CARBON SEQUESTERED IN THE TREES ON A UNIVERSITY CAMPUS

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Abstract

We investigate the ability of a New Zealand university to rely on the CO_2 sequestered in the trees on campus to mitigate the CO_2 emissions caused by operations. We count and measure the trees on the university's 68 hectare main campus, ignoring smaller trees that sequester very little CO_2. We estimate that the 4,139 trees we count contain 5,809 tonnes of CO_2. We further estimate the additional CO_2 sequestration over the next 10 years to be 253 tonnes per year. The university's annual CO_2 emissions were 4,086 tonnes in 2011. More than 70% of this amount relates to overseas travel. Therefore, CO_2 sequestration in trees promises to mitigate only about 6% of total emissions over the next 10 years. This suggests that other initiatives will be needed if the university is serious about reducing its greenhouse gas emissions impact. An obvious avenue appears to be to reduce overseas travel, e.g., by finding different ways for academic staff to network and obtain feedback on their research. Other universities and other organisations starting to investigate their environmental impact are likely to similarly find that CO_2 sequestration in trees can only provide limited mitigation opportunities.

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1. INTRODUCTION

There is a growing consensus that the greenhouse gas (GHG) emissions generated by humans cause climate change, which is seen as a negative impact on the natural environment (Solomona, Plattnerb, Knuttic & Friedlingdtein, 2009). The Kyoto Protocol of 1997 focus on the reduction of carbon emissions, a major GHG (Oberthür & Ott, 1999). The Kyoto Protocol sets binding targets at the country level aimed at reducing GHG emissions. The initiative is driven by the United Nations Framework Convention on Climate Change (UNFCCC). One of the methods advocated by the Kyoto Protocol to offset carbon emissions from fossil fuel combustion is carbon sequestration, e.g., in trees (Sedjo & Marland, 2003). This is because, as they grow, trees use carbon as the basis of their structure, storing carbon in the process (Raven & Karley, 2006). The European Union instituted an emissions trading scheme based on the Kyoto Protocol, which allows entities to offset their emissions liabilities, among other ways through carbon sequestration (Greek, 2012; Gagelmann & Hansjürgens, 2002).

According to Green (2008), higher education institutions such as universities, as well as companies, should be responsible for controlling carbon emissions. After all, universities produce carbon emissions through waste, travel and energy. Universities are also able to use carbon sequestration to offset carbon emissions as part of their sustainability approach (Johnson & Coburn, 2010). This approach should be less costly for universities than offsetting through making a payment to a third party. An essential part of this process is to calculate the carbon sequestered in trees on campus (Xu & Mitchell, 2011).

In this paper, we investigate the extent to which a university can rely on carbon sequestration in campus trees to offset their carbon emissions using a university in New Zealand (hereafter called KIWI University) as a case study. We begin by identifying the species, counting, and measuring the trees on the university's main 68 hectare campus. We then calculate the carbon sequestered in these trees according to standard rates applicable to each species of tree. The next step is to estimate the additional carbon expected to be sequestered in future, based on the growth rates of the trees, which is largely dependent on the age of the trees. We compare this expected annual sequestration rate with the annual carbon emissions. Note that the weight of CO_2 includes the oxygen component in CO_2, whereas the weight of carbon only is a smaller figure.

We find that the expected annual CO_2 sequestration over the next 10 years to be 253 tonnes, whereas CO_2 emissions (through waste, energy and travel) were 4,087 tonnes in 2011 (Goddard, 2012). Therefore, carbon sequestration can only form part of an overall carbon mitigation programme for the university. Other initiatives, such as the reduction of emissions and operational changes will have to contribute.

2. LITERATURE REVIEW

2.1. Climate change

According to the 4th Intergovernmental Panel on Climate Change's report, average temperatures are increasing globally (IPCC, 2007a). The report indicates that both ocean and land regions have warmed nearly twice as much from 1956 to 2005 as they did in the 100 years from 1906 to 2005 (IPCC, 2007a). The report also concludes that climate change is caused mainly by human activities, particularly by greenhouse gas (GHG) emissions, predominated by carbon dioxide (CO_2) emissions. Indeed, 48% more CO_2 was emitted globally in 2010 than in 1992 (Rogers, 2012). The negative effects of the resultant global warming include the melting of sea ice, landslides, and massive dust storms (Climate Progress, 2012). Two main policies are proposed to address these issues, namely mitigation and adaptation (Simonis, 2011). Climate mitigation policies aim to reduce GHG emissions (Lutsey & Sperling, 2008), while adaptation policies seek to adapt to the consequences of climate change (Carina & Keskitalo, 2010). Sustainability regulations play an important role in the implementation of climate policies (Wilbanks, 2003). Robinson and Herbert (2001) also argue that “climate policy, and the impacts of climate change, will have significant implications for sustainability decisions and options at multiple spatial scales” (p.131). Thus, climate policies and sustainability have mutual influence on each other.

The Kyoto Protocol is one of the much debated regulatory reactions to climate change. According to Lau, Lee and Mohamed (2012), the Kyoto Protocol could be seen as successful in achieving its goal through the environmental regulation passed in the various signatory nations’. For instance, in the 27 European Union (EU) countries, the total GHG emissions in 2007 were 9.3% below emissions in 1990, largely due to the successful implementation of Kyoto Protocol related regulation (Lau, Lee & Mohamed, 2012). However, the Kyoto Protocol has failed to reduce worldwide GHG emissions (Lau, Lee & Mohamed, 2012). Specifically, global GHG emissions have increased by 38% from 1992 to 2007 (Chavez, 2009). For example, New Zealand failed to achieve its “zero increase in emissions above its 1990 baseline” target in terms of the Kyoto Protocol (Clark, Kelliher & Patiño, 2011). From 1990 to 2006, the total GHG emissions in New Zealand increased by about 15% (Clark, Kelliher & Patiño, 2011).

2.2. Carbon sequestration and methods of carbon sequestration

Carbon sequestration is defined as “the process of capture and long-term storage of atmospheric CO_2” (Sedjo & Sohngen, 2012, p. 128). This is an important mitigation option to reduce the largest portion of GHG emissions (CO_2) (Mandlebaum & Nriagu, 2011). Through carbon sequestration, the effects of global warming and the attendant climate change can be reduced (IPCC, 2007b). Carbon Capture and Storage (CCS) is a technology to capture, transport and store carbons (Mitrović & Malone, 2011). CCS technology focuses on physical and chemical methods of capturing carbon from the atmosphere and storing it somewhere else (Mitrović & Malone, 2011). Stewart and Hessami (2005), in turn, demonstrate a sustainable method to sequester CO_2 as “carbon sinks” based on photosynthesis. It is proposed that carbon can be stored in the ground or in the oceans (IPCC, 2005). Thus, we now discuss carbon sequestration through geological storage, ocean storage, and biotic sequestration.

Geological storage is one method to sequester CO_2 by “injecting CO_2 into suitable deep rock formations” (IPCC, 2005, p. 199). First, CO_2 are captured in a gaseous or supercritical form through physical and chemical methods. Then it is transported through a pipeline to finally be injected into geological formations such as oil fields, gas fields and saline aquifers (IPCC, 2005). These formations need to be is carefully selected, designed and managed if they are to provide long-term solutions (IPCC, 2005). However, according to Klusman (2003), CO_2 can leak out even when stored carefully. Leaked CO_2 from underground storage could also replace O_2 near the surface, representing a major threat to plant and animal wellbeing (Dhulipala, 2007). Moreover, the cost of some carbon sequestration processes can be prohibitive (Kapdi, Vijay, Rajesh & Prasad, 2003; Klusman, 2003).

