muell. ex Engl.
Gen.(Aq124851) sp. (Boonjie L.J.Webb+ 6837A)
general
Rhaphidophora australasica F.M.Bailey
Rhodamnia blairiana F.Muell.
Rhodamnia costata A.J.Scott
Rhodamnia sessiliflora Benth.
Rhodomyrtus macrocarpa Benth.
Rhodomyrtus pervagata Guymer
Rhysotoechia florulenta S.T.Reynolds
Rhysotoechia mortoniana (F.Muell.) Radlk.
Rhysotoechia robertsonii (F.Muell.) Radlk.
Ripogonum album R.Br.
Rockinghamia angustifolia (Benth.) Airy Shaw
Rourea brachyandra F.Muell.
Rubus alceifolius Poir.
Rubus moluccanus L. var. moluccanus
Salacia disepala (C.T.White) Ding Hou
Salacia erythrocarpa K.Schum.
Sambucus canadensis L.
Sarcopteryx martyana (F.Muell.) Radlk.
Sarcotoechia cuneata Radlk.
Sarcotoechia lanceolata (C.T.White) S.T.Reynolds
Scaevola enantophylla F.Muell.
Schefflera actinophylla (Endl.) Harms
Scolopia braunii (Klotzsch) Sleumer
Selaginella longipinna Warb.
Siphonodon membranaceus F.M.Bailey
Sloanea australis subsp. parviflora Coode
Sloanea langii F.Muell.
Sloanea macbrydei F.Muell.
Smilax aculeatissima Conran
Smilax calophylla Wall. ex A.DC.
Smilax glyciphylla Sm.
Solanum hamulosum C.T.White
Solanum macoorai F.M.Bailey
Solanum magnifolium F.Muell.
Solanum mauritianum Scop.
Solanum viridifolium Dunal
Sphenostemon lobosporus (F.Muell.) L.S.Sm.
Steganthera australiana C.T.White
Steganthera laxiflora (Benth.) Whiffin & Foreman ssp. laxiflora
Steganthera macooraia (F.M.Bailey) P.K.Endress
Stenocarpus reticulatus C.T.White
Stephania japonica (Thunb.) Miers
Streblus glaber var. australianus (C.T.White) Corner
Strychnos minor Dennst.
Sundacarpus amarus (Blume) C.N.Page
Symplocos cochinchinensis var. gittonsii Noot.
Symplocos cochinchinensis var. glaberrima Noot.
Symplocos cochinchinensis var. pilosiuscula Noot.
Symplocos hayesii C.T.White & W.D.Francis
Symplocos paucistaminea F.Muell. & F.M.Bailey
Synima cordierorum (F.Muell.) Radlk.
Synima macrophylla S.T.Reynolds
Synima reynoldsiae P.I.Forst.
Synoum glandulosum subsp. paniculosum (F.Muell.) Mabb.
Syzygium apodophyllum (F.Muell.) B.Hyland
Syzygium canicortex B.Hyland
Syzygium cormiflorum (F.Muell.) B.Hyland
Syzygium cryptophlebium (F.Muell.) Craven & Biffin
Syzygium endophloium B.Hyland
Syzygium gustavioides (F.M.Bailey) B.Hyland
Syzygium johnsonii (F.Muell.) B.Hyland
Syzygium kuranda (F.M.Bailey) B.Hyland
Syzygium luehmannii (F.Muell.) L.A.S.Johnson
Syzygium papyraceum B.Hyland
Syzygium sayeri (F.Muell.) B.Hyland
Syzygium trachyphloium (C.T.White) B.Hyland
Syzygium wesa B.Hyland
Tabernaemontana pandacaqui Lam.
Tapeinochilos ananassae (Hassk.) K.Schum.
Tasmannia membranea (F.Muell.) A.C.Sm.
Tectaria confluens (F.Muell. ex Baker) Pic.Serm.
Terminalia sericocarpa F.Muell.
Ternstroemia cherryi (F.M.Bailey) Merr. ex J.F.Bailey & C.T.White
Tetracera daemeliana F.Muell.
Tetracera nordtiana F.Muell.
Tetrastigma crenatum Jackes
Tinospora smilacina Benth.
Toechima erythrocarpum (F.Muell.) Radlk.
Toechima monticola S.T.Reynolds
Trema orientalis (L.) Blume
Trichomanes bimarginatum (Bosch) Bosch

Geophila repens (L.) Johnst.
Gevuina bleasdalei (F.Muell.) Sleumer
Gillbeea adenopetala F.Muell.
Glochidion harveyanum Domin var. harveyanum
Glochidion hylandii Airy Shaw
Glochidion sessiliflorum var. pedicellatum Airy Shaw
Glossocarya hemiderma (F.Muell. ex Benth.) Benth. & Hook.f. ex B.D.Jacks.
Gmelina fasciculiflora Benth.
Gomphandra australiana F.Muell.
Goniophlebium percussum (Cav.) W.H.Wagner & Grether
Gossia dallachiana (F.Muell. ex Benth.) N.Snow & Guymer
Gossia grayi N.Snow & Guymer
Gossia myrsinocarpa (F.Muell) N.Snow & Guymer
Gossia shepherdii (F.Muell.) N.Snow & Guymer
Grevillea baileyana McGill.
Trichomanes motleyi (Bosch) Bosch
Trichomanes tahitense Nadeaud
Trichosanthes sp. (Mt Lewis B.Gray 167)
Trichospermum pleiostigma (F.Muell.) Kosterm.
Tristemma mauritianum J.F.Gmel. var. mauritianum
Trophis scandens (Lour.) Hook. & Arn. subsp. scandens
Uncaria lanosa var. appendiculata (Benth.) Ridsdale
Viticipremna queenslandica Munir
Waterhousea unipunctata B.Hyland
Wilkiea angustifolia (F.M.Bailey) J.R.Perkins
Wilkiea sp. (Barong L.W.Jessup 719)
Wilkiea sp. (Palmerston B.P.Hyland 80)
Wrightia laevis subsp. millgar (F.M.Bailey) Ngan
Xanthophyllum octandrum (F.Muell.) Domin
Xylopia maccreae (F.Muell.) L.S.Sm.

Data: CSIRO

ANNEX F:

Field Data (in CD)