IMPACT OF CARBON TRADING ON THE ECONOMICS AND ENVIRONMENTAL BENEFITS OF TREE PLANTING OPTIONS

ENVIROLINK STUDY ON McRAE TRUST LAND, WAIROA, HAWKES BAY.

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1. EXECUTIVE SUMMARY.

1. The advent of the Emissions Trading Scheme (ETS), though not yet in legislation, promises to increase revenue and improve the economic viability of plantation trees as a land use. This study shows that revenue for carbon credits can improve Land Expectation Values (LEV) from $1700/ha for pastoral farming to greater than $5000/ha for tree crops.

2. Carbon accumulated in various tree species relates directly to their respective growth rates and density. Applying this through good species/ site matching gives farmers and land managers a wider tree species choice than they previously had.

3. Species that establish quickly and grow fast with moderately dense wood, such as Eucalypts and Radiata pine are likely to be favoured for farm planting under the ETS. Management regimes are likely to be less intensive with and emphasis on volume production per hectare and crops may be grown for longer periods than currently indicated for timber harvest.

4. Root biomass has been used as a measure of soil stability and erosion prevention. i.e. more root biomass per hectare gives more stable hill soils. Tree regimes and species that optimise carbon credits are also likely to give greater soil stabilisation than traditional spaced poplar planting. Further research in this area may help guide land managers toward species that offer more in terms of soil stabilisation and erosion prevention.

5. The planting of trees for carbon sequestration has the potential to provide not only global warming reduction and economic benefits, but if practiced on erosion prone hill country sites will provide direct soil stability benefits.

CONTENTS

2. INTRODUCTION

Much of the hill country on the East Coast of the North Island of NZ is prone to erosion as a result of soil type, climate and steepness of the topography. This makes for difficult farming of sheep and cattle especially when long term sustainability of both the land and farm business are the main objectives.

The Hawkes Bay Regional Council (HBRC) has a mandate to promote land stability and sustainable land use. This project was initiated by the HBRC to investigate different land uses and the effect that new carbon sequestration policies might have on the economics of land use in hill country

SCION and Hardwood Management personnel were invited by HBRC to investigate different land use options on McRae Trust land –a steep hill country sheep and cattle farm some 18kms from Wairoa in northern Hawkes Bay. This study has been conducted with Envirolink funding provided under the Foundation for Research Science and Technology.

3. McRAE TRUST LAND

This farm was bequeathed to the people of New Zealand by Miss May McRae in 1975, to encourage the preservation of native flora /fauna, encourage improved farming methods on East Coast hill country, and encourage knowledge of horticulture and silviculture with specific reference to Rhododendrons.

A charitable Trust administers the farm activities and a Trust board attends to addressing the Trust Deed.

The HBRC has had a long involvement with the McRae Trust and its activities and Peter Manson, a HBRC Land Management Advisor, has been intimately involved over the last decade in many of the sustainable farm management activities conducted on Trust land.
The farm is approximately 614 hectares (492ha. effective) and carries some 5500 stock units.

There are small plantings of a number of tree species dating from 1982 which were established to demonstrate the potential for different tree species and their effect on soil conservation on steep, relatively dry East Coast hill country land.

Species planted include; *P.radiata* , eucalypts, cypress , poplars, alders, acacias and some oak species. Some of these plantings were measured as part of the Envirolink study.

4. STUDY OBJECTIVES

Five different tree based options for land stabilization were considered and estimates made of tree crop productivity. The amount of carbon sequestered and soil holding capacity (where data was available) was estimated for each tree Option.

Options

1. Kanuka /Manuka/ Tawhinu regeneration.
2. Mature native forest (QE II Trust area)
3. Planted poplar with run-off grazing.
4. Planted eucalypts, *E. fastigata* being the chosen species.
5. Planted *P.radiata* .

The economics of each option was analysed using a discounted cashflow approach with local costs and prices.

Key variables were examined in sensitivity analysis and compared with farming returns using land expectation value (LEV) figures.

5. PROCESS

For the above options, three regimes were modelled for Poplar, five regimes for *P.radiata* and three regimes for *E.fastigata* as shown in Figure 1 below.