Ocean storage is another method of carbon sequestration, achieved by injecting and dissolving CO_2 into ocean water (Stewart & Hessami, 2005; IPCC, 2005). However, Stewart and Hessami (2005) argue that “15-20% of the carbon dioxide injected into the ocean will leach back into the atmosphere over hundreds of years” (p. 409). Moreover, injecting CO_2 directly into the ocean will decrease the PH level of the ocean (Stewart and Hessami, 2005).

This will cause environmental issues as the balance of marine life is altered. As a result, ocean storage is not currently seen as an effective method of carbon sequestration.

Biotic sequestration overcomes many of the environmental and cost concerns associated with geological and ocean storage (Lal, 2008; Stewart & Hessami, 2005). Atmospheric CO_2 can be stored in any photosynthesising plant (Raven & Karley, 2006) and because a natural process is used, there is no need for technology or unwanted side-effects (Lal, 2008). However, the carbon storage capacity of trees is limited and remains constant after trees reach maturity (Unwin & Kriedemann, 2000). Nevertheless, biotic sequestration remains an effective method of offsetting CO_2 emissions, considering that almost "half the dry weight of a tree's biomass is carbon" and "trees store carbon in their leaves, branches, stems, bark and roots" (Johnson & Coburn, 2010, p. 1). For any organisation that owns green areas, carbon sequestration in trees can provide part of the answer to carbon offsetting. For example, California State University offsets carbon emissions through quantifying carbon sequestration of its trees (Cox, 2012).

2.3. Carbon management

2.3.1. Carbon liability

According to Adler (2006), GHG (CO2) emitters have liability for their emissions because of environmental damage. Carbon liability refers to "a calculation of values related to the economic externalities of carbon emissions in the global economy" (Fujii, 2012, p. 412). Figueiredo (2007) also points out that there is a potential tortious and contractual liability for CO_2 emitters to sequester CO_2. Many regulations such as emission trading schemes and the US Clean Air Act (CAA) have been established to force emitters to be liable for their carbon emissions and storage (Klass &Wilson, 2008; Reitze, 2009; Greek, 2012). However, it is difficult to attribute the liability for GHG emissions to individuals and entities (Allen, 2003). This is because the environmental damage caused by GHG emissions "are not themselves losses to individuals' paradigmatically protected interests and do not directly cause infringements of private property, physical injuries to individuals, or death" (Adler, 2006, p. 1861). However, whether organisations face a legal liability or not, increasingly public awareness of the effects of GHG emissions leads to public pressure on organisations to address and perhaps institute measures to reduce their emissions.

2.3.2. Carbon accounting

As global climate change issues increasingly find their way onto media headlines, governments have started to respond with regulation that affects all of society, including organisations, individuals and communities (Bebbington & Larrinaga-González, 2008). Under these conditions, accounting for carbon is a method whereby organisations can demonstrate their willingness to be accountable to stakeholders (Ascui & Lovell, 2011).

Carbon accounting means different things to different groups. For example, to political negotiators, carbon accounting implies "rules for comparing emissions and removals as reported with commitments" (IPCC, 2005, P. 165). To organisations, "carbon accounting is the measurement of carbon emissions, the collation of this data and the communication thereof, both within and between firms" (Bowen & Wittneben, 2011, P. 1025).

The various emissions trading schemes now in operation globally have led to increased carbon trading and as a result, carbon accounting is now a mainstream activity in many jurisdictions (Bebbington & Larrinaga-González, 2008; Lohmann, 2009). Haigh and Shapiro (2012) suggest that organisations have a responsibility to prepare carbon reporting for stakeholders. In order to prepare carbon reporting, carbon information needs to be collected, including carbon emissions, carbon sequestrations and carbon trading is required (Haigh & Shapiro, 2012). Moreover, McKinnon (2010) points to carbon auditing to assure the organisation's accountability for carbon accounting. Carbon auditing ensures accurate, consistent and specific information about carbon activities in organisations (Bowen & Wittneben, 2011). In summary, carbon accounting demonstrates that an organisation is assuming social responsibility for their GHG emissions.

2.3.3. Carbon emissions management

As organisations pay more attention to environmental risks, carbon emissions management plays an important role in performance management (Enernoc, 2012). Specifically, carbon management focuses on reducing emissions and proposing energy efficient projects (Enernoc, 2012). Carbon capture and sequestration requires risk management of CO_2 leakage (Wilson, Friedmann & Pollak, 2007). Effective carbon management could improve the effectiveness of carbon capture and sequestration (Wilson, Friedmann & Pollak, 2007). Moreover, Herzog, Caldeira and Reilly (2003) also advocate a correct management approach for sequestration to assist organisations to accept their carbon liability. In addition, Ogle, Conant and Paustian (2004) state that management is required to mitigate GHG emissions in carbon accounting. For example, an accountant could set a carbon emissions baseline for an organisation based on past emission figures (CMP, 2012). Therefore, carbon management is needed to mitigate any risks associated with carbon sequestration. However, there are few risks involved in carbon sequestration by natural means, i.e. in trees.

For higher education institutions, carbon management is also important to achieve the goal of sustainability (Dahle & Neumayer, 2001). Many universities establish their own carbon management to make contributions to both climate change prevention and sustainability. The Higher Education Carbon Management (HECM) Programme in Britain is a good example of assisting universities to develop the capacity to deal with carbon emissions (CMP, 2012). According to CMP (2012), HECM assists universities to set up a carbon management plan, including setting a baseline, forecasting and targeting carbon emissions and sequestration. Universities in other setting have also started with carbon management initiatives, e.g., Auckland University in New Zealand has started to calculate carbon sequestration in conventional areas on its main campus (Xu & Mitchell, 2011). Except for the calculation of carbon emission and sequestration, universities also prefer to design low carbon higher education systems (Roy, Potter & Yarrow, 2008). For example, universities could use electronic copies of lecture notes to students instead of paper copies. Clearly, carbon emissions can be reduced with the implementation of carbon related policies and management.

2.3.4. Does KIWI University have a carbon emissions liability?

We will now consider whether the university has any liability because of its carbon emissions. After 1 December 2012, the university's financial statements has to comply with the new Generally Accepted Accounting Practices in New Zealand (NZ GAAP) for public benefit entities, issued by the External Reporting Board in 2012 (External Reporting Board, 2012a). Under the *New Zealand International Accounting Standard 37 (Public Benefit Entities)-NZ IAS 37 (PBE): Provisions, Contingent Liabilities and Contingent Assets*, a liability or contingent liability arise from a past obligation event (External Reporting Board, 2012b). An obligation event is defined under *NZIAS 37 (PBE)* as "an event that creates a legal or constructive obligation that results in an entity having no realistic alternative to settling that obligation" (External Reporting Board, 2012b, p.14). A legal obligation derives from "a contract, legislation or other operation of law" (External Reporting Board, 2012b, p. 14). The *Climate Change Response Act 2002, Section 54* defines mandatory participants under the New Zealand Emissions Trading Scheme as persons conducting activities in relation to forestry, liquid fossil fuels, stationary energy, industrial processes, agriculture and waste. KIWI University, as an institution of higher education, is not a mandatory participant as defined under *Section 54.* Thus, no legal obligation exists for the University in terms of carbon emissions. Furthermore, a constructive obligation derives from actions that "the entity has indicated to other parties that it will accept certain responsibilities by an established pattern of past practice or published policies or a sufficiently specific statement and as a result, the entity has created a valid expectation on other parties that it will discharge those responsibilities" (External Reporting Board, 2012b, p.14). KIWI University has no past practice of recognising carbon emissions as an obligation, as no carbon information can be found in past annual reports, and there is no published policy or specific statement expressing the University has a responsibility to reduce carbon emissions. Thus, the University has no constructive obligation in terms of carbon emissions.

