TravelSmart and TreeSmart: Alternative Ways of Reducing Greenhouse Gas Levels

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1 Introduction

Over the past 10 years, increasing attention has been focussed on the role of transport in the production of Greenhouse Gases (GHG) and on the various strategies that are available for reducing these GHG (especially carbon dioxide) that contribute to the global warming effect. Within the transport sector, strategies such as improved vehicle efficiency, traffic flow management and travel demand management have received considerable attention.

In Australia, a substantial number of TravelSmart programs, based on voluntary behaviour change, have been implemented in various states, and these programs have generally been observed to produce reductions in vehicle-kilometres of travel (VKT) and hence GHG emissions.

An alternative to reducing the production of GHG, however, is to implement schemes to remove existing and future GHG from the atmosphere. One of the simplest methods of GHG removal is the planting of trees that absorb carbon dioxide from the atmosphere and sequester this carbon dioxide for long periods of time. Like TravelSmart, these “TreeSmart” programs are not free of charge and require up-front investment in order to achieve the carbon sequestration. The cost-efficiency of a TreeSmart program will depend on the amount of investment involved, the carbon absorbing ability of trees and the nature of the financial arrangement entered into for a tree-planting exercise.

This paper compares the cost efficiency of TravelSmart and TreeSmart projects in removing GHG from the atmosphere (in terms of $ per tonne of CO2 absorbed/reduced). The TravelSmart efficiencies are based on such projects recently conducted in Australia, while the TreeSmart efficiencies are based on a range of business models for eucalypt plantations in Victoria. Recognising that GHG removal is not the only objective of TravelSmart and TreeSmart projects, the paper also identifies some other benefits that might be achieved by each type of program.

2 Greenhouse gas reductions from TravelSmart programs

Among the many transport strategies designed to reduce Greenhouse Gas emissions, one of the more popular programs in Australia has been the TravelSmart program. Such programs, in various forms, have now been implemented in all states of Australia and a considerable body of knowledge has been built up about the methods used and the effectiveness of such programs. Work continues in all states to expand the TravelSmart programs, and to evaluate the changes in travel behaviour brought about by such programs. Much information about the TravelSmart programs in the various states can be obtained from the websites established for each of the programs, as listed in the references at the end of this paper.

For the purposes of this paper, three issues are of critical importance:

- What is the effectiveness of the TravelSmart programs in reducing greenhouse gases (especially carbon dioxide)?
- What are the costs of implementing TravelSmart programs?
- What is the consequent cost-effectiveness of using TravelSmart to bring about reductions in carbon dioxide?

2.1 Magnitude of reductions in greenhouse gases

While some authors (e.g. Stopher and Bullock, 2003) have chosen to criticise some aspects of the evaluation of some types of TravelSmart implementations, there is a generally accepted body of evidence about the overall magnitude of change in VKT attributable to TravelSmart programs. While this evidence will grow and change as more evaluations of TravelSmart are conducted, these figures provide a useful starting point for estimating the magnitude of reductions in greenhouse gases attributable to TravelSmart programs. Roth et al. (2003) provides the following table showing the range of reductions in car driver trips for various TravelSmart projects based on the IndiMark technique of Individualised Marketing.

Table 1 Extent of reductions in car driver trips achieved by IndiMark®.

IndiMark® Project	Location	Scale	Relative reduction in car driver trips
South Perth	Australia	Large-scale	14%
Goteburg	Sweden	Large-scale	13%
Viernheim	Germany	Large-scale	12%
Brisbane	Australia	Pilot	10%
South Perth	Australia	Pilot	10%
Gloucester	UK	Pilot	9%
Viernheim	Germany	Pilot	8%
Portland	USA	Pilot	8%
Cambridge	Australia	Large-scale	7%
Frome	UK	Pilot	6%

The results in Table 1 show an average reduction in car as driver trips of about 10% across the target population of all IndiMark® programs, with a range of 6% to 14% for specific interventions. To translate this into changes in VKT, one needs to know whether the car trips reduced are longer or shorter than the average car trip. The results are not unequivocal. Some studies have found that shorter trips are more likely to be reduced, while other studies have found the opposite. As a first approximation, therefore, it will be assumed for the purposes of this paper that TravelSmart programs (of the IndiMark variety) bring about an average decrease of 10% in VKT across all trip lengths for the entire population of households approached.

This change in VKT must now be translated into changes in the emission of greenhouse gases. For the purposes of this paper, the principal greenhouse gas is assumed to be carbon dioxide (CO2). Using figures from the Australian Bureau of Statistics (ABS), the Bureau of Transport and Regional Economics (BTRE) and the Australian Greenhouse Office (AGO), it has been estimated that the average Australian car emits approximately 4.3 tonnes of CO2 per year. The average Australian household has about 1.5 vehicles per household, thus producing a total emission of about 6.5 tonnes CO2 per household per year.

It is often assumed in emissions reduction calculations that emissions are directly proportional to the amount of VKT. We know this is not exactly correct, and that each unit of VKT does not produce the same quantity of emissions. For example, short trips with a “cold start” have a higher rate of fuel consumption and CO2 emissions than longer trips with a “warm start”.

Similarly, it has been well-known for a long time that travel at different speeds, and with different levels of acceleration variability, results in different levels of fuel consumption and emissions. However, if TravelSmart reduces VKT from all levels of the trip length/engine temperature/trip speed/acceleration variability spectrum, then it is probably reasonable to assume a linear relationship between VKT and CO2 emissions, at least for a first order effects model, and to consider the variations in trip length/engine temperature/trip speed/acceleration variability in a second order effects model.

Assuming a linear relationship between VKT and CO2 emissions, therefore, it could be assumed that a TravelSmart program could bring about a decrease of 0.65 tonnes of CO2 per household per year.

2.2 Cost of the TravelSmart programs

The second factor that needs to be addressed is the cost of the TravelSmart programs. This is a difficult question to answer because there are many variations of TravelSmart (even just of the IndiMark variety) since each program needs to be designed for the specific objectives of the particular client organization. Adoption of different design standards will obviously affect the costs of implementation. Therefore, as with the expected reductions in VKT and CO2, all that can be obtained at this stage is a ballpark estimate of the average costs of a TravelSmart program.