All options were modeled over a total of 60 years in either two 30 year rotations or a single rotation.

Figure 1 : Land Use Options and Regimes

Option	Rotation (Yrs)	Thinning	Timber	Carbon
Native Forest	60			Yes
Manuka/Kanuka	60			Yes
Poplar 120 sph Unthinned Timber & Carbon	2 x 30		Yes	Yes
Poplar 260 sph Unthinned Timber & Carbon	2 x 30		Yes	Yes
Poplar 550 sph Unthinned Timber & Carbon	2 x 30		Yes	Yes
Radiata Clearwood 350 sph Timber	2 x 30	Yes	Yes	
Radiata Clearwood 350 sph Timber & Carbon	2 x 30	Yes	Yes	Yes
Radiata Clearwood 450 sph Timber & Carbon	2 x 30	Yes	Yes	Yes
Radiata Framing 400 sph Timber & Carbon	2 x 30	Yes		
Radiata 750 sph Unthinned Carbon	60			Yes
E. Fastigata 600 sph Timber & Carbon	2 x 30	Yes	Yes	Yes
E. Fastigata 450 sph Timber & Carbon	2 x 30	Yes	Yes	Yes
E. fastigata 1000 sph Unthinned Carbon	60	Yes	Yes	Yes
Sheep and Beef Farming	60			

Radiata pine timber option was considered the best “timber only” option to contrast the timber & carbon scenarios with. Timber yields for Eucalypts and Poplar have not been modelled.

5.1. Option 1 – Kanuka / Manuka / Tawhinu regeneration.

Native scrub regeneration typically occurs when grazing pressure and weed control is diminished and the area “reverts”. Growth in this type of vegetation is slow (Estimate 8 t CO_2/ha/yr.) when compared to planted exotics and thus fixes much less carbon.

5.2. Option 2 – Mature native forest (QE II Trust area)

A small area of modified native forest exists on McRae Trust land and this has been fenced off and ceded to the QE II Trust for preservation in perpetuity. Growth is slow within the forest area but estimated at 3m3/ha/yr.

5.3. Option 3 – Planted Poplar with run-off grazing

A small area of “Kawa “poplar hybrids were planted on the property as poles in 1995 alongside *Eucalyptus regnans* and *P.radiata*. The present stocking of the poplar planting is 225 stems per hectare (sph) which is low in comparison to the other species but in keeping with the usual poplar planting and the desire to maintain a good sward of grass underneath the trees.

Three initial stockings are reviewed for poplars .viz. 550 sph. ; 260 sph. ;120 sph. .

As is current practice with poplars, grazing was included in all stockings, and assumed to be available until 50% canopy closure was achieved, estimated using the SCION's Poplar Calculator (McElwee and Knowles , 2000). This was reached at ages 6, 8 and 13 years for stockings of 550, 260 and 120 sph respectively.

5.4. Option 4 – Eucalypt

An area of *E.regnans*. was planted in 1995 by the Trust and had been thinned to approximately 300 sph. in 2005 . Diameter growth and height were superior to both *P.radiata*. and poplar species planted at the same time but some carbon sequestered will have been lost as a result of the thinning operation.

E.regnans is very site specific in its growth requirement so to cover more sites on the Trust property it was decided to model *E. fastigata*, as a more versatile species.

Three regimes for *E.fastigata* have been modeled

- unthinned (plant 1000 sph and leave)
- thin to 600 sph at age 6yrs for timber and carbon
- thin to 450 sph at Age 6 yrs for timber and carbon.

Site Index (age 15 Mean Top Height) used was 30.9m

5.5. Option 5 – *P.radiata*

In the 1995 plantings, two plots were established and measured and varied in their respective stocking of trees per hectare.(350 sph ;550sph)

Some four *P.radiata* regimes were modelled

- Unthinned, (plant 750 sph and leave)
- framing regime, thinned to 400 sph.
- clearwood (pruning and thinning) thinned to 450 sph
- clearwood (pruning and thinning) thinned to 350 sph

Site Index (MTH age 20) used was 30.4m and 300 Index 29.8 (average volume growth/ha/yr by age 30 year – m^3/ha/yr) as starting values for the Radiata pine Calculator (Knowles 2003).

