Carbon sequestered in the trees on a university campus: A case study

Article *in* Sustainability Accounting, Management and Policy Journal · May 2014

DOI: 10.1108/SAMPJ-11-2013-0048

Charl De Villiers
University of Auckland

Carbon sequestered in the trees on a university campus: a case study

Charl De Villiers
The University of Waikato, Hamilton, New Zealand and University of Pretoria, Pretoria, South Africa, and
Sile Chen, Chenxing jin and Yiner Zhu
The University of Waikato, Hamilton, New Zealand

Abstract

Purpose – The authors aim to 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.

Design/methodology/approach – The authors count and measure the trees on the university's 68 hectare main campus, ignoring smaller trees that sequester very little CO_2.

Findings – The authors estimate that the 4,139 trees the authors count contain 5,809 tonnes of CO_2. The authors further estimate the additional CO_2 sequestration over the next ten years to be 253 tonnes per year. The university's annual CO_2 emissions were 4,086 tonnes in 2011. More than 70 per cent of this amount relates to overseas travel. Therefore, CO_2 sequestration in trees promises to mitigate only about 6 per cent of total emissions over the next ten years.

Practical implications – 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.

Originality/value – The authors contribute to the ongoing debate around carbon emissions, exploring avenues to mitigate CO_2 emissions.

Keywords Carbon emissions, Carbon accounting

Paper type Case study

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 (IPCC, 2013; Solomona *et al.*, 2009). The Kyoto Protocol of 1997 focus on the reduction of carbon emissions, a major GHG (Oberthür and 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 and Marland, 2003). This is because, as they grow, trees use carbon as the basis

The authors would like to thank Carol Adams for comments and feedback on an earlier draft of the paper.

Sustainability Accounting, Management and Policy Journal
Vol. 5 No. 2, 2014
pp. 149-171

2040-8021
DOI 10.1108/SAMPJ-11-2013-0048

of their structure, storing carbon in the process (Raven and Karley, 2006). The European Union (EU) 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 and Hansjürgens, 2002). These emissions trading schemes have created a whole new "carbon economy" (Boyd *et al.*, 2011). Apart from private organisations, carbon emissions and management is also becoming a major issue for the public sector (Shead *et al.,* 2009).

Following recent research, and calls for further research, into universities' sustainability activities (Adams, 2013; Cebrián *et al.*, 2013; Mader *et al.*, 2013), we focus on this aspect of a university's sustainability management. 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. Ozawa-Meida *et al.* (2011) report the findings of a case study calculating the carbon footprint of a university, focussing their attention on carbon consumption. This study shows the extensive carbon emissions associated with universities. Universities are also able to use carbon sequestration to offset carbon emissions as part of their sustainability approach (Johnson and Coburn, 2010). This approach should be less costly for universities than offsetting through making a payment to a third party. However, carbon sequestration in trees may not be sufficient and may have to be only one of several tools used by universities to manage their carbon footprints.

Carbon sequestration is potentially important for universities, because of several pressures and enablers (CMP, 2012). Universities can be subject to increased scrutiny of their sustainability practices due to universities being publicly funded and due to the fact that university students and staff may be well informed of sustainability issues, some even specialising in sustainability. Public policy in some countries are also moving in the direction of requiring carbon management from universities, e.g. in Scotland (Climate Change (Scotland) Act, 2009) and in Norway (Norwegian Sectoral Klimakur plans). Thus, there may be a greater demand for universities to embrace sustainable practices, such as carbon sequestration. These pressures may be the driving force for many universities to sign the United Nations' "Commitment to Sustainable Practices of Higher Education Institutions". Universities can, on the other hand, also be well placed to investigate and take action in the sustainability arena, because universities often have large campuses with substantial plantings that lend itself to carbon sequestration, and because staff specialising in sustainability can provide the expertise needed to implement sustainability programmes. These programmes can include engaging students by incorporating sustainability assignments and research projects in course work. In the UK, there is an outside initiative to assist universities to set up a carbon management plan, including setting a baseline, forecasting and targeting carbon emissions and sequestration (CMP, 2012). Thus, universities may be better placed to engage in carbon sequestration projects. These factors render an examination of the potential for carbon sequestration in the trees of university campuses an important issue to be considered. The sheer number of universities around the world (about 20,000) also suggests that universities potentially play a major role in global CO_2 emissions. In addition, a university case study may well have lessons and implications for businesses and other organisations.

An essential part of a process of carbon management is to calculate the carbon sequestered in trees on campus (Xu and 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 counting, and measuring the trees on the university's main 68 hectare campus, which includes large green areas. We then calculate the carbon sequestered in these trees. 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, therefore the weight of carbon alone is a smaller figure.

We find that the expected annual CO_2 sequestration over the next ten years is 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 5th Intergovernmental Panel on Climate Change's report, average temperatures are increasing globally (IPCC, 2013). The previous IPCC report indicated 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 current report concludes that climate change is caused mainly by human activities, particularly by GHG emissions, predominated by carbon dioxide (CO_2) emissions (IPCC, 2013). Indeed, 48 per cent more CO_2 was emitted globally in 2010 than in 1992 (Rogers, 2012). The IPCC (2013, p. 9) reports that "the atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years" and that "carbon dioxide concentrations have increased by 40 per cent since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions". 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 and Sperling, 2008), while adaptation policies seek to adapt to the consequences of climate change (Carina and Keskitalo, 2010). Sustainability regulations play an important role in the implementation of climate policies (Wilbanks, 2003). Robinson and Herbert (2001, p. 131) also argue that "climate policy, and the impacts of climate change, will have significant implications for sustainability decisions and options at multiple spatial scales". 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 *et al.* (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 EU countries, the total GHG emissions in 2007 were 9.3 per cent below emissions in 1990, largely due to the successful implementation of Kyoto Protocol related regulation (Lau *et al.*, 2012). However, the Kyoto Protocol has failed to reduce worldwide GHG emissions (Lau *et al.*, 2012). Specifically, global GHG emissions have increased by 38 per cent 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 *et al.*, 2011). From 1990 to 2006, the total GHG emissions in New Zealand increased by about 15 per cent (Clark *et al.*, 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 and Sohngen, 2012, p. 128). This is an important mitigation option to reduce the largest portion of GHG emissions (CO_2) (Mandlebaum and 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 and Malone, 2011). CCS technology focuses on physical and chemical methods of capturing carbon from the atmosphere and storing it somewhere else (Mitrović and 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 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 *et al.*, 2005; Klusman, 2003).