Finding costs of TravelSmart schemes has relied on a variety of sources, such as conventional publications, departmental annual reports, and tender websites. A sampling of costs for various IndiMark-type schemes is given in Table 2.

Table 2 Typical Costs per Contacted Household for TravelSmart Programs

Scheme	**Source**	**Year**	**Cost per Contacted Household**
South Perth	Ker and James	1999	$40.25
Perth	DPI Annual Report	2003	$74.46
Perth	DPI Annual Report	2004	$103.27
Melbourne	Ker	2003	$90
Melbourne	DOI Tenders Website	2004	$55
Melbourne	DOI Tenders Website	2005	$60

There is substantial variation in costs per contacted household across the schemes, even within the same city. Some of this difference may be due to differences in design, while other differences may be due to different inclusions in the costing. For example, the costs obtained for the 2004 and 2005 TravelSmart programs from the DOI Tenders Website include only the cost of the contract for the implementation team divided by the number of contacted households, and do not include any costs incurred by the DOI in the design and supervision of the program. It does not include the cost of evaluation, which is fairly intensive for these projects at about $30 per contacted household. The specific inclusions in the other costings are not known precisely, but could include some administrative and evaluation costs.

As a compromise between the various costs shown in Table 2, the analysis reported in this paper uses the following costs for the various aspects of TravelSmart programs:

- TravelSmart implementation contractor: $60 per contacted household in year 1 of project

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- TravelSmart evaluation contractor: $25 per household (with 70% in year 1 and 30% in year 2)
- Government Supervision of TravelSmart: $5 per household in year 1, $2.50 per household in year 2 and $0.50 per household thereafter for life of project
- Monitoring of performance: $1 per household from year 2 onwards for life of project.

2.3 Cost-effectiveness of reductions in greenhouse gases

Assuming the conclusions reached in sections 2.1 and 2.2 with respect to the CO2 reductions and the costs of TravelSmart, the cost-effectiveness of greenhouse gas reductions via a TravelSmart program can be calculated using a relatively simple spreadsheet program as shown below.

The major assumptions required for the calculation of the cost-effectiveness of TravelSmart in reducing CO2 emissions are shown in Table 3 (the white boxes require input values, while the shaded boxes are intermediate calculations). This calculation is based on a large TravelSmart project comparable in size to the Darebin project recently conducted in Melbourne (i.e. about 30000 households contacted). It is assumed for this example that the project has a Life Cycle of 8 years, in that the effects of the TravelSmart implementation in year 1 are assumed to have a lingering effect for the next 8 years, with the CO2 reductions in each year decreasing by one-eighth, until there is no more effect after year 8. This is purely an assumption, since no TravelSmart projects have yet been measured to observe such long-term effects. Since the costs and benefits may extend over many years, the cost and benefits must be discounted to allow for the Social Time Preference rate of money and the Social Time Preference rate for CO2 reductions. Most carbon accounting models (e.g. Boscolo et al., 1998; Hean et al., 2003) now agree that CO2 reductions in the future must be discounted in the same way that monetary costs and benefits in the future must be discounted. A discount rate of 5% p.a. has been assumed for both monetary amounts and CO2 reductions.

Table 3 Assumptions for TravelSmart Cost-Effectiveness in Reducing CO2

INPUT PARAMETERS	
Households Contacted	30000
TravelSmart Cost/HH	$60
Evaluation Cost/HH	$25
Monitoring Cost/HH/year after year 2	$1
Government Supervision/HH in year 1	$5
Cars per HH	1.5
VKT/car p.a	14000
Tonnes CO2/car p.a	4.3
Tonnes CO2/VKT	0.000307
% VKT reduction	10%
Year 1 VKT savings	63000000
Year 1 CO2 savings	19350
Life Cyle (years)	8
Money Discount Rate	5%
CO2 STP Rate	5%

Using the input assumptions in Table 3, the TravelSmart program costs and the CO2 reductions over the 8 year life cycle of the program are shown in Table 4. All the implementation costs occur in year 1, while the evaluation costs (for some form of before-after evaluation) are spread over the first two years. Longer-term monitoring begins in year 3 and continues for the life of the project. The Government's involvement in project supervision is substantial in the early years and then continues at a lower rate for the life of the project.

The CO2 savings are assumed to be the maximum in year 1 (i.e. the full 10% reductions in VKT and hence CO2), and then to linearly decrease until there are no reductions after year 8.

Table 4 TravelSmart Program Costs and CO2 Reductions

	Costs of TravelSmart					
Year	Implementation	Evaluation	Monitoring	Government	Total Cost	CO2 reductions (tonnes)
1	$1,800,000	$525,000		$150,000	$2,475,000	19350
2		$225,000		$75,000	$300,000	16931
3			$30,000	$15,000	$45,000	14513
4			$30,000	$15,000	$45,000	12094
5			$30,000	$15,000	$45,000	9675
6			$30,000	$15,000	$45,000	7256
7			$30,000	$15,000	$45,000	4838
8			$30,000	$15,000	$45,000	2419
9			$0	$0	$0	0
10			$0	$0	$0	0
TOTAL	$1,800,000	$750,000	$180,000	$315,000	$3,045,000	87075

The Net Present Value calculations for the costs and CO2 reductions are shown in Table 5. Under the assumption of an 8 year life cycle for the program, the average NPV of cost per NPV of tonne reduction in CO2 is $38/tonne.

Table 5 NPV of TravelSmart Program Costs and CO2 Reductions

Year	NPV TravelSmart Cost	NPV CO2 Reductions (tonnes)	NPV $/tonne CO2
1	$2,357,143	18429	$128
2	$272,109	15357	$18
3	$38,873	12536	$3
4	$37,022	9950	$4
5	$35,259	7581	$5
6	$33,580	5415	$6
7	$31,981	3438	$9
8	$30,458	1637	$19
9	$0	0	$0
10	$0	0	$0
TOTAL	$2,836,423	74342	$38

The above finding on the cost-effectiveness of TravelSmart, however, should be treated with caution, since the result is very sensitive to the assumed life of the project. By assuming different values for the life of the program's effects, from 1 to 10 years, a more realistic range of cost-effectiveness values can be calculated as shown in Figure 1.