Thus, the University has no legal or constructive obligations associated with carbon emissions. Therefore, the University has no carbon emissions liability or contingent liability on carbon emissions.

2.3.5. Does the University have an obligation to disclose carbon information?

Participants under the New Zealand Emissions Trading Scheme are legally required to collect, calculate, verify and record carbon emissions and removals, according to the *Climate Change Response Act 2002, Section 62.* Since KIWI University is not a mandatory participant of the New Zealand Emissions Trading Scheme defined under *Section 54,* the University is not legally required to disclose carbon information.

However, the University signed the UN 'Commitment to Sustainable Practices of Higher Education Institutions' in 2012 (KIWI University, 2012a). This commitment requires universities to adopt sustainable practices, but does not specifically mention carbon disclosure. Therefore, there is no obligation to disclose carbon information emanating from this UN commitment.

Nevertheless, the University has general obligations towards society and the environment in the form of social responsibility towards the natural environment. Sustainability and the lowering of carbon emissions have become key social concerns and organisations, to be good citizens, need to consider efforts to reduce carbon emissions (Rondinelli & Berry, 2000). Huang and Kung (2010) suggest that environmental disclosure is an important component of environmental responsibility. Environmental disclosure is increasingly demanded, i.e. carbon disclosure is a part of environmental responsibility to conform to social expectations. Therefore, the University has social and environmental obligations rather than mandatory obligation on carbon disclosure.

2.3.6. How can the University disclose carbon information?

Despite not having any legal obligation to disclose carbon emissions information, the University can voluntarily disclose carbon information. The University is not a participant in the New Zealand Emissions Trading Scheme and does not partake in any carbon trading. The University could apply the *Climate Change Reporting Framework (Edition 1.1)* to disclose carbon information. The disclosure content includes 'strategic analysis, risk and governance' and 'greenhouse gas emissions' (Climate Disclosure Standards Board, 2012). In the part of 'strategic analysis, risk and governance', the University should disclose: "strategic analysis-a statement of the impacts of climate changes on organisation's strategic objectives; risks-an assessment of organisation's climate change risks; opportunities-an assessment of organisation's opportunities associated with climate change; management actions-a description of the organisation's plan on managing climate change risks and opportunities; future look-a explanation of future climate change impacts and management; governance-a description of organisation's governance on climate change" (Climate Disclosure Standards Board, 2012, p.19-21). In the section on 'greenhouse gas emissions', the University could disclose "gross absolute greenhouse gas emissions" and "movements in greenhouse gas emissions" with an explanation of the movement (Climate Disclosure Standards Board, 2012, p.22).

Should the University choose to follow this framework, the total CO_2 emissions, the categories of emissions, and CO_2 sequestered could be disclosed. The University could disclose the above carbon information in a greenhouse gas emissions report or a sustainability/environment report.

3. METHOD

3.1. Study site

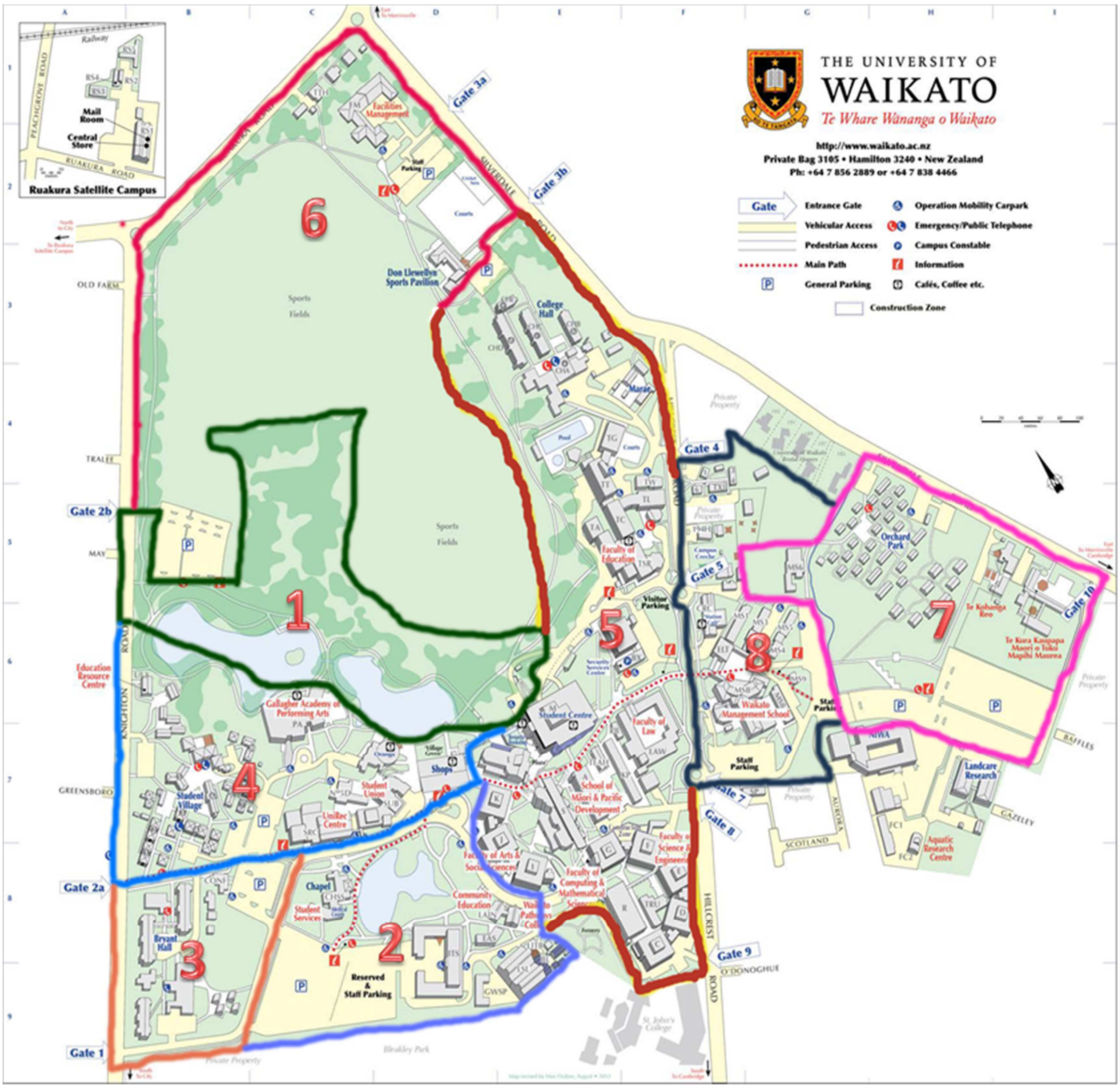

Figure 1: Map of Main campus

The main campus of KIWI University was established in 1965 and covers 65 hectares (University of KIWI, 2012b). Almost 6000 trees, representing over 200 species, have been planted on the campus. Some of the trees were planted around 1912, some in the 1940s when Hillcrest Road was constructed, but most were planted after 1965. We record trees measuring more than three meters, as trees under this height do not store much CO_2. Slightly more than 4000 trees are over 3 metres in height and were measured. Trees were counted in the eight areas of the campus indicated on Figure 1.