Ocean storage is another method of carbon sequestration, achieved by injecting and dissolving CO_2 into ocean water (Stewart and Hessami, 2005; IPCC, 2005). However, Stewart and Hessami (2005) argue that "15-20 per cent 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 and Hessami, 2005). Atmospheric CO_2 can be stored in soil organic matter and any photosynthesising plant (Raven and 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 and Kriedemann, 2000). Storage in wood subsequently used in construction and furniture prolong the period of sequestration and allow for replanting forests to further increase sequestration. Thus, biotic sequestration remains an effective method of offsetting CO_2 emissions, considering that almost "half the dry weight of a tree [. . .] is carbon" and "trees store carbon in their leaves, branches, stems, bark and roots" (Johnson and Coburn, 2010, p. 1). Although deforestation represent a major global concern (IPCC, 2013), for an individual organisation that owns green areas, carbon sequestration in trees can provide part of the answer to carbon offsetting, e.g. 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 (CO_2) 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 and 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). 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, and thus a moral obligation may come to be established. However, there are no specific legal carbon liabilities for New Zealand universities at this stage.

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 and Larrinaga-González, 2008). Under these conditions, accounting for carbon is a method whereby organisations can demonstrate their willingness to be accountable to stakeholders (Ascui and 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 and 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 and 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 and 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 and 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 overall risk 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 *et al.*, 2007). Effective carbon management could improve the effectiveness of carbon capture and sequestration (Wilson *et al.*, 2007; Herzog *et al.*, 2003). In addition, Ogle *et al.* (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 can play a role in mitigating risks associated with carbon sequestration. However, note that there are few risks involved in carbon sequestration in trees.

For higher education institutions, a carbon management programme can also be important to achieve the goal of sustainability (Dahle and Neumayer, 2001). Many universities establish their own carbon management programme to make contributions to both climate change prevention and sustainability. KIWI University is moving in that general direction through the activities of the recently created position of “environmental and sustainability manager” and the establishment of the Environmental Policy Committee (EPC), but there is as yet no formal carbon management programme or goals. 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 settings have also started with carbon management initiatives, e.g. Auckland University in New Zealand has started to calculate carbon sequestration in some areas on its main campus (Xu and Mitchell, 2011). Except for the calculation of carbon emissions and sequestration, universities can also design low carbon higher education systems (Roy *et al.*, 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 (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 can be argued to have general obligations towards society and the environment in the form of social responsibility towards the natural environment (Glennie and Lodhia, 2013; Lawrence *et al.*, 2013). 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 and Berry, 2000; Samkin, 2012). Environmental disclosure is an important component of environmental responsibility (Huang and Kung, 2010; De Klerk and De Villiers, 2012). Environmental disclosure is increasingly demanded, i.e. carbon disclosure is a part of environmental responsibility to conform to social expectations (Schaltegger *et al.*, 2013). 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, pp. 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 GHG emissions report or a sustainability/environment report.

3. Method

3.1 Study site

The main campus of KIWI University was established in 1965 and covers 65 hectares (University of KIWI, 2012c). Almost 6,000 trees, representing over 200 species, have been planted on the campus. Some of the trees were planted around 1912, some in the 1940s, 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 (Broward County, 2012). Slightly more than 4,000 trees are over 3 m in height and were measured.

3.2 Method for calculating current CO_2 sequestration in trees

We use the method of carbon counting devised by Broward County (2012). The equation to estimate a tree's dry weight is based on the physical relationship between tree volume and wood density (Xu and Mitchell, 2011). As tree density figures can vary, even within the same species, using different formula for each tree species does not necessarily provide more accurate CO_2 estimations. Therefore, the method we used is based on average wood density figures across species.

There are five steps to measure the amount of CO_2 sequestered in a tree per annum, namely:

(1) estimate the total weight of the tree using the diameter of the trunk and an estimate of the height;

(2) convert the weight of the tree to the dry weight of organic matter (on average 72.5 per cent of the total weight);

(3) estimate the amount of carbon, being a proportion of the dry weight (on average 50 per cent of the dry weight);

(4) convert the amount of carbon to the amount of CO_2 sequestered (multiply by 3.6663, because two oxygen molecules are added to each carbon molecule); and

(5) convert the total CO_2 sequestered into an annual amount sequestered (by dividing by the age of the tree) (Broward County, 2012).

Given differing wood densities, the measurement of CO_2 sequestered in a tree per year can be summarised in the following equations:

$$W = \frac{0.25*D^2*H*120\%*72.5\%*50\%*3.6663}{Tree\ age} \quad (\text{When } D < 11 \text{ inches}) \quad (1)$$

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

where:

W = weight of CO_2 sequestered in the tree per year in pounds.

D = tree diameter in inches.

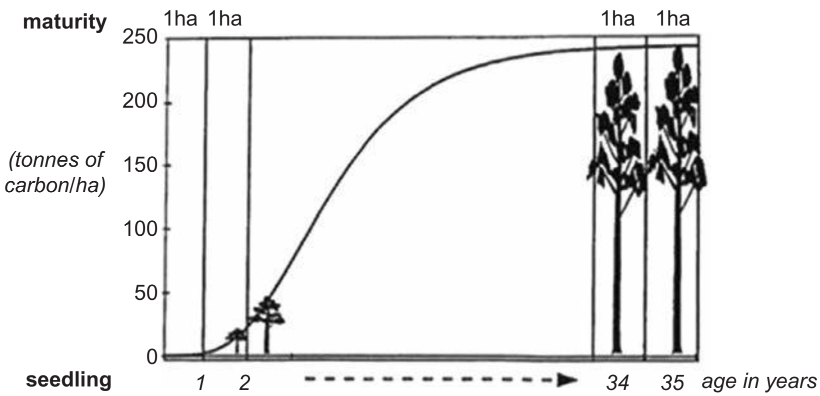
H = tree height in feet.