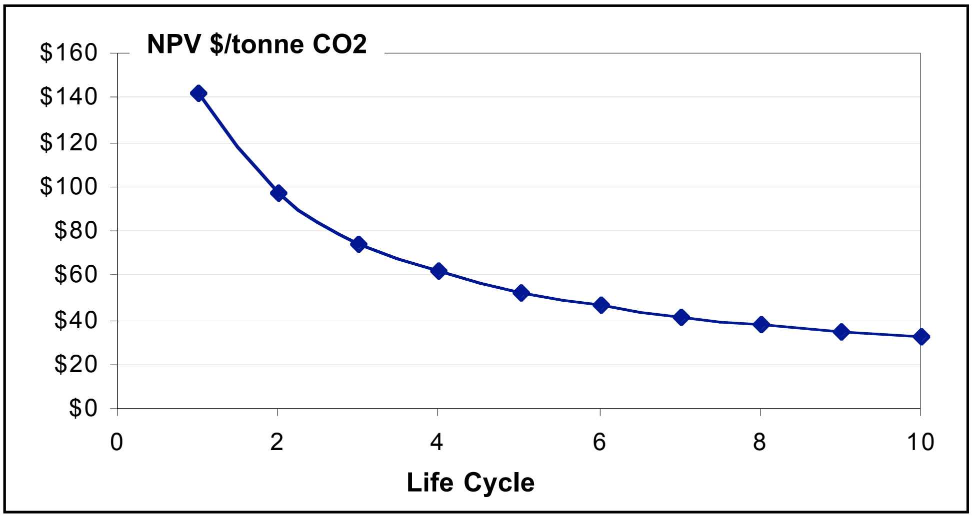

Figure 1 TravelSmart Cost-effectiveness for a Range of Life Cycle Values

While the NPV of cost per tonne of CO2 reduced is as low as $33 for a 10 year life cycle, it is as high as $143 when the life cycle is assumed to be only 1 year (this is in the same ballpark as the $150/tonne quoted on the AGO website for the Living Neighbourhoods program implemented in Onkaparinga in 1998). Since no one has yet been able to establish the true life cycle of a TravelSmart program (without repeated encouragement of households and expenditure on the implementation), it is probable that the true life cycle lies somewhere in the middle with a life cycle of perhaps 4-5 years, giving a cost effectiveness of about $50-60 per tonne of CO2 reduced.

3 Greenhouse gas reductions from tree-planting programs

An alternative way of reducing CO2 in the atmosphere is to remove it after it has been emitted, rather than prevent its emission in the first place. While many ways have been suggested for carbon sequestration (such as deep sea sequestration), the most popular method proposed has been by the planting of trees which absorb CO2 as they grow, and then by keeping the carbon in the trees sequestered for a long period of time. While such schemes have been mooted for some time (e.g. BTCE, 1996), they are only recently becoming a commercial reality. Because CO2 (as a greenhouse gas) is a global problem, the sequestration can be done at a site which is distant from the source of the emissions and which is best suited for the growing of the trees. It doesn’t matter where the CO2 is emitted or where it is absorbed from a global warming perspective; all that matters is how much is left in the atmosphere and for how long it is left there.

As with the TravelSmart programs, the cost-effectiveness of the “TreeSmart” programs will depend on two factors:

- What is the effectiveness of the tree-growing programs in reducing greenhouse gases (especially carbon dioxide)?
- What are the costs of implementing tree-growing programs?

3.1 Magnitude of reductions in greenhouse gases

As trees grow, they absorb carbon dioxide from the atmosphere and via a process of photosynthesis they use the energy from sunlight to convert the CO2 into carbon that is stored in the wood of the tree (and as a by-product they release oxygen back to the atmosphere). The rate at which they absorb carbon dioxide will depend on the rate at which the trees grow.

The science of tree growth rates is a well-developed discipline, with many models of tree growth having been proposed in the literature. A comprehensive set of modelling options has recently been released by AGO as the National Carbon Accounting System (the FullCAM model based on the work of Richards and Evans, 2000). This modelling system contains various options for modelling tree growth. In essence, however, most of the models assume that tree growth over time can be described by a sigmoid curve, with low rates of growth in the early years of a tree’s life (the juvenile phase), followed by a growth spurt in the middle years (the mature phase), and then a slowing down of growth in the later years (the senescent phase) until an equilibrium situation is reached whereby the tree stops growing. The shape of this tree growth rate curve may be described by various sigmoid curves such as the three-parameter Chapman-Richards function (Wong et al., 2000):

$$V = m(1 - e^{(b.a)})^{c}$$

where V = volume of tree at age a
a = age of tree
m = maximum achievable volume
b, c = constants

Using a suitable choice of m, b and c for a species such as *Eucalyptus Nitens* (Shining Gum), one can depict the tree growth curve as shown in Figure 2 for one hectare of plantation. Note that most forestry calculations are performed on a "per hectare" basis rather than a "per tree" basis, because the total volume of wood in a plantation is more constant on a "per hectare" basis irrespective of the tree density. That is, denser plantations have smaller trees, such that the total volume of wood per hectare stays relatively constant.

