Carbon sequestration in the standing biomass of orchard crops in New Zealand

Report prepared for Horticulture New Zealand Ltd by

L.H.J. Kerckhoffs and J.B. Reid

New Zealand Institute for Crop & Food Research Ltd, RD2, Hastings, New Zealand

26 March 2007

Objective

- Review available NZ and overseas information on the standing biomass of young and mature orchards of pipfruit, stonefruit, green kiwifruit, and avocadoes, and indicate the likely carbon content of that biomass.

Background

Carbon sequestration plays an important role in the global carbon cycle. Green plants remove (sequester) carbon from the atmosphere through photosynthesis. They extract carbon dioxide from the air, separating the carbon and oxygen atoms, returning oxygen to the atmosphere, and using the carbon to make biomass in the form of roots, stems, and foliage. Every year on a global scale a very large amount of carbon dioxide (on the order of 100 billion metric tons) is sequestered. At the same time, carbon is released to the atmosphere from vegetative respiration, combustion of wood as fuel, consumption of biomass for food, and natural decay. The net numerical difference or flux between carbon sequestration and release can be viewed as measure of the relative contribution to biomass to the carbon cycle. World flux is thought to provide a net sink of about 0.7 billion metric tons of carbon dioxide/year (Intergovernmental Panel on Climate Change, 1995). The Kyoto Protocol in 1997 formalised the concept of carbon credits as a result of increasing awareness of the need for pollution control. Carbon credits are certificates awarded to countries that are successful in reducing the emissions that cause global warming.

New Zealand is unusual among developed countries in that our economy is largely based around agriculture. Emissions from agriculture make up nearly half of our annual greenhouse gas emissions (www.climatechange.govt.nz/policy-initiatives). The New Zealand Government developed the Projects to Reduce Emissions (PRE) programme to support initiatives that will reduce emissions of greenhouse gases beyond the reductions that would have occurred without the project by awarding emissions units, or "carbon credits". Emission units are internationally tradable and add to the financial value of a project that will reduce greenhouse gas emissions.

Here we review the potential for the horticultural industry to pursue the concept of carbon credits for New Zealand orchards.

Approach

We searched the published literature for measurements or reliable estimates of the standing biomass of orchard crops. Wherever possible we gave priority to reports of crops grown in NZ or under conditions that approximate those in NZ. Having gathered those figures we next calculated the proportion of the standing biomass that would be made up of carbon, and from this calculated the likely equivalent amount of CO_2 sequestered (3.67 times the amount of carbon). Along with many other authors we assumed that 50% of tree dry matter is carbon – the exact percentage will vary between species and situations, but not enough to materially affect our conclusions.

Often we had to calculate the crop biomass ourselves from information given in one or more published papers. For example, to estimate biomass carbon stocks on fruit orchards we used a general allometric equation (Fournier *et al*., 2003; Chalmers & Van Den Ende, 1975) and published average diameters of peach, nectarine, and apple trees at various ages and spacings (Jiménez and Diaz, 2003; 2004).

In the time available for this project we were not able to consider the amount of carbon sequestered in the soil beneath orchard crops (and the swards between the rows). While it is hard to compare orchards and alternative land uses at the moment for such impacts, this carbon may be a significant addition to the figures for the standing biomass of the trees.

Findings

Our results are summarised in Table 1.

Table 1: Estimates of standing biomass per area (t/ha or Mg/ha), and calculated CO_2 equivalents per ha for perennial crops.

	Total DW (t/ha)	Total CO_2 (t /ha)	Main source of data for calculations
Apple	36	66	Jiménez and Diaz, (2004), Palmer et al. (2002)
Peach and nectarine	40	73	Chalmers & Van Den Ende (1975); Jiménez and Diaz, (2003)
Citrus (orange)	37	68	Morgan et al, 2006; Kroodsma & Field, 2006
Citrus (lemon)	50	92	Kroodsma & Field, 2006
Plums, prunes	62	114	Kroodsma & Field, 2006
Almond	100	183	Kroodsma & Field, 2006
Walnuts	75	138	Kroodsma & Field, 2006
Avocado	20-30	37-55	Lovatt, 1996; personal communication Dr Jonathan Dixon, NZ Avocado Growers Association
Kiwifruit	22	40	Buwalda and Smith, 1987
Grape vines	4	8	Nendel & Kersebaum, 2004
Forest stands	300-500	550-900	Ford-Robertson et al, 1999; Robertson et al, 2004; www.maf.govt.nz/forestry/pfsi/

We were not able to find good data for shelterbelt species in horticulture. For some of the shelterbelt species used overseas, the mean aboveground carbon content was 79 kg/tree (32 t/km) for green ash, 263 kg/tree (105 t/km) for poplar and 144 kg/tree (41 t/km) for white spruce. Improved, fast-growing poplar clones had the greatest biomass at maturity and fixed the greatest amount of carbon (Kort and Turnock, 1998). If those figures are representative for an orchard situation, then for an orchard with roughly 400 m of shelterbelt per ha, the amount of C sequestered in the shelter belt would be less than 41 t/ha. However, Hort and Turnock's figures are for shelterbelts used on the Canadian prairies, and probably more than double the sorts of values that can be expected under NZ orchard situations where the trees are regularly pruned.