Therefore, in this method, each tree's diameter has to be measured and its height and age estimated (Appendix 1 for more detailed information). Three measures were recorded for each tree estimated to be three meters or taller, namely the circumference (which was later converted to diameter), the estimated height, and the estimated age. Ages were estimated based on grounds staff's detailed records and personal knowledge of tree plantings in specific areas over the years.

3.3 Method for predicting future CO_2 sequestration in trees

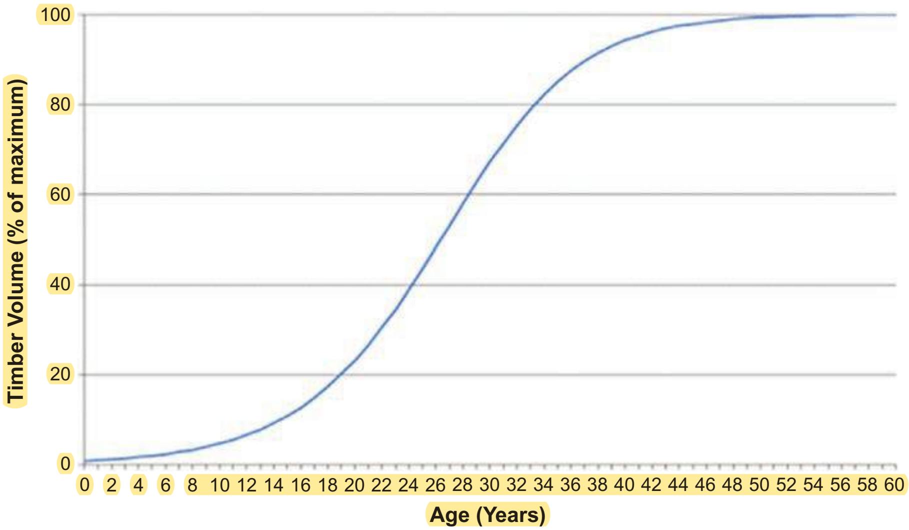
In order to assess the future CO_2 sequestration in trees in the next ten years, we used estimates of tree growth rates. Figure 1 illustrates forest tree growth in New Zealand, showing that tree volumes increase slowly during the first ten years, increasing dramatically during the age range of ten to 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 2 shows that very little carbon is sequestered during the early years. This increases dramatically between the ages of ten and 40, but levels off around the age of 40 (Figure 2).

Leoni *et al.* (2011) provide specific estimates of average annual tree diameter and height increments for trees in different age ranges, matching the age ranges indicated by an inspection of Figures 2 and 3 (Appendix 2). Therefore, we follow the



Source: Unwin and Kriedemann (2000)

Figure 1.
Sequestration of carbon of a tree at different ages



Source: Ministry for the Environment (2008)

Figure 2.
Forest tree growth

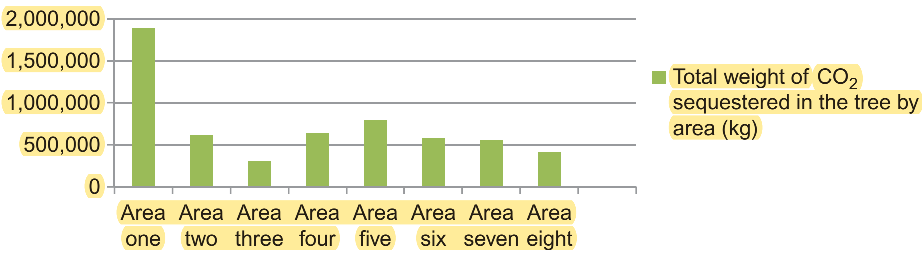


Figure 3.
Current total weight of CO_2 sequestration in trees on the main campus of KIWI University, by area, as calculated in this research project

Leoni *et al.* (2011) estimates, namely for trees less than ten years of age, the incremental diameter was estimated at 0.4 cm per year and the incremental height at 0.6 m per year; for trees aged 11-40 years, the incremental diameter was estimated to be 0.38 cm per year and the incremental height at 1 m per year; and finally, for trees more than 40 years old, the tree diameter and height was estimated to remain constant. On the basis of these estimates of the diameter, height and age of trees in ten years' time (2022), we estimated the CO_2 that will have been sequestered in trees at that stage using equations (1) and (2). Finally, we deducted the 2022 total CO_2 sequestered from the 2012 figure and divided by ten as an estimate of the annual CO_2 sequestration to be expected during the next decade.

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 arbitrary areas to facilitate record keeping. Figure 3 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. 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.

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 *et al.*, 2009). With the help of expert ground staff, the measured trees were divided into these two groups. According to Table I, 70 per cent of main campus trees are evergreen, whilst 30 per cent are deciduous. There are profound differences in CO_2 sequestration between evergreen and deciduous plants (Buchmann *et al.*, 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 CO_2 per year, while deciduous trees sequester an average of 40.87 kg of CO_2 per annum (Figure 4).

4.1.3 Trees at different ages. We already mentioned that trees store different amounts of CO_2 depending on their age (Unwin and 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 and 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 *et al.*, 2002).