5.6. Economic Assumptions

For each option costs, yields and log prices were entered into Hardwood Management's land evaluation model to produce cashflows, and estimates of LEV and where possible Internal Rate of Return.

The following assumptions were used:

- Discount Rate 8%
- Carbon Price $20/tonne CO_2

- Carbon yields were assumed to be 90% of modeled carbon values because of the possible negative impacts of slips, windthrow, and drought.
- Carbon revenue was assumed to occur annually from year 3 with an annual return cost as well. Carbon audits were assumed to occur every 5 years.

- Rates $15/ha
- Management Fees - $100/ha for first two years and $20/ha thereafter.
- Land Rental $139/ha. This is the MAF Economic Farm Surplus for Sheep and Beef farming in the Gisborne/Wairoa districts for 2006/07 and is taken as the opportunity cost for converting to other land use.
- All options had some road maintenance, animal control, noxious weed control and re-mapping at age 3 costs.
- Forestry options had pre plant weed control, seedlings, planting, disease monitoring or control, fire insurance and where appropriate pruning and thinning costs.
- Eucalypts also had fertilizer application costs.

- Grazing rental was assumed for poplar regimes equivalent to $139 per ha for each year until ages 6, 8 and 13 years for stockings of 550, 260 and 120 sph respectively, when 50 percent canopy closure was estimated to occur.
- ETS compliance costs for each option have been assumed to be for an area less than 100 ha. This requires an application fee of $439 at the outset and $217 per return which will be for each year after year 3.
- ETS liability assumes purchase of carbon credits at the same price as previously sold.