3.2. Method for calculating current CO_2 sequestration in trees

We use the method of carbon counting devised by Brown Country (2012). The equation to estimate tree biomass is based on the physical relationship between tree volume and wood density (Xu & Mitchell, 2011). As the tree variables are complex, and tree species information is not sufficient, this calculation method used average figure of trees instead of variables based on tree species (Brown Country, 2012).

There are five steps to measure the weight of CO_2 in a tree per year (Brown Country, 2012). The detailed information of each step is shown in Appendix 1. The equation for the measurement of CO_2 sequestered in a tree per year is summarised as follows:

$$W = \frac{0.25 * D^2 * H * 120\% * 72.5\% * 50\% * 3.6663}{Tree\ age} \quad \text{(When D < 11 inches)}$$

$$W = \frac{0.15 * D^2 * H * 120\% * 72.5\% * 50\% * 3.6663}{Tree\ age} \quad \text{(When D >= 11 inches)}$$

Where:
W= Weight of CO2 sequestered in the tree per year in pounds,
D = Tree diameter in inches, and
H = Tree height in feet.

3.3. Method for predicting future CO_2 sequestration in trees

In order to assess the future CO_2 sequestration in trees in the next 10 years, we used estimates of tree growth rates. Figure 2 illustrates forest tree growth in New Zealand, showing that tree volumes increase slowly during the first 10 years, increasing dramatically during the age range of 10 to 40 years, and stabilising after the age of 40 years when trees achieve maturity. The relationship between carbon sequestration and tree ages is similar to the relationship between tree volume and tree ages. Figure 3 shows that very little carbon is sequestered during the early years. This increases dramatically between the ages of 10 and 40, but levels off around the age of 40 (Figure 3).

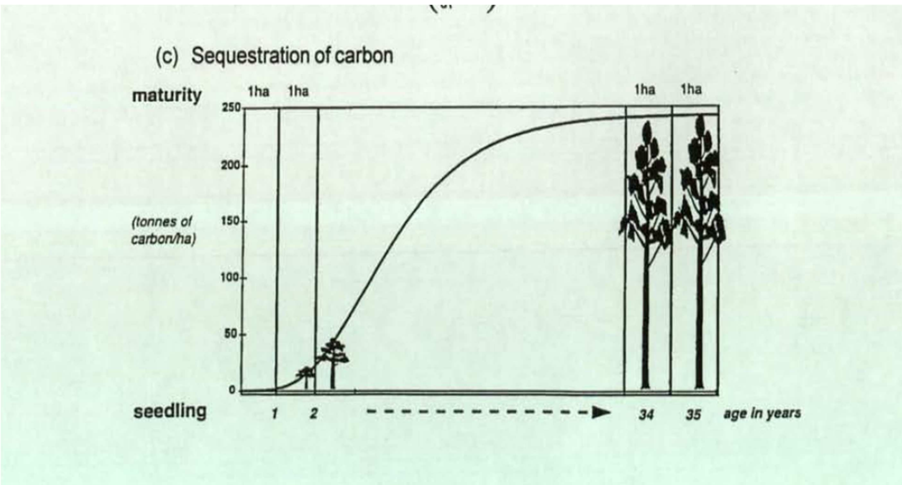

Figure 2: Sequestration of carbon of a tree at different ages (Source: Unwin & Kriedemann, 2000)

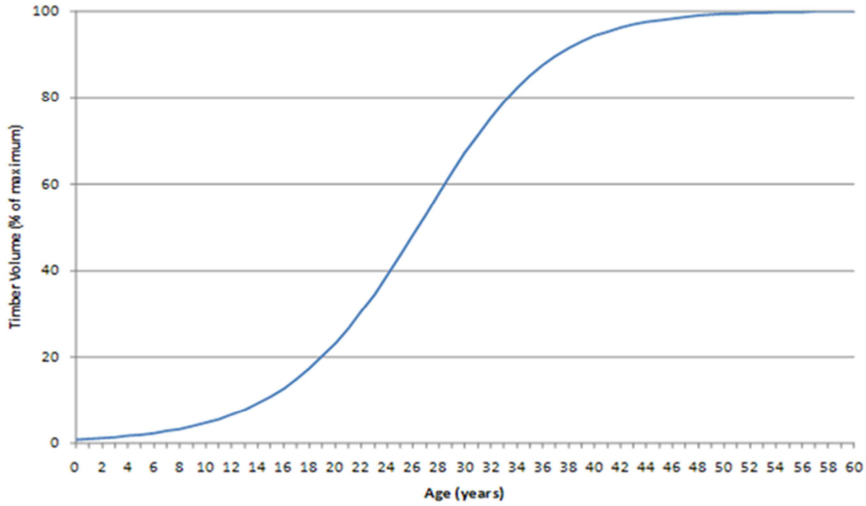

Figure 3: Forest tree growth (Source: Ministry of the Environment, 2008)

Leoni, Fonseca and Schöngart (2011) point out the relationship between tree volume (including tree diameter and height) and tree ages in a quantitative approach (Appendix 2). Based on Figures 2 and 3, the average growth rate in different ranges of tree ages was estimated: for trees less than 10 years, the incremental diameter was estimated at 0.4 cm per year and the incremental height at 0.6 m per year; for trees aged 10-40 years, the incremental diameter was estimated to be 0.38 cm per year and the incremental height at 1m per year; an finally, for trees more than 40 years old, the tree diameter and height was estimated to remain constant (Appendix 2). The future carbon sequestration in trees is estimated using the equation provided by Brown Country (2012).

4. RESULTS AND ANALYSIS

Tree counting was conducted during September and October 2012. A total of 4,137 trees, representing 129 major species were measured around the main campus. We calculated the total weight of carbon sequestered in these trees to have been 1,585 tonnes. This translates to 5,809.4 tonnes when expressed in terms of CO_2 sequestered.

4.1. Current carbon sequestration in trees

4.1.1. Trees in separate areas

We divided the campus into eight areas to facilitate record keeping. Figure 4 shows the total weight of CO_2 sequestered in the trees by area. Note that the trees in area one have sequestered almost one third of CO_2 of the main campus. The major reason for the highest CO_2 sequestration in this area is that almost one quarter of the total number of trees is in this area (Figure 1). Moreover, the majority of trees in area one is large and high. The trees in the other areas have only stored about 500,000 kg of CO_2 per area. In these areas, most of the trees are around buildings or along roads.