University	Proportion of area coverage (%)	Tree numbers	Carbon sequestration (tonnes)	CO_2 sequestration (tonnes)
KIWI University	100	4,137	1,585	5,809
California State University	100	3,900	862	3,170
Eastern Illinois University	100	4,051	1,591	5,828
Auckland University (conservation area)	26	400 +	225	736

Source: Xu and Mitchell (2011) and Cox (2012)

Table I. CO_2 sequestration in trees in different universities

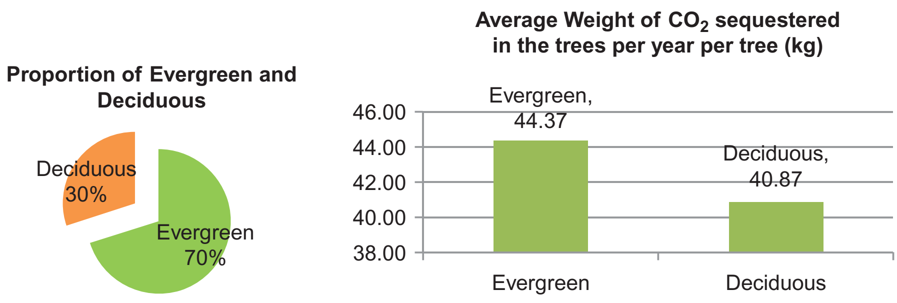


Figure 4. Comparisons of evergreen and deciduous trees on the main campus of KIWI University, as calculated in this research project

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 5 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 per cent 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 per cent of the total number of trees is under ten years of age and will reach the age range of ten to 40 years by 2022. As a result, the proportion of trees aged over 40 years will, over the next ten years, increase from 44 to 60 per cent, which means that the capability of trees at KIWI University to store additional carbon will start to reduce (Figure 6).

The CO_2 sequestered in campus trees are expected to grow from 5,809 to 8,334 tonnes over the next ten years, i.e. an additional 2,525 tonnes over ten 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.

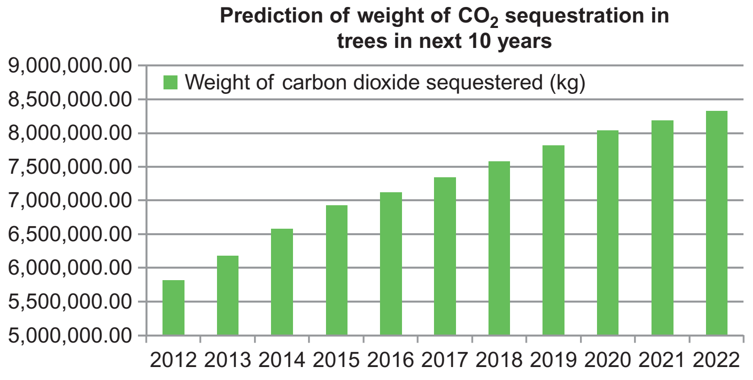


Figure 5.
Prediction of total weight of CO_2 to be sequestered in trees during the next ten years, on the main campus of KIWI University, as calculated in this research project

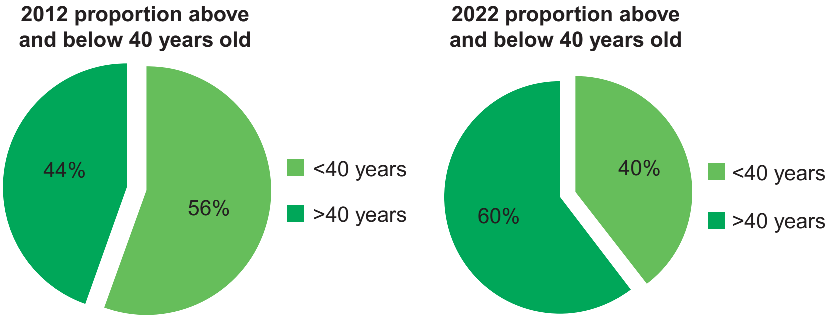


Figure 6.
The proportion of trees on the main campus of KIWI University to be above and below 40 years of age in 2012 and 2022, as counted and estimated in this research project

4.3 Comparison with other universities

Table I 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.

4.4 Potential limitations

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.

In addition, we acknowledge that the methods and formula we use rely on averages, which may have led to inaccurate estimates. However, we believe our estimates are a good starting point for further research to build on.

5. 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 II shows the CO_2 emissions for 2011, as estimated by the university's environmental and sustainability manager. The total CO_2 emissions in 2011 were 4,086.8 tonnes. Specifically, international travel emitted 2,953 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.

We estimated that trees on the campus of KIWI University will sequester an additional 253 tonnes of CO_2 per annum over the next ten years. This is only a fraction of the 4,086.8 tonnes emitted during 2011. The sequestration of CO_2 in trees can thus only account for a small part of the university's emissions. The university may have to consider other projects in order to address this issue.

Table II. KIWI University CO_2 emissions during 2011

KIWI University CO_2 emissions during 2011

Air travel	CO_2 (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 CO_2 (tonnes)	4,086.8

Source: Goddard (2012)

6. Discussion

6.1 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 and Neumayer, 2001). There are many potential benefits to universities for being seen as leaders in sustainable development. First, "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. Second, 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. Third, "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. First, sustainability initiatives are essentially voluntary in nature and thus many universities have no legal obligation to pursue this agenda. Many universities may thus opt to maintain their historic practices (Chen, 2012). Second, pursuing a sustainability agenda may be costly. For example, universities require the collection of data 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.

6.2 Carbon management and related issues at KIWI University

The EPC was established to plan and implement initiatives regarding KIWI University's environmental responsibilities. This is an internal committee, composed of members of the university community, being mostly staff members, and reporting to the assistant vice-chancellor operations. 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 (University of KIWI, 2012b). The implementation of this policy is under constant revision to ensure continued effectiveness (University of KIWI, 2012d). 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. 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. First, the university boast some significant recent achievements in the reduction of resources usage (University of KIWI, 2012a). For example, there was reduction of 29 per cent 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. A reduction in energy use implies a reduction in CO_2 emissions. Second, the university is busy implementing an energy reduction plan through a building management system (BMS). About 95 per cent of all air conditioning and lighting are now controlled by timers to reduce the waste of energy. Third, the university also has a community garden and green living roofs on two buildings. These initiatives are all designed to reduce energy usage and thus CO_2 emissions.

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 other initiatives, such as a focus on carbon sequestration.

Our research project (the current paper) provides a useful foundation for future action by the ECP. Our carbon sequestration records could 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 *et al.* (2011) demonstrate that there are gaps in knowledge about what, how and why carbon-related information should be collected. Therefore, the university may have to develop its own carbon management initiatives. These initiatives may include training for both staff and students to ensure that the reduction of the university's carbon footprint continues.