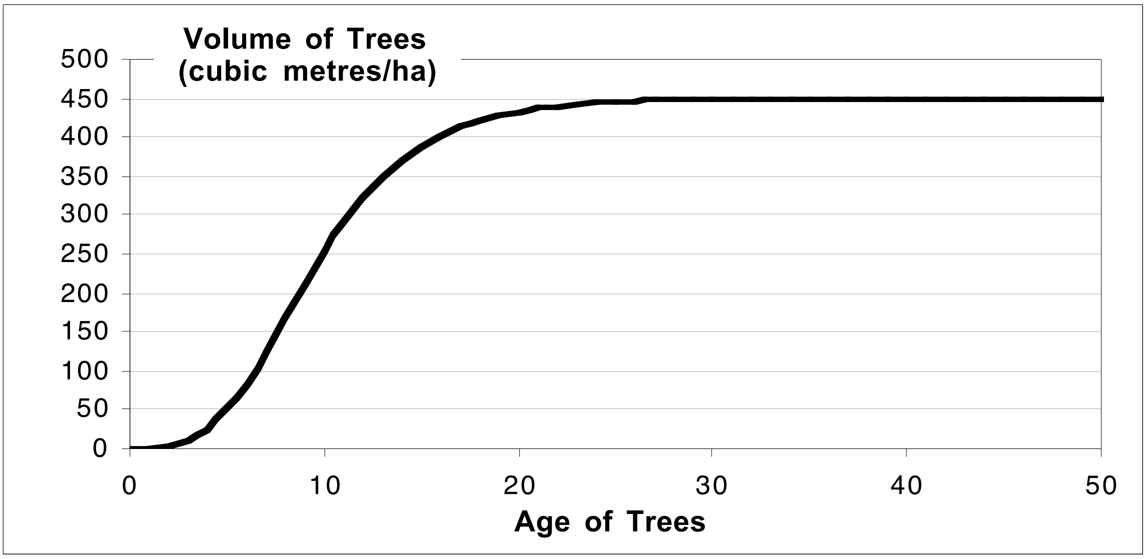

Figure 2 Tree Growth for a species such as *E. Nitens*

Conversion of the volume of the tree into the amount of CO2 absorbed over the life of the tree requires a number of conversion parameters, such as:

- Convert tree volume to tree weight (assume dry density of 0.75 tonne/m3)
- Convert tree weight to weight of carbon sequestered (assume 50% carbon by weight)
- Convert carbon sequestered to CO2 absorbed (assume 44 tonnes CO2 absorbed for every 12 tonnes carbon sequestered, based on molecular weights)

Using the above conversion factors, the hectare of trees shown in Figure 2 will have absorbed 619 tonnes of CO2 over its lifetime.

Many existing tree-planting carbon sequestration schemes, such as Greenfleet, have a policy whereby they "undertaking environmental plantings, where the original ecosystems are permanently restored" (www.greenfleet.com.au). That is, they plant the trees and then leave them there "in perpetuity", such that the growth of the tree plantation is as shown in Figure 2, whereby the trees grow to full size by about 25-30 years and then stop growing (and, importantly, stop absorbing CO2).

An alternative strategy is to plant the trees and let them grow to "almost" full size, then harvest them, and re-plant the plantation area with new seedlings that then begin on a new life cycle. Such a strategy has two major advantages. Firstly, as will be shown below, there is an environmental advantage in that more CO2 can be absorbed under a plant-and-harvest strategy with an appropriate choice of rotation length (i.e. the time between harvests) and usage of the harvested wood as long-lived wood products. Secondly, as will be shown in a later section of this paper, there is an economic advantage in that the financial returns from the harvest can be used to offset the cost of the planting, thus enabling more trees to be planted and more CO2 to be absorbed at a very attractive cost per tonne of CO2 absorbed.

The amount of CO2 that can be absorbed under a continual regime of plant-and-harvest can be estimated by means of a simulation of the planting-growing-harvesting cycle using a variety of rotation lengths. Fundamental to a plant-and-harvest regime is that the timber harvested at the end of the life cycle must be converted into timber products that continue to sequester the carbon for an extended period of time, such as furniture or building timber. While the Kyoto Protocol regulations for carbon trading assumed that all carbon is released back to the environment at the moment of harvesting (primarily because of the current difficulties with auditing the history of the timber once harvesting has taken place), it is clear that carbon will continue to be sequestered for as long as the timber product is in existence. For example, Jaakko Pöyry Consulting (1999, 2000) show that many timber products have extended life spans from 3 years (for paper and paper products) up to 90 years (for timber used in house construction). Not all products in each category last for the entire life span, however, and so the concept of a half-life has often been adopted, with 50% of the carbon being assumed to be released back to the atmosphere in a given time span (either through degradation of the product or through accidental or planned destruction of the product).

Assume that the plantation depicted in Figure 2 is harvested at year 20 and replaced with new seedlings. Further assume that timber products made from the trees have an average half-life of 15 years (some of the products will have much longer half-lives, while some including the waste will have very short half-lives). The amount of carbon sequestered in each successive plantation of trees (and hence the amount of CO2 removed from the atmosphere) will be as shown in Figure 3. For each planting, there is a juvenile phase, followed by a mature phase, but just as the senescent phase is entered at year 20, the plantation is harvested and re-planted. The timber products from the initial plantation then enter a long decline in sequestration according to the half-life chosen for the timber products. As this is happening, however, the next plantation is growing and absorbing CO2. This process repeats ad infinitum (or at least as long as the re-plantings are continued).