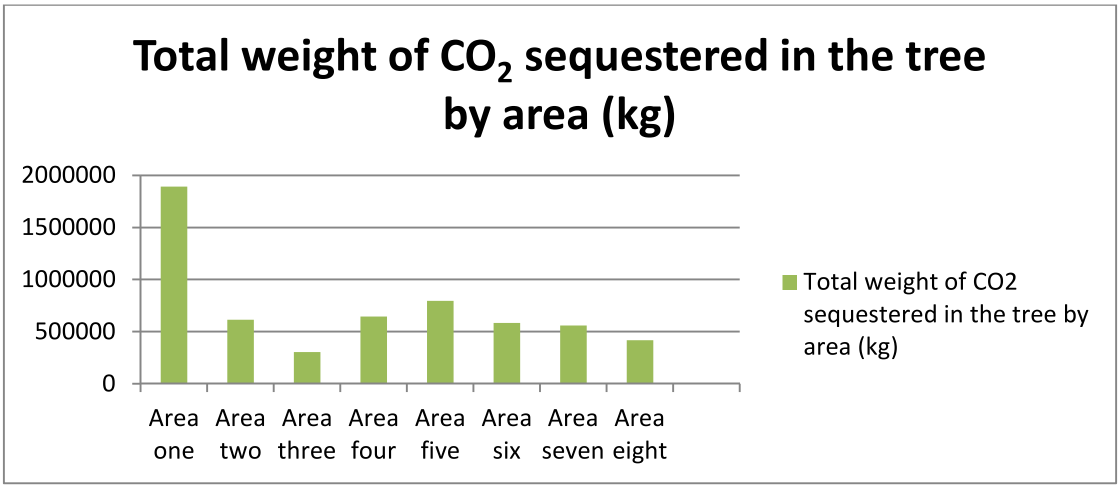

Figure 4: Current total weight of CO_2 sequestration in trees by area

4.1.2. Tree classification

Evergreen plants have leaves in all seasons, while deciduous plants have leafless periods during the winter or dry season (Benavides, Douglas & Osoro, 2009). With the help of expert ground staff, the measured trees were divided into these two groups. According to Table 1, 70% of main campus trees are evergreen, whilst 30% are deciduous. There are profound differences in CO_2 sequestration between evergreen and deciduous plants (Buchmann, Kao & Ehleringer, 1997). The differences in CO_2 storage between species are less marked (Kirby and Potvin, 2007). Therefore, the use of an average CO_2 sequestration for evergreen trees and for deciduous trees is regarded as fairly accurate. Evergreen trees sequester an average of 44.37 kg of CO2 per year, while deciduous trees sequester an average of 40.87 kg of CO_2 per annum – see Figure 5.

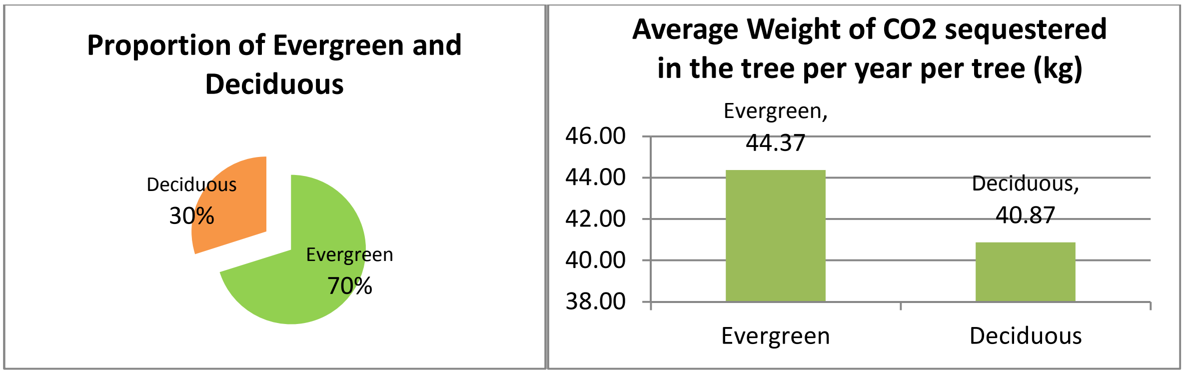

Figure 5: Comparisons of evergreen and deciduous trees in the research

4.1.3. Trees at different ages

We already mentioned that trees store different amounts of CO_2 depending on their age (Unwin & Kriedemann, 2000). In trees younger than 15 years old, the weight of CO_2 sequestered increases smoothly. Between the ages of 15 and 45, CO_2 sequestration increases dramatically (Unwin & Kriedemann, 2000). However, after 45 years of age, the weight of

CO_2 sequestered declines slowly as trees start to release some CO_2 back into the atmosphere (Nowak, Stevens, Sisinni & Luley, 2002).

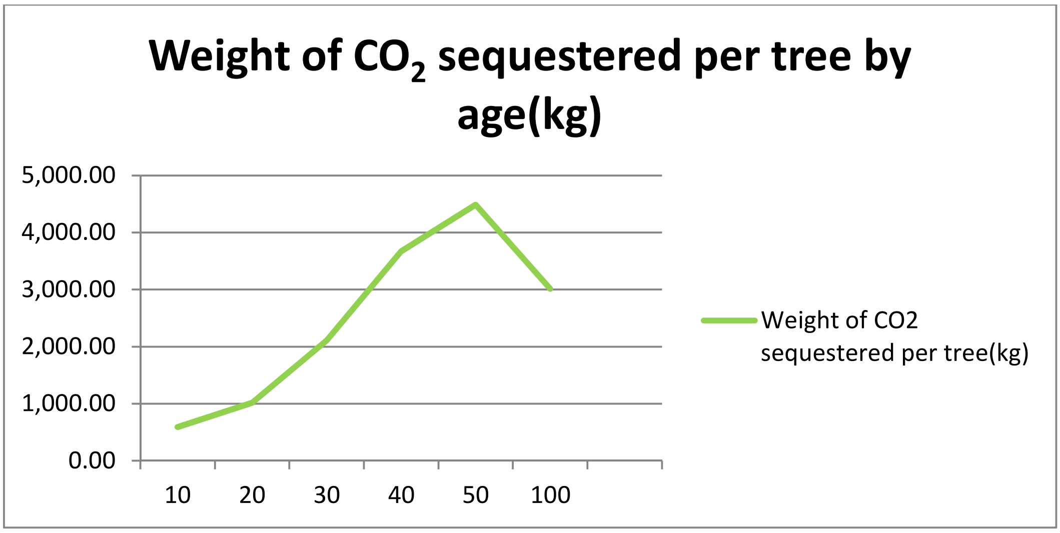

Figure 6: Weight of CO_2 sequestered per tree by tree ages

4.2. Prediction of carbon sequestration from 2012 to 2022

We estimated future carbon sequestration based on tree growth rates in the different age groups, i.e. in the age ranges: <10 years, 10-40 years, and >40 years. Figure 7 shows that carbon sequestration is expected to increase smoothly from 2013 to 2022. By 2022, the total carbon sequestered in trees will be about 2,273 tonnes, and CO_2 sequestration will be 8,334 tonnes, an increase of 43.46% on the figures for 2012. This estimate ignores new trees that may be planted at KIWI University in the future. Note that the number of trees over 40 years will increase dramatically by 2022, because more than a quarter of the trees are currently aged between 30 and 40 years. Moreover, only 6.6% of the total number of trees is under 10 years of age and will reach the age range of 10 to 40 years by 2022. As a result, the proportion of trees aged over 40 years will, over the next 10 years, increase from 44% to 60%, which means that the capability of trees at KIWI University to store additional carbon will start to reduce – see Figure 8.

The CO_2 sequestered in campus trees are expected to grow from 5,809 tonnes to 8,334 tonnes over the next 10 years, i.e. an 2,525 tonnes over 10 years, or 253 tonnes per year. The annual figure of 253 tonnes does not compare favourably with the university's annual emissions figure of 4,087 tonnes. Therefore, the university cannot rely on carbon sequestration alone to mitigate the emissions the university is responsible for.