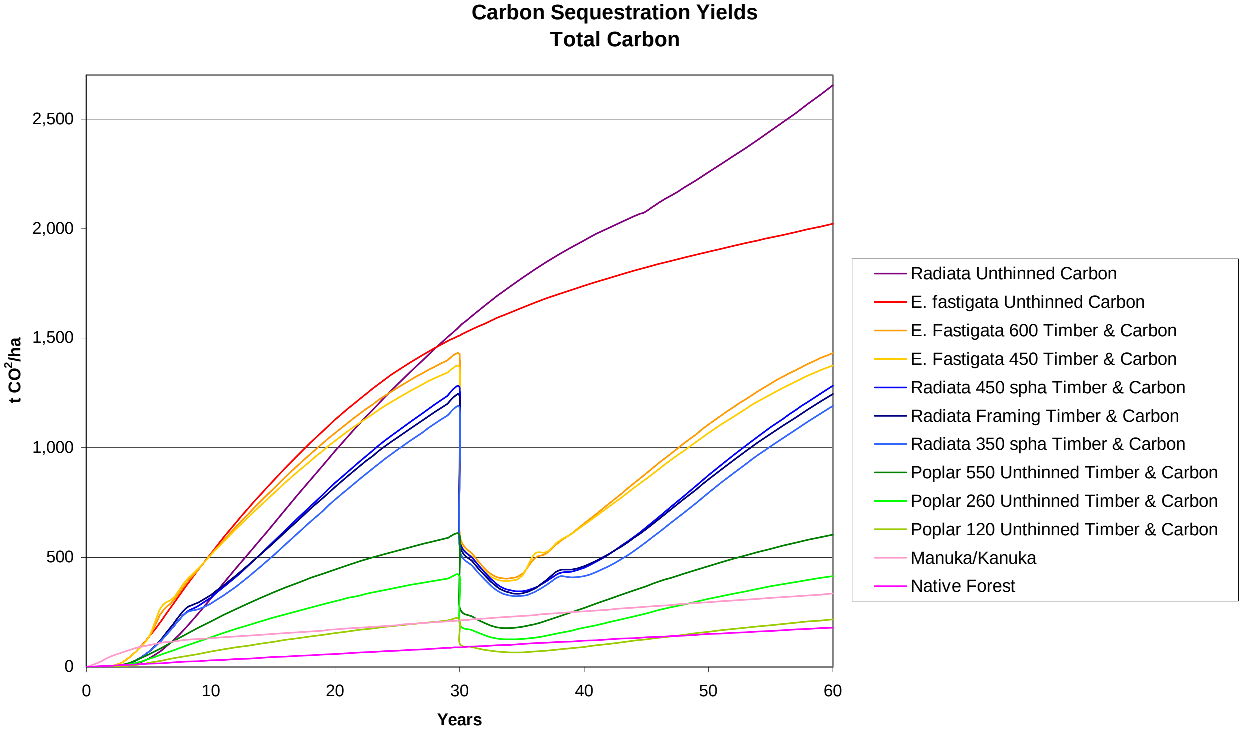
6. CARBON YIELD

All volume yields were modelled by SCION using appropriate growth models for timber and the carbon model C Change (Beets et al 1999) for carbon yields.

During a visit to the site, some temporary sample plots were measured in the eucalypt, *P.radiata,* and poplar plantings on the McRae's Trust property. These were used as benchmarks, with knowledge of growth from surrounding areas, for setting starting points for the growth models.

The resultant carbon yields are in Figure 2 as yields and Figure 3 as annual increments. Detailed carbon yields are found in Appendix 1.