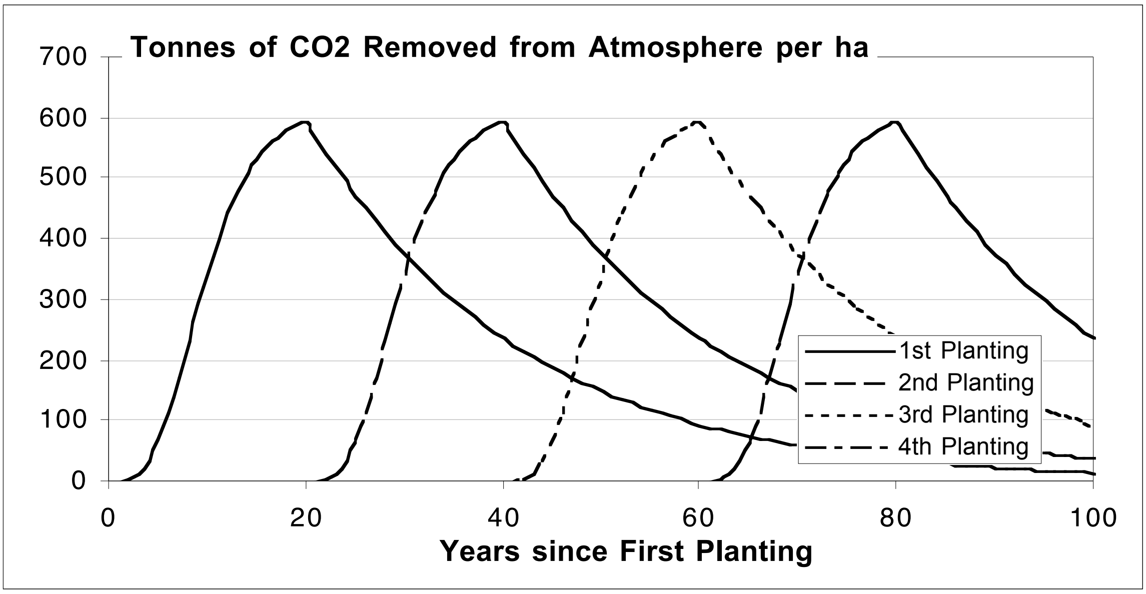

Figure 3 CO2 Sequestration for Sequences of Planting-and-Harvesting

The total amount of CO2 removed from the atmosphere during the overall sequence of planting-and-harvesting on a 20 year rotation can be obtained by adding the amount sequestered in each planting (or subsequent conversion into timber products) at any given year. This total sequestration will fluctuate over time as shown in Figure 4, in which the perpetual forest sequestration is also shown.

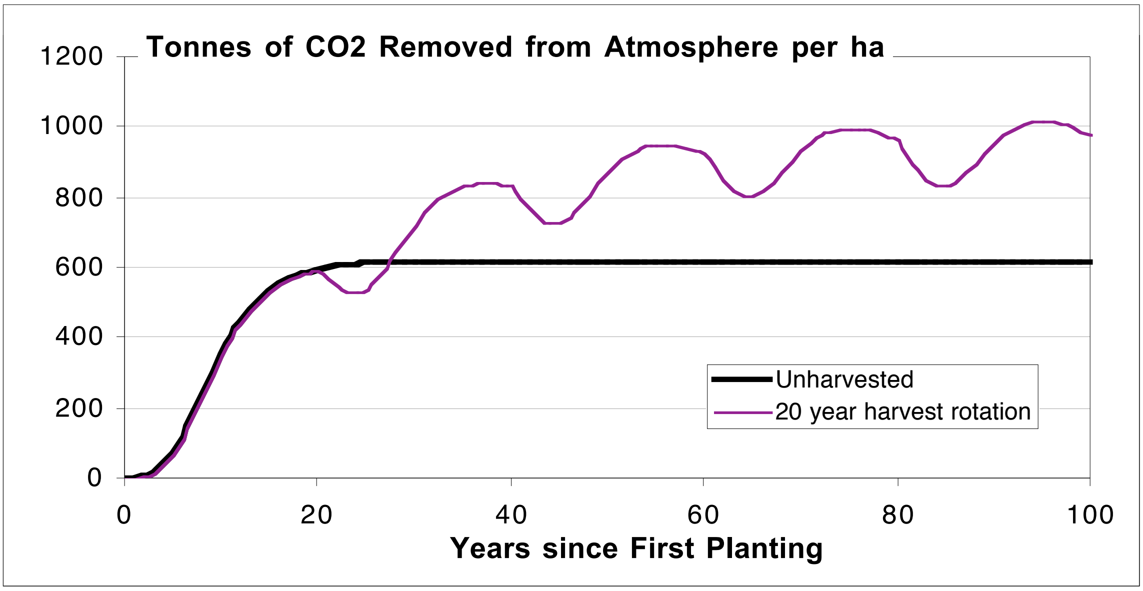

Figure 4 CO2 Sequestration for two Different Harvesting Options

It can be seen that, compared to the plantation left standing in perpetuity, the harvested plantation shows a decline in CO2 sequestration immediately after harvesting in year 20, as some of the CO2 is released back to the atmosphere. However, as the new plantation enters its mature phase after another 5-6 years, the total CO2 sequestered begins to increase until after about year 28 the total CO2 sequestered is now greater than the trees in the perpetual forest. At year 40, there is another decline in sequestration after the second harvesting, but this time the plant-and-harvest regime does not dip below the perpetual forest sequestration. From then onwards, the plant-and-harvest regime always has higher levels of cumulative sequestration, even in the years immediately after a harvest.

The above simulation may be run for a range of rotation lengths, and the results are shown in Figure 5. It can be seen that for any harvesting regime with a rotation greater than about 8 years, the cumulative CO2 sequestration eventually is higher then the perpetual forest sequestration. However, it should be noted that with a rotation of only 8 years, the trees would not be mature, and the likelihood of producing long-lived timber products from such trees would be unlikely, since trees harvested at this age are usually used for pulp and paper making.