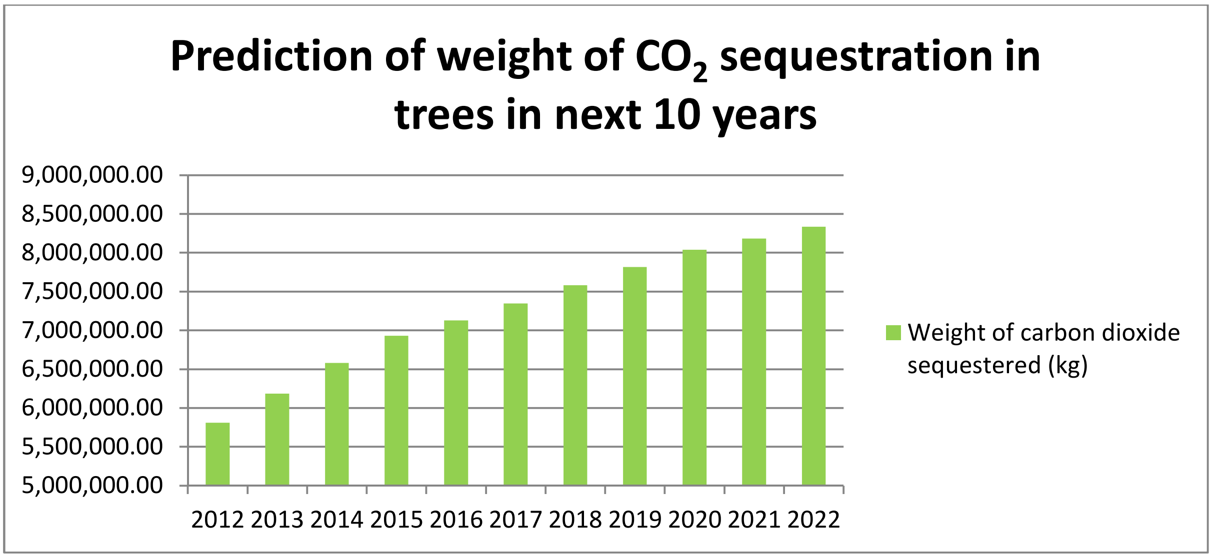

Figure 7: Prediction of total weight of CO_2 sequestration in trees in next 10 years

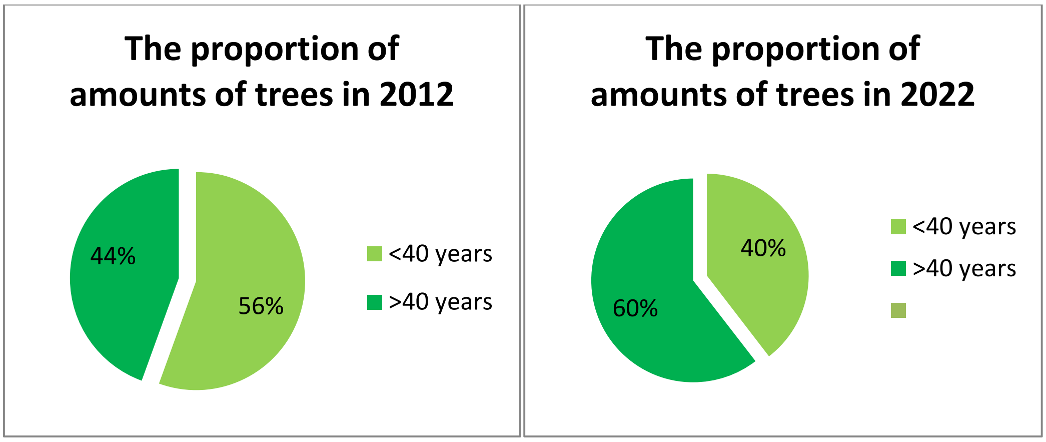

Figure 8: The proportion of numbers of trees in 2012 and 2022

4.3. Comparison with other universities

Table 1 shows the comparison of total CO_2 sequestration in trees in different universities. It indicates that the capability of CO_2 sequestration in Eastern Illinois University is the strongest among those universities. The carbon sequestration of 4,051 trees is 1,591 tonnes and 5,828 tonnes of CO_2 sequestrations. In contrast, KIWI University's trees have stored 1,585 tonnes of carbon from 4,137 trees and 5,809 tonnes of CO_2. It is indicated that trees on different campuses have similar capability of carbon sequestration depending on similar tree numbers.

University	Proportion of area coverage	Tree numbers	Carbon sequestration (tonnes)	CO_2 sequestration (tonnes)
KIWI University	100%	4137	1,585	5,809
California State University	100%	3,900	862	3170
Eastern Illinois University	100%	4,051	1,591	5,828
Auckland University (conservation area)	26.00%	400 +	225.2	736

Table 1: CO_2 sequestration in trees in different universities (Source: Xu & Mitchell, 2011; Cox, 2012)

4.4.Carbon emissions by KIWI University

KIWI University emits GHG (CO_2) in three major areas: international and domestic air travel by university staff, waste to landfill, and travel of fleet cars. Table 2 illustrates the CO_2 emissions in 2011 at the university. The total CO_2 emissions in 2011 were 4,086.8 tonnes. Specifically, international travel emitted 2953 tonnes of CO_2 and domestic travel emitted 275.8 tonnes of CO_2. Waste to landfill emitted 354 tonnes of CO_2 and fleet cars on campus emitted 504 tonnes of CO_2 (Table 2).

Carbon Calculations for the year 2011 at KIWI University	
Air travel	CO2 (tonnes)
International	2,953.0
Domestic	275.8
Total air travel	3,228.8
Waste	
Waste to landfill (to gas collection landfill)	354.0
Travel (fleet of cars)	504.0
Total CO2 (tonnes)	**4,086.8**

Table 2: Carbon calculation for the year 2011 at KIWI University. (Goddard, 2012).

The results of CO_2 sequestration in trees in 2012 at KIWI University is about 5,809 tonnes. Based on the tree growth rate, and ignoring the uncertainty elements such as tree turnovers, the CO_2 sequestration in 2011 at the university could be estimated as 5,460 tonnes. As CO_2 emissions in 2011 was 4,086.8 tonnes, there are about 1,373 tonnes of differences between carbon emissions and carbon sequestrations. This means that the university can offset all CO_2 emissions caused by its campus operations in 2011. Furthermore, the university sequestered an extra 1,373 tonnes of CO_2 for society in 2011.

The statistic results of CO_2 emissions and CO_2 sequestration in trees demonstrate a positive view for the university to seek a sustainable approach. That is, the university has the strong capability to offset its own carbon emissions and the results indicate that it has made a significant contribution to doing this. As a result, the reputation of the university will be improved. Moreover, the university will be encouraged to do further research about carbons on campus, and to conduct other projects related to campus greening. Thus, the environmental issues caused by the university will decline. Therefore, the calculation results of this paper benefit the university in taking its social responsibility and protecting environment positively.

4.5. Potential limitation

Tree ages were estimated by staff responsible for tree maintenance at KIWI University. In some cases these estimates were based on accurate historic records, but some data had been lost due to staff turnover and other issues. Some estimates were also based on comparisons of the sizes of trees compared to similar sized trees elsewhere on campus where accurate records were available, e.g. a limited tree census dating from 2006 providing information on the majority of trees on campus. Thus, we are confident that our estimates are fairly accurate.

5. DISCUSSION

5.1. Benefits and barriers to campus greening

According to Dahle and Neumayer (2001), higher educational institutions are well suited to being leaders in environmental protection, because universities have a profound influence on the whole of society based on their research, teaching and policy development expertise (Dahle & Neumayer, 2001). There are many potential benefits to universities for being seen as leaders in sustainable development. Firstly, "green" campuses could use resources efficiently and create less waste, e.g., through hazardous waste recycling, which reduces GHG emissions such as CO_2 (Hazardous Waste Recycling Benefits, 2012). After all, hazardous waste recycling reduces air, water and soil pollution. Secondly, universities would have a competitive advantage by "greening" campuses compared to others who do not act on sustainable development. Filho (2011) demonstrates that inclusion of sustainability dimensions into university programmes benefits several groups, such as university administration staff, teachers and students, who would like to live, work, and be associated with an environmentally friendly university. As a result, "green" universities could potentially attract better staff and students compared to their counterparts. Thirdly, "greening" of campuses could improve the reputation and image of universities. These potential benefits should be attractive to universities.