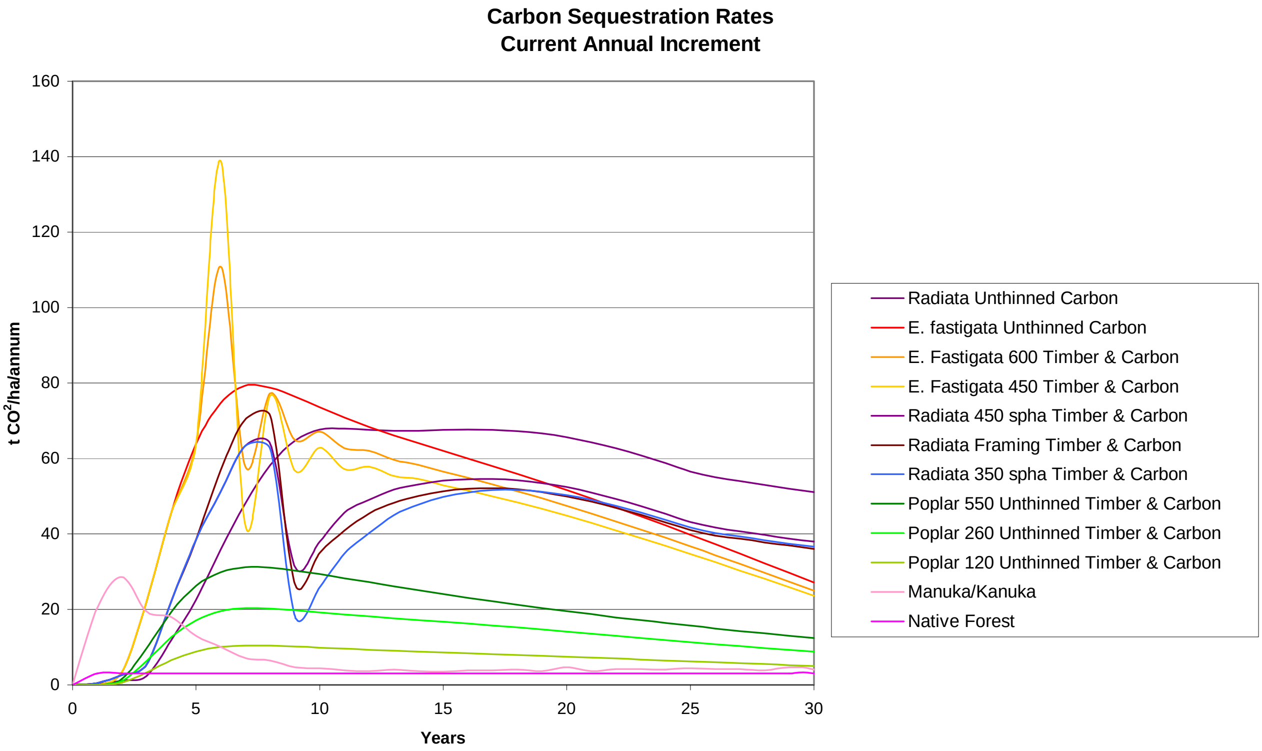
Figure 2 : Carbon Sequestration Yields



For the two 30 year regime options, carbon is lost after felling the crop. Due to carbon build up in the soil and sequestration in the roots, the level following felling at 30 years is still appreciable. For the first few years following felling the level continues to decline until the newly planted crop starts sequestering carbon at a greater rate than the level of decline. The final level of the second crop is comparable to that of the first crop when it too is felled at 60 years (age 30).

Although not visible in the chart, for the timber options the carbon level is assumed to drop after the final harvest at age 60 to the same level as after the first harvest at age 30, as the options are assumed to be managed as perpetual forests.
Generally, unthinned options sequester more carbon than thinned options and higher stockings of the same species sequester more carbon.

Figure 3 : Carbon Sequestration Annual Increments



To more easily see the differences in rate of sequestration between the various options, only the first 30 years are shown. Blips in the thinned options at ages 6 for eucalypt and age 8 for *P.radiata* are carbon losses due to the thinnings.

Annual carbon sequestration rates show similar trends to timber annual growth rates. They show an initial growth spurt until competition between trees occurs and then they gradually decline. The thinned options show a sharp decline following thinning, but then recover as remaining trees use up the available light, moisture and nutrients made available by the demise of the thinned trees.