7. Conclusion

We calculated the carbon sequestered in trees on the main campus of KIWI University and estimated the annual expected sequestration over the next ten years. In order to calculate the current CO_2 sequestered in trees on the main campus of the university, equations (1) and (2) were used, depending on the diameter of the tree trunk. We measured the circumference of 4,137 trees and estimated their height and age. We estimate that these trees currently store 5,809.4 tonnes of CO_2. Based on estimated growth rates specific to the age ranges of the trees, we estimate that 8,334 tonnes of CO_2 will be stored in the trees currently on campus by 2022, an increase of 43.46 per cent on the 2012 figure. Further plantings could potentially increase these figures.

7.1 Practice and policy implications

In terms of practice and policy implications, our results suggest that only 10 per cent of the emissions that the university is responsible for will be sequestered in trees. Specifically, only 253 tonnes of CO_2 is expected to be sequestered per annum over the next ten 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 per cent 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 per cent and would increase the relative contribution of carbon sequestration in trees to the university's overall carbon mitigation from the current 6 per cent (253/4,087) to 22 per cent (253/(4,087 − 2,953)).

7.2 Further practice and policy implications

KIWI University has a relatively large campus, allowing for many trees. Nevertheless, a relatively small proportion of CO_2 emissions can be offset by carbon sequestration in trees. Universities with smaller campuses will be even worse off. In terms of the implications for other organisations, such as business enterprises, few businesses will have extensive tree plantings on their own premises and many businesses will be more intensive CO_2 emitters, suggesting that carbon sequestration in trees can only be of limited use for most business organisations.

Despite the limited usefulness of carbon sequestration in trees, a tree census could form the basis for a formal and on-going carbon management programme, with the potential to do more. Apart from the environmental benefits, a carbon management programme could also garner accolades and improve an organisation's environmental reputation. At KIWI University, the university's EPC is well placed to implement a carbon management programme. The 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.

This study has several other practice and policy implications, which we now list in the form of recommendations for universities considering a carbon management programme:

- 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 web site 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.

In addition to the tree related points we make above, there are also other avenues to consider in order to manage carbon, such as:

- 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.

References

Adams, C.A. (2013), "Sustainability reporting and performance management in universities: challenges and benefits", *Sustainability Accounting, Management and Policy Journal*, Vol. 4 No. 3, pp. 384-392.

Adler, M.D. (2006), "Corrective justice and liability for global warming", *University of Pennsylvania Law Review*, Vol. 155, pp. 1859-1868.

Allen, M. (2003), "Liability for climate change", available at: http://climateprediction.net/science/pubs/nature_allen_270203.pdf (accessed 28 October 2012).

Ascui, F. and Lovell, H. (2011), "As frames collide: making sense of carbon accounting", *Accounting & Accountability Journal*, Vol. 24 No. 8, pp. 978-999.

Bebbington, J. and Larrinaga-González, C. (2008), "Carbon trading: accounting and reporting issues", *European Accounting Review*, Vol. 17 No. 4, pp. 697-717.

Benavides, R., Douglas, G.B. and Osoro, K. (2009), "Silvopastoralism in New Zealand: review of effects of evergreen and deciduous trees on pasture dynamics", *Agroforestry Systems*, Vol. 76 No. 2, pp. 327-350.

Bowen, F. and Wittneben, B. (2011), "Carbon accounting: negotiating accuracy, consistency and certainty across organisational fields", *Accounting, Auditing & Accountability Journal*, Vol. 24 No. 8, pp. 1022-1036.

Boyd, E., Boykoff, M. and Newell, P. (2011), "The 'new' carbon economy: what's new?", *Antipode*, Vol. 43 No. 3, pp. 601-611.

Broward County (2012), "How to calculate the amount of CO_2 sequestered in a tree per year", available at: www.broward.org/NaturalResources/ClimateChange/Documents/Calculating%20CO2%20Sequestration%20by%20Trees.pdf

Buchmann, N., Kao, W.Y. and Ehleringer, J. (1997), "Influence of stand structure on carbon-13 of vegetation, soils, and canopy air within deciduous and evergreen forests in Utah, United States", *Oecologia*, Vol. 110, pp. 109-119.

Burritt, R.L., Schaltegger, S. and Zvezdov, D. (2011), "Carbon management accounting: explaining practice in leading German companies", *Australian Accounting Review*, Vol. 21 No. 1, pp. 80-98.

Carina, E. and Keskitalo, H. (2010), *Developing Adaptation Policy and Practice in Europe: Multi-level Governance of Climate Change*, available at: http://books.google.co.nz/books?hl=en&lr=&id=H78uqYbtXSoC&oi=fnd&pg=PR5&dq=what+is+adaptation+policy&ots=UJLnE0oSDM&sig=T4TOId7EMo77AjHeL5SDDEE88e8#v=onepage&q=what%20is%20adaptation%20policy&f=false (accessed 29 November 2012).

Cebrián, G., Grace, M. and Humphris, D. (2013), "Organisational learning towards sustainability in higher education", *Sustainability Accounting, Management and Policy Journal*, Vol. 4 No. 3, pp. 285-306.

Chavez, M. (2009), "The Kyoto Protocol: accomplishment and failures", available at: www.atmos.washington.edu/2009Q1/111/ATMS111%20Presentations/Folder%201/ChavezM.pdf (accessed 29 November 2012).

Chen, B. (2012), "Moral and ethical foundations for sustainability: a multi-disciplinary approach", *Journal of Global Citizenship & Equity Education*, Vol. 2 No. 2, pp. 1-20.

Climate Disclosure Standards Board (2012), *Climate Change Reporting Framework Edition 1.1*, available at: www.cdsb.net/file/116/cdsb-framework-2012_web2.pdf.

Clark, H., Kelliher, F. and Patiño, C.P. (2011), "Reducing CH_4 emissions from grazing Ruminants in New Zealand: challenges and opportunities", *Asian-Australian Journal of Animal Science*, Vol. 24 No. 2, pp. 295-302.