The values summarised in Table 1 indicate that even the most vigorous stands of orchard fruit trees are unlikely to sequester much more than 50 t C/ha. If we add in a generous estimate of 20 t C/ha for shelterbelts then most NZ orchards will sequester less than 70 t C/ha. The life expectancy of those orchards varies greatly with species, but will usually be between 10 and 30 years.

To put these values into perspective they can be compared to nut orchards and forest stands such as *Pinus radiata.* Unsheltered nut orchards may achieve 75 – 100 tonnes CO_2/ha with an average lifespan of at least 25 years (Table 1). Under NZ conditions *Pinus radiata* forests may sequester 300-500 t C/ha depending on climate, soil and management (Table 1). **So the standing biomass carbon of NZ forests represents roughly four to seven times that of the most vigorous orchards.** Orchards, like forests, are occasionally "clearfelled", usually to change tree varieties every 10 to 30 years. If we assume that the orchard wood is all burnt, then this makes the comparison with forests still less favourable.

It must be stressed that this analysis is somewhat simplistic and does not take into account differences between orchards and forests in the **rate** at which they grow and sequester carbon. Tree size in orchards is usually well controlled by pruning, and the amount of carbon sequestered may change relatively little after about 10 years. By contrast, although the lower branches on forest trees are occasionally pruned the main objective of management is to get the trees as big as possible as quickly as possible. Overall it seems possible that orchards and forests may sequester similar amounts of carbon for the first few years after establishment, but thereafter the forests will dominate to a considerable degree.

Conclusions

The potential for carbon credits based on standing (aboveground) biomass for NZ orchards are limited when compared with forest stands, like *Pinus radiata*. For forest stands total C equivalent of 300-500 t carbon/ha are reached. Most fruit orchards though will achieve rather less than 70 t carbon/ha.

It is worth noting that most annual crops fix less than 15 t carbon/ha/y, and much of that is returned to the atmosphere as CO_2 within 12 months.

The above comparison does not include allowance for differences between land uses in the amounts of carbon sequestered below ground in roots and soil organic matter. However, it seems most unlikely that below ground biomass on orchards would be so large as to make orchards comparable to forests overall.

So, by comparison with forestry, fruit orchards seem to have a minor role in sequestering carbon. The value of that role to the industry itself though will depend strongly on what value is assigned to carbon credits, and how well the industry can put forward a case to government.

References used

Bartelink, H.H. (1998). A model of dry matter partitioning in trees. Tree Physiology 18: 91-101.

Buwalda, J.G. and G.S. Smith (1987). Accumulation and partitioning of dry matter and mineral nutrients in developing kiwifruit vines. Tree Physiology 295-307.

Chalmers D.J. and B. Van Den Ende (1975). Productivity of peach trees: factors affecting dry-weight distribution during tree growth. Annals of Botany: 423-432.

Ford-Robertson, J. K. Robertson and P. Maclaren (1999). Modelling the effect of land-use practices on greenhouse gas emissions and sinks in New Zealand. Environmental Science and Policy 2: 135-144.

Fournier, R.A., J.E. Luther, L. Guindon, M.C. Lambert, D. Piercy, R.J. Hall and W.A. Wulder (2003). Mapping of aboveground tree biomass at the stand level from inventory information: test cases in New Foundland and Quebec. Canadian Journal of Forest Research 33:1846-1863.

Intergovernmental Panel on Climate Change (1995). Climate Change 1995: The Science of Climate Change. Cambridge University Press, Cambridge, UK. p77

Jiménez C.M. and J.B.R. Diaz (2003). A statistical model to estimate potential yields in peach before bloom. Journal of the American Society of Horticultural Science128: 297-301.

Jiménez C.M. and J.B.R. Diaz (2004). Statistical model estimates potential yields in 'Golden Delicious' and 'Royal Gala' apples before bloom. Journal of the American Society of Horticultural Science 129: 20-25.

Kort, J. and R. Turnock (1999). Carbon reservoir and biomass in Canadian prairie shelterbelts. Agroforestry Systems 44: 175-186.

Kroodsma, D.A. and C.B. Field (2006). Carbon sequestration in California agriculture 1980-2000. Ecological Applications. 16: 1975-1985.

Lovatt, C.J. (1996) Nitrogen allocation within the "Hass" avocado. Californian Avocado Society 1996 Yearbook 80:75-83.

Morgan, K.T., J.M.S. Scholberg, T.A. Obreza and T.A. Wheaton. Size, biomass, and nitrogen relationships with sweet orange tree growth. Journal of the American Society of Horticultural Science 131: 149-156.

Nendel, C. and K.C. Kersenbaum (2004). A simple model approach to simulate nitrogen dynamics in vineyard soils. Ecological Modelling 177: 1-5.

Palmer, J.W., J.N. Wünsche, M. Meland and A. Hann (2002). Annual dry-matter production by three apple cultivars at four within-row spacings in New Zealand (2002). Journal of Horticultural Science Biot. 77: 712-717.

Robertson, K., I. Loza-Balbuena and J. Ford Robertson (2004). Monitoring and economic factor affecting the economic viability of afforestation for carbon sequestration projects. Environmental Science and Policy 7: 465-475.

Smith, P. (2004). Carbon sequestration in croplands: the potential in Europe and the global context. European Journal of Agronomy 20:229-236.

Villalobos, F.J., L. Testi, J. Hidalgo, M. Pastor and F. Orgaz. Modelling potential growth and yield of olive (*Olea europaea* L.) canopies. European Journal of Agronomy 24: 296-303.