There are also some barriers to universities pursuing green initiatives on campuses. Firstly, sustainability initiatives are essentially voluntary in nature and thus universities have no legal obligation to pursue this agenda. Many universities may this opt to maintain their historic practices (Chen, 2012). Secondly, pursuing a sustainability agenda may be costly. For example, universities require statistics to calculate carbon emissions and carbon sequestrations. Moreover, new staff may have to be employed to take responsibility for issues such as carbon management and carbon accounting. As a result, the cost of implementing green initiatives could be high.

5.2. Carbon management and related issues at KIWI University

The Environmental Policy Committee (EPC) was established to plan and implement initiatives regarding KIWI university's environmental responsibilities. The members of the

EPC discuss any environmental issues and solutions at the university. The Environmental Management Working Party (EMWP), as a formal subcommittee of the EPC, formulated an Environmental Policy to integrate the University's commitment to implementing sustainable practice on its campus in 1995 (University of KIWI, 2012d). The implementation of this policy is under constant revision to ensure continued effectiveness (University of KIWI, 2012c). For example, a small battery recycling station approved by EPC has been set up to better manage and reduce waste on campus, and the university's fleet of motorcars have recently been replaced with fuel efficient Toyota Prius C vehicles. Our research project form an integral part of the EPC's programme. Thus, the EPC plays an important role in driving new environmental initiatives.

Among other initiatives, the EPC drives campus greening projects. Campus greening contributes to the mitigation of carbon emissions produced through air travel, waste, and energy consumption. Firstly, the university boast some significant recent achievements in the reduction of resources usage (University of KIWI, 2012a). For example, there was reduction of 29% in copier paper usage over the last two years. This equates to a saving of 57 pine trees and the significant amount of energy used to turn trees into paper. Secondly, the university is busy implementing an energy reduction plan through a Building Management System (BMS). About 95% of all air conditioning and lighting are now controlled by timers to reduce the waste of energy. Thirdly, the university also has a community garden and green living roofs on two buildings. These initiatives are all aligned with an environmental agenda.

The EPC is now starting to implement a carbon management policy. Carbon management is a new area for the university to develop and the EPC will have to consider both the reduction of carbon emissions and the development of carbon sequestration and management initiatives.

Our carbon sequestration records should form the basis for a database to inform the on-going management of carbon sequestration, including the planning of new planting and decisions regarding the management of mature trees on campus. Burritt, Schaltegger and Zvezdov (2011) demonstrate that there are gaps in knowledge about what, how and why carbon-related information should be collected. Therefore, the university will have to develop their carbon management initiatives.

It may also be necessary to initiate carbon training for both staff and students to ensure that the reduction of the university's carbon footprint continues.

5.3. Carbon management at KIWI University

Previous KIWI University environmental projects were mainly focused on energy and waste reduction. These initiatives link with carbon management. However, our results should encourage the EPC to further formalise carbon management as a separate project to ensure that garden maintenance policies maximise the opportunities for carbon sequestration. A database of carbon sequestration-related information, based on the information gathered in our research, will probably form part of such a project. In this way, this paper will play a role in carbon management at KIWI university.

6. CONCLUSION

We calculated the carbon sequestered in trees on the main campus of KIWI University and estimated the annual expected sequestration over the next 10 years. Our results suggest that the university can rely on carbon sequestration to mitigate less than 10% of the emissions the university is responsible. Specifically, only 253 tonnes of CO_2 is expected to be sequestered per annum over the next 10 years, whereas CO_2 emissions for 2011 already amounted to 4,087 tonnes. The main source of CO_2 emissions were overseas travel, accounting for more than 70% of the university's GHG emissions. A moratorium on overseas travel may not be a practical solution for a university, but would reduce the university's GHG emissions by more than 70% and would increase the relative contribution of carbon sequestration in trees to the university's overall carbon mitigation from the current 6% (253/4,087) to 22% (253/(4,087-2,953)).

In order to calculate the current CO_2 sequestration in trees at the university, the formula: $W = \frac{(0.25\ or\ 0.15)*D^2*H*120\%*72.5\%*50\%*3.6663}{Tree\ age}$, was used. We measured 4,137 trees, representing 129 major species of trees. We estimate that these trees currently store 5809.4 tonnes of CO_2. By 2022, we estimate that 8,334 tonnes of CO2 will be stored in the trees currently on campus, an increase of 43.46% on the 2012 figure. Further plantings could potentially increase these figures.

This tree census and estimates could form the basis for a more formal on-going carbon management programme, which could garner accolades and further improve the university's environmental reputation. The university's EPC has in the past contributed to reducing carbon emissions at the university through various programmes, e.g., encouraging the reduced use of copiers, using sustainable material for printing, and establishing green living roofs.

Our results show that the university can offset a small percentage of its carbon emissions through carbon sequestration in campus trees.

Some recommendations for universities considering a carbon management programme are provided below:

- A committee, similar to KIWI University's EPC, could be established and charged with the responsibility to develop a carbon management policy.
- Information regarding the carbon management policies could be disclosed on the university's website to increase staff, student, and public awareness of the initiative.
- University could establish a database to store carbon sequestration-related information such as tree species, ages, carbon sequestered in trees, CO_2 emissions, waste management and energy usage, and other issues related to carbon emissions and mitigation.
- This database could be maintained and updated on a regular basis.
- The database could form the basis for the university to prepare and disclose carbon related information.
- The database could also be used as input for decision-making regarding tree plantings and the management of mature trees.
- University staff and students could be recruited to contribute ideas, reduce emissions-related activities as far as possible, and disseminate information about the university's carbon initiatives to colleagues and university stakeholders.
- Electronic conferences could be encouraged to reduce the amount of air travel.

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Appendix 1: Methods for carbon sequestration in trees (Source: Broward County, 2012)

How to calculate the amount of CO2 sequestered in a tree per year

We at Trees for the Future estimate that our agroforestry trees, planted in tropical climates, will sequester atmospheric carbon dioxide at an average of **50 pounds** of carbon dioxide per tree per year.

The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. It is greatest in the younger stages of tree growth, between 20 to 50 years.1 Further complicating the issue is the fact that far less research has been done on tropical tree species as compared to temperate tree species.

Nevertheless, we can roughly estimate the amount of CO2 sequestered in a given tree, and if we divide by the tree's age, get a yearly sequestration rate.

We got this process from two educational websites who had conceived it as a learning activity for their students. 2 This is the process:

1. Determine the total (green) weight of the tree.
2. Determine the dry weight of the tree.
3. Determine the weight of carbon in the tree.
4. Determine the weight of carbon dioxide sequestered in the tree
5. Determine the weight of CO2 sequestered in the tree per year

Determine the total (green) weight of the tree

Based on tree species in the Southeast United States, the algorithm to calculate the weight of a tree is: 3

W = Above-ground weight of the tree in pounds

D = Diameter of the trunk in inches

H = Height of the tree in feet

For trees with D < 11:

W = 0.25D2H

For trees with D >= 11:

W = 0.15D2H

Depending on the species, the coefficient (e.g. 0.25) could change, and the variables D2 and H could be raised to exponents just above or below 1. However, these two equations could be seen as an "average" of all the species' equations.

The root system weighs about 20% as much as the above-ground weight of the tree.

Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120%.

Determine the dry weight of the tree

This is based on an extension publication from the University of Nebraska.4 This publication has a table with average weights for one cord of wood for different temperate tree species.