Climate Progress (2012), *10 Ways Climate Change Is Already Negatively Affecting the World*, available at: http://oilprice.com/The-Environment/Global-Warming/10-Ways-Climate-Change-is-Already-Negatively-Affecting-the-World.html

CMP (2012), "Carbon trust higher education programme", Carbon Management Programme, available at: http://www3.imperial.ac.uk/facilitiesmanagement/energy/carbonmanagementprogramme (accessed 28 October 2012).

Cox, H.M. (2012), "A sustainability initiative to quantify carbon sequestration by campus trees", *Journal of Geography*, Vol. 111 No. 5, pp. 173-183.

Dahle, M. and Neumayer, E. (2001), "Overcoming barriers to campus greening: a survey among higher educational institutions in London, UK", *International Journal of Sustainability in Higher Education*, Vol. 2 No. 2, pp. 139-160.

De Klerk, M. and De Villiers, C. (2012), "The value relevance of corporate responsibility reporting: South African evidence", *Meditari Accountancy Research*, Vol. 20 No. 1, pp. 21-38.

Dhulipala, S. (2007), "Dangers of carbon sequestration", available at: http://suite101.com/article/dangers-from-carbon-sequestration-a24305 (accessed 28 October 2012).

Enernoc (2012), "What is carbon management?", available at: www.enernoc.com/our-resources/term-pages/720-what-is-carbon-management (accessed 28 October 2012).

External Reporting Board (2012a), *Current Standards "New" Accounting Standards Framework*, available at: www.xrb.govt.nz/

External Reporting Board (2012b), *New Zealand International Accounting Standard 37* (*Public Benefit Entities*) *NZ IAS 37* (*PBE*)*: Provisions, Contingent Liabilities and Contingent Assets*, available at: www.xrb.govt.nz/

Figueiredo, M.A.D. (2007), "The liability of carbon dioxide storage", available at: http://esd.mit.edu/people/dissertations/defigueiredo.pdf (accessed 28 October 2012).

Filho, W.L. (2011), "About the role of universities and their contribution to sustainable development", *Higher Education Policy*, Vol. 24, pp. 427-438.

Fujii, Y. (2012), *Carbon Liability, Handbook of Climate Change Mitigation*, Springer, Berlin, pp. 411-431.

Gagelmann, F. and Hansjürgens, B. (2002), "Climate protection through tradable permits: the EU proposal for a CO_2 emissions trading system in Europe", *European Environment*, Vol. 12 No. 4, pp. 185-202.

Glennie, M. and Lodhia, S. (2013), "The influence of internal organisational factors on corporate-community partnership agendas: an Australian case study", *Meditari Accountancy Research*, Vol. 21 No. 1, pp. 52-67.

Goddard, R. (2012), "Carbon calculation for the year 2011 for the University of KIWI", Retrieved from the Facilities Management Division of the University of KIWI.

Greek, T. (2012), "Role of carbon capture in CO_2 management", available at: http://library.certh.gr/libfiles/PDF/GEN-PAPYR-1042-ROLE-by-CREEK-in-PTQ-V-9-ISS-3-PP-63-69-Y-2004.pdf (accessed 26 August 2012).

Green, J. (2008), "Environmental issues", *McPhail Center for Environmental Studies*, Vol. 7 No. 2, pp. 1-4.

Haigh, M. and Shapiro, M.A. (2012), "Carbon reporting: does it matter?", *Accounting, Auditing & Accountability Journal*, Vol. 25 No. 1, pp. 105-125.

Hazardous Waste Recycling Benefits (2012), *Wastes-Hazardous Waste*, available at: www.epa.gov/osw/hazard/recycling/benefits.htm

Herzog, H., Caldeira, K. and Reilly, J. (2003), "An issue of permanence: assessing the effectiveness of temporary carbon storage", *Climatic Change*, Vol. 59, pp. 293-310.

Huang, C. and Kung, F. (2010), "Drivers of environmental disclosure and stakeholder expectations: evidence from Taiwan", *Journal of Business Ethics*, Vol. 96 No. 3, pp. 435-451.

IPCC (2005), *Special Report on Carbon Dioxide Capture and Storage: Underground Geological Storage*, available at: www.ipcc.ch/pdf/special-reports/srccs/srccs_chapter5.pdf (accessed 19 November).

IPCC (2007a), *Climate Change 2007: Synthesis Report*, available at: www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

IPCC (2007b), *Working Group III Fourth Assessment Report*, available at: www.ipcc-wg3.de/assessment-reports/fourth-assessment-report/working-group-iii-fourth-assessment-report

IPCC (2013), *Climate Change 2013: The Physical Science Basis*, available at: www.climatechange2013.org/images/uploads/WGI_AR5_SPM_brochure.pdf

Johnson, I. and Coburn, R. (2010), *Trees for Carbon Sequestration*, Vol. 19, available at: www.dpi.nsw.gov.au/data/assets/pdf_file/0003/317559/Trees-for-carbon-sequestration.pdf (accessed 19 August 2012).

Kapdi, S.S., Vijay, C.K., Rajesh, S.K. and Prasad, R. (2005), "Biogas scrubbing, compression and storage: perspective and prospectus in Indian context", *Renewable Energy*, Vol. 11, pp. 1-8.

Kirby, K.R. and Potvin, C. (2007), "Variation in carbon storage among tree species: implications for the management of a small-scale carbon sink project", *Forest Ecology and Management*, Vol. 246 Nos 2/3, pp. 208-221.

KIWI University (2012a), *Current Projects*, available at: www.KIWI.ac.nz/fmd/environment/projects.shtml

KIWI University (2012b), *Environmental Policy*, available at: www.KIWI.ac.nz/official-info/index/docs/environmental-policy/

KIWI University (2012c), *The History of the University of KIWI*, available at: www.KIWI.ac.nz/about/history.shtml

KIWI University (2012d), *The University of KIWI Environmental Policy Committee*, available at: www.KIWI.ac.nz/fmd/environment/emwp.shtml

Klass, A.B. and Wilson, E.J. (2008), *Climate Change and Carbon Sequestration: Assessing a Liability Regime for Long-term Storage of Carbon Dioxide*, available at: http://works.bepress.com/alexandra_klass/4/ (accessed 28 October 2012).