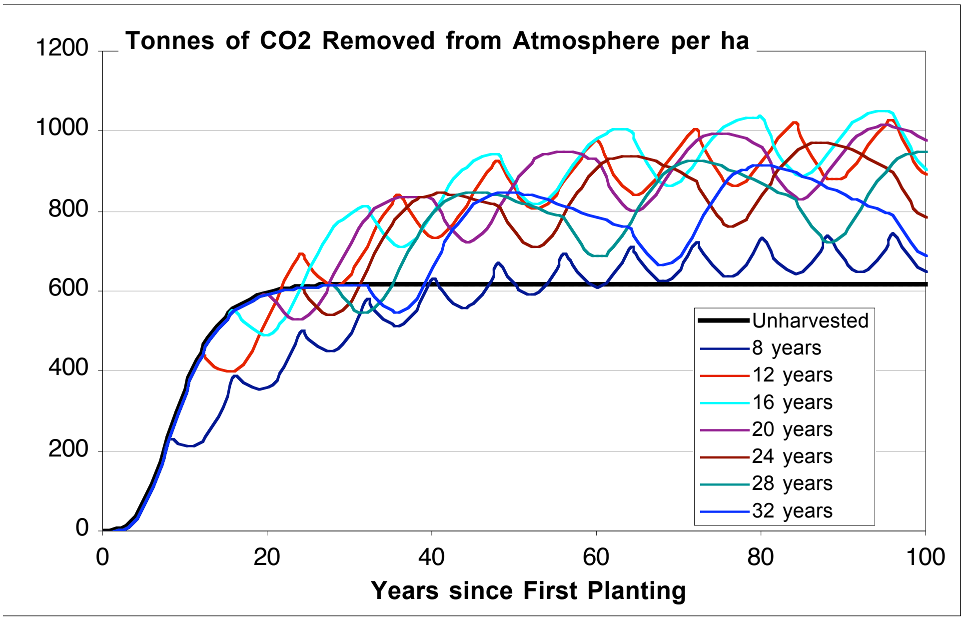

Figure 5 CO2 Sequestration for Harvesting Rotations of Various Lengths

The above argument about sequestration in plant-and-harvest rotations, however, is invalid for two reasons, Firstly, the addition of the sequestrations should be based on annual quantities of CO2 absorbed, rather than on cumulative totals. The amount of CO2 sequestered in year n should not be counted as a benefit in every year after n, just as the amount of CO2 prevented from being emitted by a TravelSmart scheme should not be counted as a benefit in every year after the travel is not made. Rather, the sequestration should only be counted as a benefit in the year in which the sequestration occurs. In forestry terms, the benefit is that the tree has grown in a year, not that it is already a certain size at the start of the year.

Secondly, as noted earlier, the value of CO2 reductions depends on when the reduction occurs. A tonne of CO2 reduced this year is worth more than a tonne of CO2 reduced in 100 years time. Therefore, the stream of CO2 reductions over time should be discounted just as a stream of monetary costs and benefits is discounted (Boscolo et al., 1998).

Taking these two ideas together, one can calculate the NPV of the time-stream of annual CO2 sequestrations for the various rotation lengths. Using a discount rate of 5% p.a., the results are shown in Figure 5 (where the perpetual forest is arbitrarily shown as a plantation with rotation cycle of 100 years).

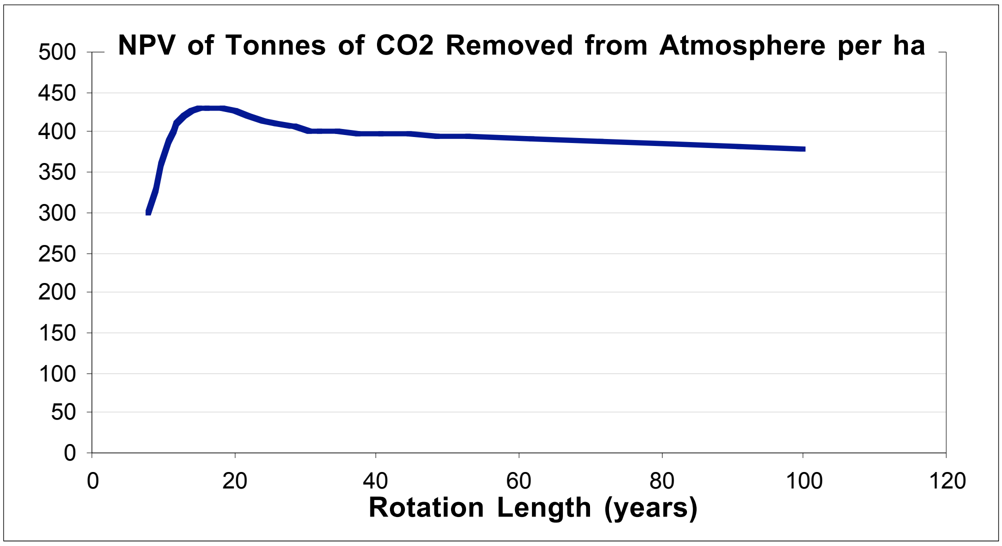

Figure 5 NPV of CO2 Sequestration for Rotations of Various Lengths

It can be seen that for any rotation longer than 12 years, the NPV of the annual CO2 sequestrations is greater than the NPV of sequestrations that would be obtained for the perpetual forest (assuming to have an effective rotation of 100 years). With the assumptions used in these calculations, the optimum harvesting rotation for maximising the NPV of the annual CO2 sequestrations appears to be around 16 years, with an NPV of CO2 sequestration of about 430 tonnes of CO2 per hectare of plantation (note that this is less than the 619 tonnes mentioned earlier, because of the discounting of sequestrations in future years). Assuming that one vehicle year of motoring is equivalent to 4.3 tonnes of CO2 emissions, the sequestration from one hectare of *E. Nitens* plantation is equivalent to about 100 vehicle years of motoring. Alternatively, each vehicle year of motoring requires 0.01 hectares to be grown to maturity over a 16 year rotation, and then re-planted for a total of at least 6 rotations. Given that 1000 stems per hectare would be planted to obtain a final stocking density of 150 trees per hectare, this would require about 10 stems to be planted per vehicle year of motoring.

3.2 Cost of the tree planting programs

The cost of planting trees will depend on a number of factors, including the price of labour, the planting density, the objectives of the planting and the consequent silviculture practices (e.g. pruning and thinning). Given the environmental benefits of a plant-and-harvest regime, it

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is assumed in all the following analyses that the trees are being grown for harvest (as well as carbon sequestration) and that the trees are being harvested for the purpose of obtaining high quality sawlogs that can more easily be converted into long-lived timber products with an average half-life of 15 years. As a result, the silviculture practices will be relatively intensive and costly, compared to the plant-and-forget perpetual forest strategy. In addition, there would be costs involved in certification and auditing of the wood products obtained from harvesting to ensure that the carbon remained sequestered in the wood products.