7. ECONOMICS OF DIFFERENT OPTIONS

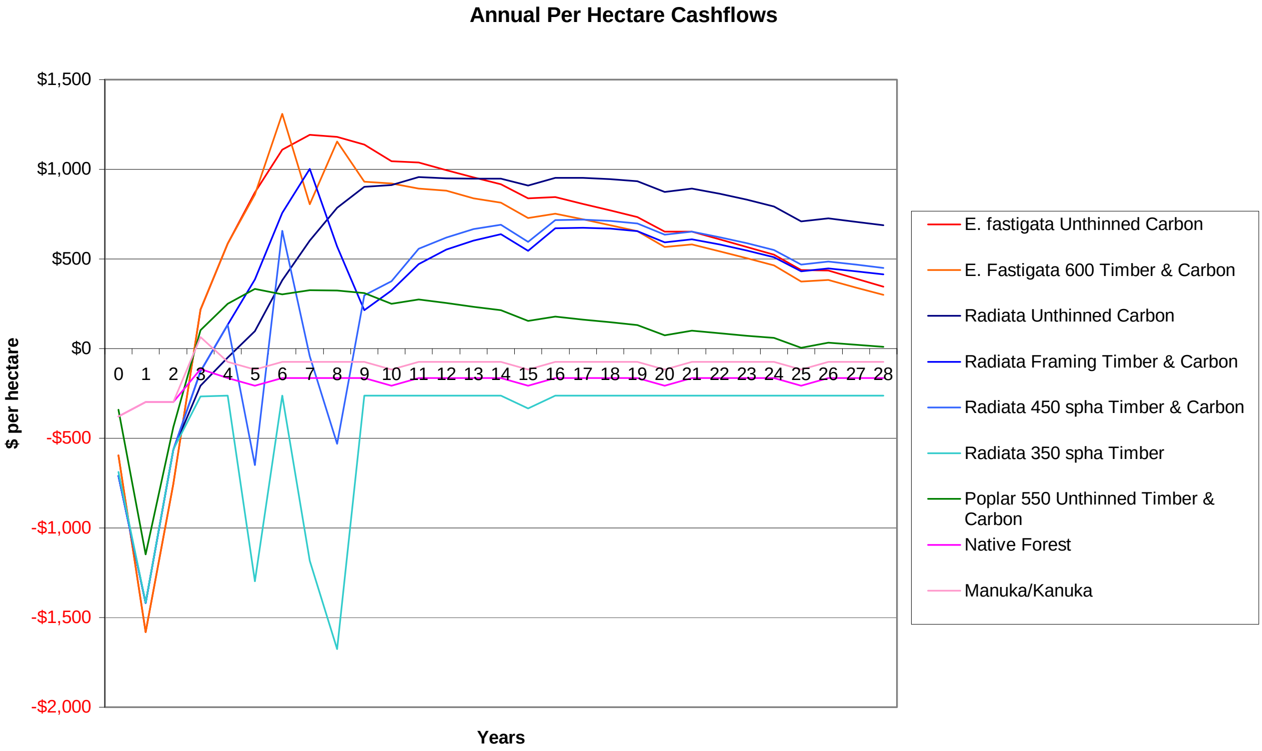
7.1. Cashflows

Annual per hectare cashflows are shown for the best regime for each treatment for each option in Figure 4.

To make the graph more readable, data is restricted to the first 28 years and only the best option/regime combinations are shown. At age 30, for the timber options there is a large increase in revenue from timber sales that more than exceeds the carbon credit payback, and dwarfs the initial costs. Because of this, all graphs except the Radiata 350 sph Timber option include carbon revenue in the 28 year period visible.

Detailed cashflows are found in Appendix 2.

Figure 4 : Per Hectare Cashflows



All options, except for manuka/kanuka and native trees have high planting and releasing expenditure in the first two years.

Carbon revenue starts at age 3, so for carbon options cashflows become positive.

Eucalypts have high initial cashflows and then tail off as growth declines. Radiata , with slower initial growth, have lower initial cashflows , but are higher later on in the rotation.

Dips in cashflows for the timber options occur at time of thinning (6 for eucalypt and 8 for *P.radiata*) and pruning for *P.radiata* (ages 4, 6 and 7).

All carbon options have small dips in cashflow at five yearly intervals when carbon auditing is carried out and all timber options have a mid rotation inventory at age 15.

Native and manuka/kanuka have negative cashflows, the carbon being sequestered not enough to offset rental and other costs.

The *P.radiata* timber only option has no revenue until age 30, contributing to its poorer economic performance.

7.2. Land Expectation Value and Internal Rate of Return

The economic returns for the various options and regimes were compared using both Internal Rate of Return (IRR) (where possible) and Land Expectation Values, shown in Figure 5.
LEV represents the productive value of the land at 8% discount rate and could be considered as the maximum price a buyer should be willing to offer to purchase bare land in order to achieve a required rate of return in a forestry land use, assuming that the use continues in perpetuity.(NZIF 1999).

Figure 5 : Land Expectation Value and Internal Rate of Return.

	LEV $/ha	Stumpage $/m3	IRR %
E. fastigata Unthinned Carbon	7,031	n/a	22.3%
E. Fastigata 450 Timber & Carbon	5,836	18	21.1%
E. Fastigata 600 Timber & Carbon	5,479	13	20.9%
Radiata Unthinned Carbon	5,459	n/a	15.3%
Radiata Framing Timber & Carbon	5,032	33	14.5%
Radiata 450 sph Timber & Carbon	3,556	37	10.6%
Radiata 350 sph Timber & Carbon	3,106	42	9.8%
Poplar 550 Unthinned Timber & Carbon	1,931	-3	8.5%
Sheep and Beef Farming	1,738	n/a	n/a
Poplar 260 Unthinned Timber & Carbon	482	-3	n/a
Manuka/Kanuka	149	n/a	n/a
Poplar 120 Unthinned Timber & Carbon	-101	-3	n/a
Native Forest	-886	n/a	n/a
Radiata 350 sph Timber	-2,422	42	4.2%

The table is sorted in descending order of LEV.

For the top option, one could afford to buy the land for $7,031 per hectare plant successive crops of unthinned *E.fastigata* in perpetuity and make 8 percent return.
By contrast at the other end of the range, for timber only options the LEV is negative, indicating at current timber prices, the 8% discount rate cannot be achieved and returns of 3-4% are likely.

Because of its rapid growth rate and higher wood density, eucalypts head the table with lower levels of management intensity proving the best. This is followed by *P.radiata* also with lower levels of management intensity proving the best.
Sheep and beef farming then follows, with poplar, manuka/kanuka and timber only *P.radiata* bringing up the rear.