Taking all species in the table into account, the average tree is 72.5% dry matter and 27.5% moisture.

Therefore, to determine the dry weight of the tree, multiply the weight of the tree by 72.5%.

Determine the weight of carbon in the tree

The average carbon content is generally 50% of the tree's total volume.5 Therefore, to determine the weight of carbon in the tree, multiply the dry weight of the tree by 50%.

Determine the weight of carbon dioxide sequestered in the tree

CO2 is composed of one molecule of Carbon and 2 molecules of Oxygen.

The atomic weight of Carbon is 12.001115.

The atomic weight of Oxygen is 15.9994.
The weight of CO_2 is C+2*O=43.999915.
The ratio of CO_2 to C is 43.999915/12.001115=3.6663.
Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.6

Determine the weight of CO2 sequestered in the tree per year

Divide the weight of carbon dioxide sequestered in the tree by the age of the tree. Etvoila!

EXAMPLES

Estimated growth rates and sizes of agroforestry trees were taken from the World Agroforestry Centre's "Agroforestree Database"7:
Let's see how much a Calliandra calothyrsus might sequester in a year. A 10-year-old Calliandra would probably grow about 15 feet tall with a trunk about 8 inches in diameter. Therefore:
W = 0.25D2H = 0.25(82)(15) = 240 lbs. green weight above ground.
240 lbs. * 120% = 288 lbs. green weight (roots included)
288 lbs. * 72.5% = 208.8 lbs. dry weight
208.8 lbs. * 50% = 104.4 lbs. carbon
104.4 lbs * 3.6663 = 382.8 lbs. CO_2 sequestered
382.8 lbs / 10 years = **38.3 lbs**. CO_2 sequestered per year
Or consider a 10-year-old Grevillia robusta, 45 feet tall with a trunk 6 inches in diameter. Using the same calculations as above, the amount of CO_2 sequestered would be **64.6** lbs. per year.
Or a newly-planted Acacia angustissima, 2.5 years old, 15 feet tall with a trunk 3 inches in diameter: **21.5** lbs. of CO_2 sequestered per year.
Or an Albizzia lebbek, 15 years old, 30 feet tall, with a 12 inch trunk: **68.9** lbs. of CO_2 sequestered per year.

Other methods

Another way to estimate the amount of CO_2 sequestered by a tree in a year is to estimate the amount sequestered in a hectare per year, and divide that amount by the number of trees per hectare. Scanning around on the Internet, it seems that the number of trees per hectare (in agroforestry and/or industrial plantations) ranges from under 500 to over 2,000.
According to Myers and Goreau, tropical tree plantations of pine and eucalyptus can sequester an average of **10 tons** of carbon per hectare per year. 8 Therefore, the plantation can sequester an average of 20,000 lbs * 3.6663 = 73,326 lbs CO_2/ha/year, or, taking an average of 1,000 trees per hectare, **73.326** lbs CO_2/tree/year.
Of course, we heavily discourage the planting of pine and/or eucalyptus in our agroforestry systems. Our trees may not grow as fast or as straight as eucalyptus, but they are not invasive, and they do not destroy the water table and the soil!

Disclaimer

This research and methodology is based on research papers, university publications, and other information freely available on the Internet. As we stated before, it is difficult to calculate the amount of carbon dioxide sequestered per tree per year due to the complexity of the variables involved, as well as the lack of research on tropical tree species. If you have any information that could further refine or enhance our calculations, please let us know at info@treesftf.org.
Thanks and happy tree planting!

1 http://www.rcfa-cfan.org/english/issues.13.html
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http://www.ilea.org/birdsey/fcarbon_index.html#toc
6 http://www.ncsec.org/cadre2/team18_2/students/helpCalcCO2.htm
7 http://www.worldagroforestrycentre.org/Sites/TreeDBS/aft.asp
8 "Tropical Forests and the Greenhouse Effect: A Management Response," Norman Myers and Thomas J.
Goreau, Discovery Bay Marine Laboratory, University of the West Indies, Discovery Bay, Jamaica, 1991.
http://www.ciesin.columbia.edu/docs/002-163/002-163.html

Appendix 2: Tree growth rates

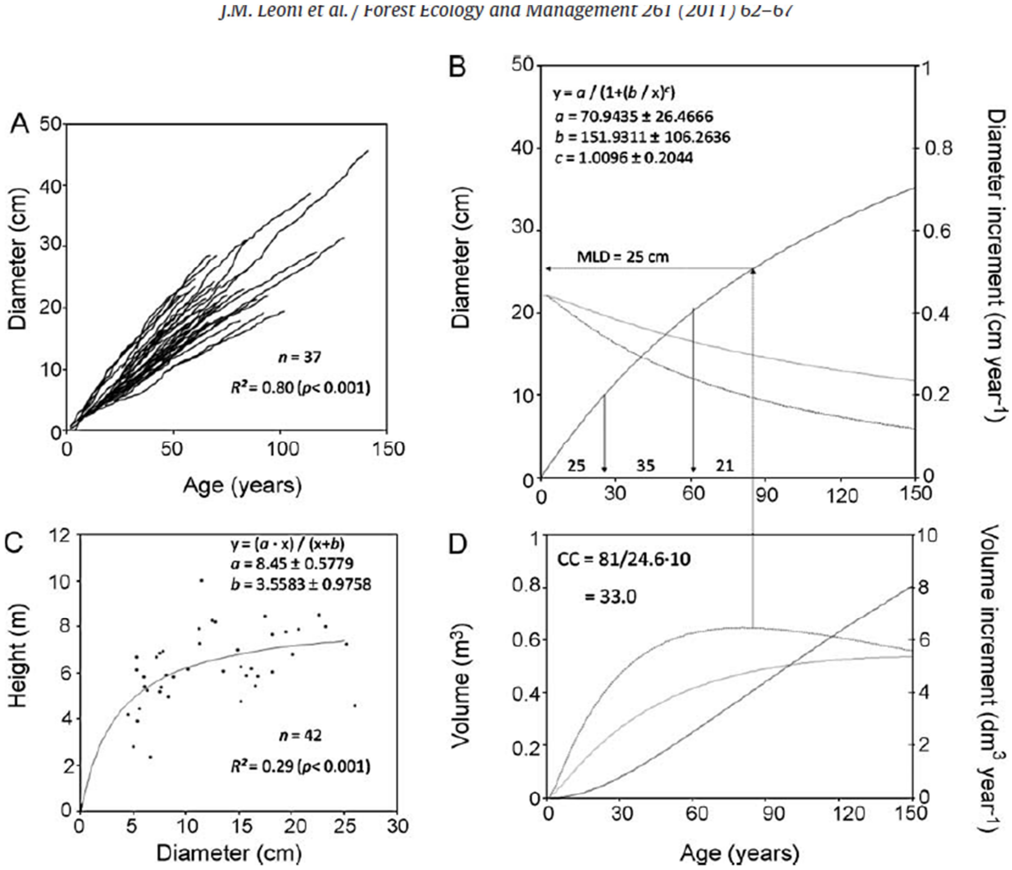

Diagram above: Relationship between tree volume and tree ages.

(Source: Leoni, Fonseca & Schöngart, 2011)

Based on the relationship between tree volume and tree ages, the tree growth rates regarding to tree diameter and height are summarised as below:

Age range	Incremental diameter (cm)	Incremental height (m)
0-10	0.4	0.6
11-40	0.38	1
>40	Nearly Constant	Nearly Constant

Table 1: Growth rates of trees based on age of trees.