Approximate unit costs per hectare for the planning, preparation, planting and maintenance of a plantation designed to produce high-grade sawlogs are as follows (assuming a plantation of at least 25 hectares):

- Planning and set-up costs: $10/ha
- Legal costs: $10/ha
- Annual management fee (including certification): $50/ha p.a.
- Ground Preparation and Planting: $1650/ha
- Year 2 Silviculture (thinning and pruning): $1000/ha
- Year 4 Silviculture (thinning and pruning): $650/ha
- Year 6 Silviculture (final pruning): $650/ha

On the other side of the economic fence, one must also consider the revenue to be expected come harvest time. Assuming no financial returns from the sale of thinnings and prunings during the life of the plantation, all the revenue will come from the sale of the timber at the end of the rotation for high-grade sawlogs. The stumpage is the amount of timber (measured in m^3) that can be sold for sawlogs at harvest time. Not all the volume of the tree can be sold as stumpage, since the branches and any trunk higher than about 6m (the normal length of sawlogs) cannot be converted to sawlogs. A reasonable percentage of total tree volume that could be converted to stumpage would be about 60%. From the gross revenue from the sale of stumpage, one must deduct the costs of harvesting and transporting the logs to the mill. A reasonable expectation for the net value of stumpage for *E. Nitens* would be about $75/$m^3$, although this value could vary substantially (up or down) given market conditions at the time of harvest and the proximity of the plantation to the mill.

3.3 Cost-effectiveness of reductions in greenhouse gases

Assuming the conclusions reached in sections 3.1 and 3.2 with respect to the CO2 sequestration abilities of harvested plantations and the costs and revenues that might be expected for *E. Nitens* plantations, the cost-effectiveness of greenhouse gas reductions via such tree-planting can again be calculated using a relatively simple spreadsheet program, with the results as described below. However, the cost-effectiveness of tree-planting in reducing CO2 in the atmosphere will depend on the management strategy adopted for the plantation. Two major decisions are, firstly, whether to harvest or not (which will affect both the costs and the revenues of the tree-planting), and secondly how the land for the plantation is going to be obtained.

3.3.1 Plantations in Perpetuity

As a base case, consider the situation where the plantation is to be planted in perpetuity with no harvesting strategy. In such a case, the costs will be lower (because extensive silviculture will not be required) but the revenue from harvesting will be non-existent. It is also assumed that the annual management fee will be relatively low at $10/ha, and that there are no land costs involved (assuming that the trees will be planted on an existing property, or on a property donated for the purpose of the perpetual forest – as often happens with such schemes). It is assumed, however, that an overdraft will be required to finance the operation and that an interest rate of 8% must be paid on the outstanding balance. Under such circumstances the NPV of the 100-year cost stream is $4764.

With respect to CO2 sequestration it is assumed that the 1000 trees planted and allowed to grow per hectare of perpetual forest will absorb no more CO2 than the 150 trees that are allowed to grow (after thinning) on the plantation destined for harvesting. This is because the individual trees on the higher density plantation will not grow to the same size as the individual trees on the lower density plantation due to increased competition for sunlight, water and soil nutrients. In practice, the growth in tree volume (and hence the amount of CO2 sequestration) is limited by the size of the plantation and not the number of trees on the plantation. It is therefore assumed that the perpetual forest will have an NPV of annual CO2 sequestrations of 380 tonnes, as shown in Figure 5 for the 100 year rotation.

The perpetual forest therefore has a cost of $12.53/tonne CO2 (in NPV terms). This compares more than favourably with the best TravelSmart cost of $33/tonne CO2 shown in Figure 1.

3.3.2 Harvested plantations on own land

An alternative to the plantation in perpetuity is to plan to harvest the trees after a specified rotation period. As noted earlier, the optimum rotation period for CO2 sequestration appears to be about 16 years, with an NPV of annual CO2 sequestrations of 430 tonne. If the plantation is to be treated as a commercial operation, then all costs must be accounted for, including the cost of land on which the plantation will be grown. The simplest option at face value is to grow the plantation on an existing block of land owned by the forester or to buy a block of land and grow the plantation on that block. If the plantation is grown on an existing block and harvested after 16 years, and if no account is taken of the opportunity cost of using the land for the plantation (as might occur on many properties which are not currently being used productively for agricultural purposes), the NPV of the costs (which now includes the cost of the silvicultural) over a 96 year life cycle is $10,732/ha. However, because of the revenue from the harvest every 16 years, the NPV of the revenue over a 96 year life cycle is $14,359/ha, giving a NPV of profit of $3627/ha. Given that this plantation produces an NPV of CO2 sequestrations of 430 tonne, the overall NPV of cost/tonne CO2 is -$8.43/tonne CO2. That is, the proponent of the scheme is being paid $8.43 for every tonne of CO2 sequestered, instead of having to pay $33/tonne to sequester CO2 via a TravelSmart project.

The situation changes somewhat if the land must be bought before the plantation can be planted. Assume that the cost of the land is $5000/ha and that it can be re-sold for the same price at the end of the project (i.e. no capital appreciation on the land), but that an interest-only mortgage must be taken out to pay for the land. Under these circumstances, the NPV of the costs (which now includes the cost of the silviculture and mortgage payments for the land) over a 96 year life cycle is $21,700/ha. The NPV of the revenue over a 96 year life cycle is still $14,359/ha, giving a NPV of net cost of $7341/ha. Given that this plantation produces an NPV of CO2 sequestrations of 430 tonne, the overall NPV of cost/tonne CO2 is $17.07/tonne CO2.

A better financial option, instead of the interest only loan, would be to take out an overdraft to buy the land and then make interest payments on this overdraft until the first harvest occurs in year 16, when the overdraft could then be paid off, thereby stopping interest payments on the land for the rest of the project. Under these circumstances, the NPV of the costs (which now includes the cost of the silviculture and the overdraft costs for purchase of the land) over a 96 year life cycle is $20,423/ha. The NPV of the revenue over a 96 year life cycle is still $14,359/ha, giving a NPV of net cost of $6064/ha. Given that this plantation produces an NPV of CO2 sequestrations of 430 tonne, the overall NPV of cost/tonne CO2 is reduced to $14.10/tonne CO2.