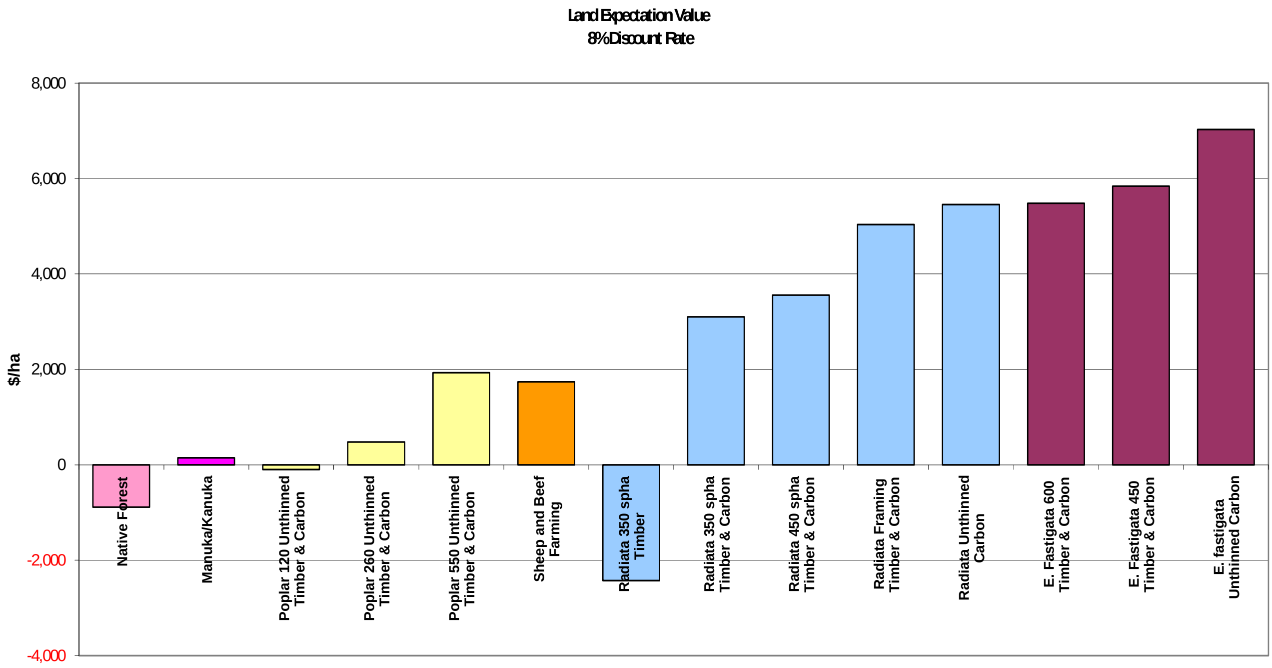
The pine option of prune/thin to 350 sph for timber shows graphically how carbon returns can add positively for farm cashflow once the ETS is operational.

Though present farming fortunes are poor for a number of reasons, the results suggest that overall cash flow for the land could be improved by consigning the poorer farmland on the property to carbon forestry.

The cashflow for Sheep and Beef farming was assumed to consist entirely of $139/ha per year revenue in perpetuity. Equating to the Economic FarmSurplus in perpetuity, this is simplistic and probably optimistic given the cyclic nature of farming returns.

Figure 6 gives a graphic representation of LEV's in Figure 5, coloured by species.

Figure 6 : Land Expectation Values



Internal Rates of Return, naturally, follow the same trend as LEV, but could not be calculated for the sheep and beef, poplar, manuka/kanuka and native options. For the better tree crop options IRRs exceed 15% and are very attractive for investment.

The trends are clear:

- Faster, early growth rates coupled with high wood density produce more carbon.
- Higher stockings sequester more carbon which translate into better returns
- Less intensive management reduces cost, which further contributes to better returns.

7.3. McRae Trust Farming Returns

The farming returns on McRae Trust over time, from 2004 to 2008 have been a trend of increasing losses.