Klusman, R.W. (2003), "Evaluation of leakage potential from a carbon dioxide EOR/sequestration project", *Energy Conversion and Management*, Vol. 44 No. 12, pp. 1921-1940.

Lal, R. (2008), "Carbon sequestration", *Philosophical Transaction of the Royal Society B: Biological Science*, Vol. 363 No. 1492, pp. 815-830.

Lau, L.C., Lee, K.T. and Mohamed, A.R. (2012), "Global warming mitigation and renewable energy policy development from the Kyoto Protocol to the Copenhagen accord – a comment", *Renewable and Sustainable Energy Reviews*, Vol. 16 No. 7, pp. 5280-5284.

Lawrence, S.R., Botes, V., Collins, E. and Roper, J. (2013), "Does accounting construct the identity of firms as purely self-interested or as socially responsible?", *Meditari Accountancy Research*, Vol. 21 No. 2, pp. 144-160.

Leoni, J.M., da Fonseca, S.F. and Schöngart, J. (2011), "Growth and population structure of the tree species Malouetia tamaquarina (Aubl.) (Apocynaceae) in the central Amazonian floodplain forests and their implication for management", *Forest Ecology and Management*, Vol. 261 No. 1, pp. 62-67.

Lohmann, L. (2009), "Toward a different debate in environmental accounting: the case of carbon and cost-benefit", *Accounting, Organizations and Society*, Vol. 39, pp. 499-534.

Lutsey, N.P. and Sperling, D. (2008), "America's bottom-up climate change mitigation policy", *Energy Policy*, Vol. 36, pp. 673-685.

McKinnon, A.C. (2010), "Product-level carbon auditing of supply chains: environmental imperative or wasteful distraction?", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 No. 1, pp. 42-60.

Mader, C., Scott, G. and Razak, D.A. (2013), "Effective change management, governance and policy for sustainability transformation in higher education", *Sustainability Accounting, Management and Policy Journal*, Vol. 4 No. 3, pp. 264-284.

Mandlebaum, S. and Nriagu, J. (2011), "Carbon sequestration and agriculture", *Encyclopedia of Environmental Health*, Vol. 1, pp. 198-504.

Ministry for the Environment (2008), *Deforestation Liabilities – Allocation to Pre-1990 Forests*, available at: www.climatechange.govt.nz/emissions-trading-scheme/building/reports/deforestation-liabilities-pre-1990-forests/deforestation-liabilities.pdf (accessed 29 November 2012).

Mitrović, M. and Malone, A. (2011), "Carbon capture and storage (CCS) demonstration projects in Canada", *Energy Procedia*, Vol. 4, pp. 5685-5691.

Nowak, D.J., Stevens, J.C., Sisnni, S.M. and Luley, C.J. (2002), "Effects of urban tree management and species selection on atmospheric carbon dioxide", *Journal of Arboriculture*, Vol. 28 No. 3, pp. 113-122.

Oberthür, S. and Ott, H.E. (1999), *The Kyoto Protocol: International Climate Policy for the 21st Century*, available at: http://books.google.co.nz/books?hl=en&lr=&id=-qp7Wt9GvccC&oi=fnd&pg=PA1&dq=Kyoto+Protocol+for+climate+change&ots=ZFGLks9CQK&sig=BGQ-bOCaCms7aqXbUIqiS0Rfbrw#v=onepage&q=Kyoto%20Protocol%20for%20climate%20change&f=false (accessed 26 August 2012).

Ogle, S.M., Conant, R.T. and Paustian, K. (2004), "Deriving grassland management factors for a carbon accounting method developed by the intergovernmental panel on climate change", *Environmental Management*, Vol. 33 No. 4, pp. 474-484.

Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J. and Fleming, P. (2011), "Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study", *Journal of Cleaner Production*, Vol. 56, pp. 185-198.

Raven, J.A. and Karley, A.J. (2006), *Carbon Sequestration: Photosynthesis and Subsequent Processes*, available at: http://sigmea.scri.sari.ac.uk/the_kernel/pdf/Raven_Karley.pdf (accessed 28 October 2012).

Reitze, A.W. (2009), "Federal control of carbon dioxide emissions: what are the options?", *Environmental Affairs*, Vol. 36, pp. 1-78.

Robinson, J.B. and Herbert, D. (2001), "Integrating climate change and sustainable development", *International Journal of Global Environmental Issues*, Vol. 1 No. 2, pp. 130-149.

Rogers, S. (2012), "World carbon emissions: the league table of every country", available at: www.guardian.co.uk/environment/datablog/2012/jun/21/world-carbon-emissions-league-table-country

Rondinelli, D.A. and Berry, M.A. (2000), "Environmental citizenship in multinational corporations: social responsibility and sustainable development", *European Management Journal*, Vol. 18 No. 1, pp. 70-84.

Roy, R., Potter, S. and Yarrow, K. (2008), "Designing low carbon higher education systems: environmental impacts of campus an distance learning systems", *International Journal of Sustainability in Higher Education*, Vol. 9 No. 2, pp. 116-130.

Samkin, G. (2012), "Changes in sustainability reporting by an African defence contractor: a longitudinal analysis", *Meditari Accountancy Research*, Vol. 20 No. 2, pp. 134-166.

Schaltegger, S., Gibassier, D. and Zvezdov, D. (2013), "Is environmental management accounting a discipline? A bibliometric literature review", *Meditari Accountancy Research*, Vol. 21 No. 1, pp. 4-31.

Sedjo, R.A. and Marland, G. (2003), "Inter-trading permanent emissions credits and rented temporary carbon emissions offsets: some issues and alternatives", *Climate Policy*, Vol. 3 No. 4, pp. 435-444.