3.3.3 Harvested plantations on leased land

Since the cost of the land seems to make a substantial difference to the profitability of the plantation, many foresters have looked for other ways to acquire land on which to establish plantations. One of the most popular methods is to enter into a lease arrangement with another land-holder who owns land that is not currently being used productively. They are then offered an annual lease payment per hectare in return for having the trees planted on their property. This has the advantage for the land-holder that they receive a guaranteed income stream for a long period, without having any up-front expenditure to establish the plantation themselves (many farmers refer to these arrangements as “money for jam”). On the other hand, the forester has the advantage of not having to buy land in order to establish the plantation, thereby avoiding the high up-front costs associated with the purchase of the land. It is a good example of a win-win situation. A typical annual lease payment is in the vicinity of 3% of land value, which equates in this case to $150/ha p.a.

Under these circumstances, the NPV of the costs (which now includes the cost of the silviculture and the leasing of the land) over a 96 year life cycle is $14,970/ha. The NPV of the revenue over a 96 year life cycle is still $14,359/ha, giving a NPV of net cost of $611/ha. Given that this plantation produces an NPV of CO2 sequestrations of 430 tonne, the overall NPV of cost/tonne CO2 is $1.42/tonne CO2.

3.3.4 Harvested plantations in joint ventures

Another option that is starting to be used to gain access to land for plantations is an arrangement whereby the forester and the land-holder enter into a joint venture arrangement, where the land-holder provides the land at no cost, the forester pays for the establishment and maintenance of the plantation and then they share in the revenue obtained from harvest, in proportion to how much each has contributed to the venture. In this way, the forester can reduce his ongoing costs by not having to make lease payments and can share the risk of the venture, while the land-holder has the potential to make considerably more profit if they do not need the lease income and are willing to contribute towards some of the costs and wait for the revenue from the harvest.

Under these circumstances, assume that the land-holder shares the costs of establishing the plantation equally with forester, in return for 50% of the revenue from the harvest. In this case, the NPV of the costs to the forester (which now includes the half the cost of establishing the plantation and no leasing of the land) over a 96 year life cycle is $5,395/ha. The NPV of the revenue to the forester over a 96 year life cycle is now $7,179/ha, giving a NPV of net profit of $1784/ha. Given that this plantation still produces an NPV of CO2 sequestrations of 430 tonne, the overall NPV of cost/tonne CO2 is -$4.15/tonne CO2. That is, the proponent of the scheme (the forester) is being paid $4.15 for every tonne of CO2 sequestered.

4 Comparisons of cost effectiveness

The results from the TravelSmart and TreeSmart cost-effectiveness calculations are summarised in Table 6.

Table 6 Cost –Effectiveness of TravelSmart and TreeSmart CO2 Reductions

TravelSmart	
Life Cycle	**NPV $cost/tonne CO2**
1 year	$143
3 years	$75
5 years	$53
7 years	$42
9 years	$35
10 years	$33

TreeSmart		
Harvest Rotation	**Land Arrangement**	**NPV $cost/tonne CO2**
Unharvested	Free	$12.53
16 years	Own Land (free)	-$8.43 (profit)
16 years	Interest-only Mortgage	$17.07
16 years	Bank overdraft	$14.10
16 years	Leased Land	$1.42
16 years	Joint Venture (50/50)	-$4.15 (profit)

The previous sections have demonstrated a range of costs per tonne of CO2 removed from the atmosphere, either via stopping the emissions at source or by sequestering them from the atmosphere. In the case of TravelSmart, the costs range from $33/tonne CO2 up to $143/tonne CO2, depending on the assumptions about the longevity of the effect from one implementation of TravelSmart The most likely value is a cost of about $50/tonne CO2.

In the case of TreeSmart, the costs range from a profit of $8.43/tonne CO2 when trees are planted and harvested on land already owned, where no opportunity cost of the land is considered (i.e. land that is currently unproductive and laying idle), up to a cost of $17.07/tonne CO2, where land is purchased on an interest-only mortgage in order to plant the trees. In between these extremes, there is a range of options involving various ways of obtaining the land which give positive and negative costs per tonne of CO2 sequestered. The simplest option of just planting the trees and leaving them as a perpetual forest has a cost of $12.53/tonne of CO2 sequestered. In all cases for TravelSmart and TreeSmart the cost-effectiveness is calculated on the basis of NPV of cost per NPV of tonnes of CO2 sequestered.

Importantly, all of the TreeSmart methods considered are far more cost-effective ways of reducing CO2 in the atmosphere than current TravelSmart schemes.

5 Other costs and benefits of TravelSmart and TreeSmart

The above analysis, and indeed this entire paper, has concentrated on the cost-effectiveness of different ways of reducing CO2 in the atmosphere. It should be remembered, however, that both TravelSmart and TreeSmart have many other benefits that might provide good reasons for proceeding down those avenues. Without going into the details of these other benefits, they include benefits such as those listed in Table 7.

Table 7 Other Benefits of TravelSmart and TreeSmart

TravelSmart	TreeSmart
Increases in public transport usage	Reduction in pressure for logging of native forests
Increases in use of walking / cycling	Control of salinity
Increases in physical activity	Control of erosion
Reductions in other pollutants	Retention of labour in the forest industry
Reductions in traffic accidents	Sources of income for farmers
Reductions in traffic noise	Expansion of habitat for birds and animals

6 Conclusions

This paper has compared the cost efficiency of TravelSmart and TreeSmart projects in removing CO2 from the atmosphere (in terms of $ per tonne of CO2 absorbed/reduced). The TravelSmart efficiencies are based on such projects recently conducted in Australia, while the TreeSmart efficiencies are based on a range of business models for eucalypt plantations in Victoria.

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While not ignoring the other benefits of TravelSmart or TreeSmart, it must be concluded that in terms of reducing CO2 in the atmosphere, the TreeSmart programs of tree planting and carbon sequestration are much more cost-effective than the TravelSmart programs of travel behaviour change.

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