Sedjo, R.A. and Sohngen, B. (2012), "Carbon sequestration in forests and soils", *Annual Review of Resource Economics*, Vol. 4, pp. 127-144.

Shead, B., Best, P.J. and McCabe, S. (2009), *Carbon Reporting in the Queensland Public Sector: The State of Play, Trends and Better Practices*, BDO Kendalls, Adelaide, available at: http://eprints.usq.edu.au/18582/1/Shead_Best_McCabe_PV.pdf

Simonis, U.E. (2011), "Greening urban development: on climate change and climate policy", *Journal of Social Economics*, Vol. 38 No. 11, pp. 919-928.

Solomona, S., Plattnerb, G.K., Knuttic, R. and Friedlingstein, P. (2009), "Irreversible climate change due to carbon dioxide emissions", *The National Academy of Sciences of the USA*, Vol. 106 No. 6, pp. 1704-1709.

Stewart, C. and Hessami, M.A. (2005), "A study of methods of carbon dioxide capture and sequestration – the sustainability of a photosynthetic bioreactor approach", *Energy Conversion and Management*, Vol. 46 No. 3, pp. 403-420.

Unwin, G.L. and Kriedemann, P.E. (2000), "Principles and processes of carbon sequestration by trees: state forests of New South Wales", Technical Paper No. 64, available at: www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/389859/Principles-and-Processes-of-Carbon-Sequestration-by-Trees.pdf (accessed 29 November 2012).

Wilbanks, T.J. (2003), "Integrating climate change and sustainable development in a place-based context", *Climate Policy*, Vol. 3 No. 1, pp. 147-154.

Wilson, E.J., Friedmann, S.J. and Pollak, M.F. (2007), "Research for deployment: incorporating risk, regulation, and liability for carbon capture and sequestration", *Environmental Science Technology*, Vol. 41 No. 17, pp. 5945-5952.

Xu, B. and Mitchell, N. (2011), "Carbon sequestration by trees on the city campus", unpublished working paper, The University of Auckland, Auckland.

Further reading

Bodansky, D. (2010), "The Copenhagen climate change conference", *The American Journal of International Law*, Vol. 104 No. 2, pp. 230-240.

Lal, R. (2004), "Soil carbon sequestration to mitigate climate change", *Geoderma*, Vol. 123, pp. 1-22.

Appendix 1. How to calculate the amount of CO_2 sequestered in a tree per year (Source: Broward County (2012))

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 and 50 years. 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 CO_2 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. 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 CO_2 sequestered in the tree per year.

Determine the total (green) weight of the tree

The algorithm to calculate the weight of a tree is:

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 $D < 11$:

$W = 0.25D^2H$.

For trees with $D \geq 11$:

$W = 0.15D^2H$.

Depending on the species, the coefficient (e.g. 0.25) could change, and the variables D^2 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 per cent 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 per cent.

Determine the dry weight of the tree

This is based on an extension publication from the University of Nebraska. 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 per cent dry matter and 27.5 per cent moisture.

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

Determine the weight of carbon in the tree

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

Determine the weight of carbon dioxide sequestered in the tree.

CO_2 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 $C + 2'O = 43.999915$.

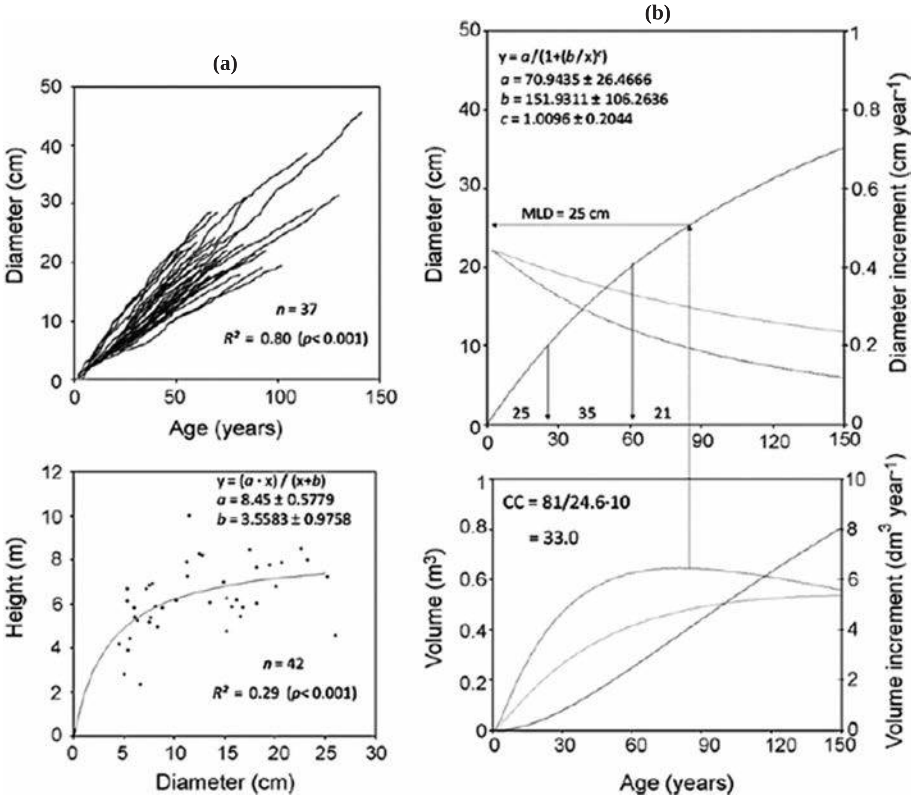
The ratio of CO_2 to C is $43.999915/12.001115 = 3.6663$.

Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

Determine the weight of CO_2 sequestered in the tree per year

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

Appendix 2. Tree growth rates



Source: Leoni *et al.* (2011, pp. 62-67)

Figure A1. Relationship between tree volume and tree ages

Based on the relationship between tree volume and tree ages, the tree growth rates regarding to tree diameter and height are summarised as Table AI.

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 AI. Growth rates of trees based on age of trees

Corresponding author
Charl De Villiers can be contacted at: cdev@waikato.ac.nz