Figure 6: McRae Trust profits

Year	2004	2005	2006	2007	2008
Profit	$13,463	$28,752	($45,330)	($66,961)	($75,110) est.

There are a number of reasons for this :

- drought, poor lambing survival in 2006 and other costs which are affecting returns for all rural land industries,
- freight rates –internal and external,
- labour costs and availability,
- input costs –especially fossil fuel and its derivatives.

For those rural land based industries who are also exporting, exchange rate has also had a major impact on farm returns over the last 5 years.

From the above figures, it is presumed that the Trust does not have the capital to invest in alternative land use such as trees for carbon, so it may have to consider forestry right lease on the poorer parts of the farm as a means of gaining revenue, and also improving soil stability if the poorer parts are also steep.

A review of Land Use classes on the farm and possible lease options may help improve the farming returns by concentrating farming effort on the better land use classes. This would need to be done in concert with tree species/site matching and consideration of farm stock access.

7.4. Risk analysis

Carbon Price

All regime options and carbon sequestered has been costed at $20/ tonne.

The three most sensitive economic variables are land price (rental or purchase), carbon yield and carbon price.

Figure 7 : LEV sensitivity to Carbon Price

	LEV $/ha Carbon Price Sensitivity				
	$ 10.00	$ 15.00	$ 20.00	$ 25.00	$ 30.00
Native Forest	-1,197	-1,042	-886	-731	-576
Poplar 120 Unthinned Timber & Carbon	-704	-402	-101	201	502
Manuka/Kanuka	-679	-265	149	563	977
Poplar 260 Unthinned Timber & Carbon	-683	-100	482	1,064	1,646
Poplar 550 Unthinned Timber & Carbon	194	1,063	1,931	2,799	3,667
Radiata 350 spha Timber & Carbon	273	1,690	3,106	4,522	5,938
Radiata 450 spha Timber & Carbon	471	2,013	3,556	5,098	6,640
Radiata Unthinned Carbon	849	3,154	5,459	7,764	10,069
E. Fastigata 600 Timber & Carbon	1,289	3,384	5,479	7,574	9,669
Radiata Framing Timber & Carbon	1,965	3,499	5,032	6,565	8,098
E. Fastigata 450 Timber & Carbon	1,723	3,779	5,836	7,893	9,949
E. fastigata Unthinned Carbon	1,767	4,399	7,031	9,663	12,295

LEV is indeed very sensitive to changes in carbon price and there is much speculation about this pricing as the carbon markets are poorly developed at this time.

When the NZ Government first announced the ETS proposals they announced a figure of ~ $15NZD per tonne. With reviews of the European carbon trading to date, plus news of Australia's recognition of the Kyoto Protocols and their discussions over price, the tendency has been for various commentators to suggest the price will climb to unsustainable levels. However, nobody knows what the price might stabilize to over time, but it is generally accepted that $20 NZD /tonne is a conservative base figure to model future pricing on.

Discount Rate

Discount rate can have significant impacts on long term investments discussed in this analysis. Discount rates are often used as indicators of risk and where government policy is a significant factor in the investment, higher rates can be expected to be used. Also species choice, markets and

infrastructure (such as ports and processing plants) should be considered when choosing a discount rate.
For example, an increase in discount rate to 9 % for the E.fastigata Unthinned Carbon option decreases the LEV from $6,668/ha to $5,860/ha

Diversification

The ETS may offer the opportunity to diversify the land use into tree plantations not only for carbon farming but also timber production. A portfolio of species may be the lowest risk approach to take and probably adds to the aesthetics of the property as well.

8. SOIL STABILITY

8.1. Root Biomass

The ability of trees to hold soil on slopes and thus perform an erosion prevention function depends on a number of factors:

- Species –growth rate, depth of root penetration, tensile strength of roots
- Soil –characteristics –clay content, underlaying bedrock, friability
- Site – slope steepness, rainfall pattern and intensity, land use.

For *P.radiata* and poplars, there has been work done by a number of scientists to calculate the tonnage of roots required to provide an effective root holding capacity (McElwee, 1998).

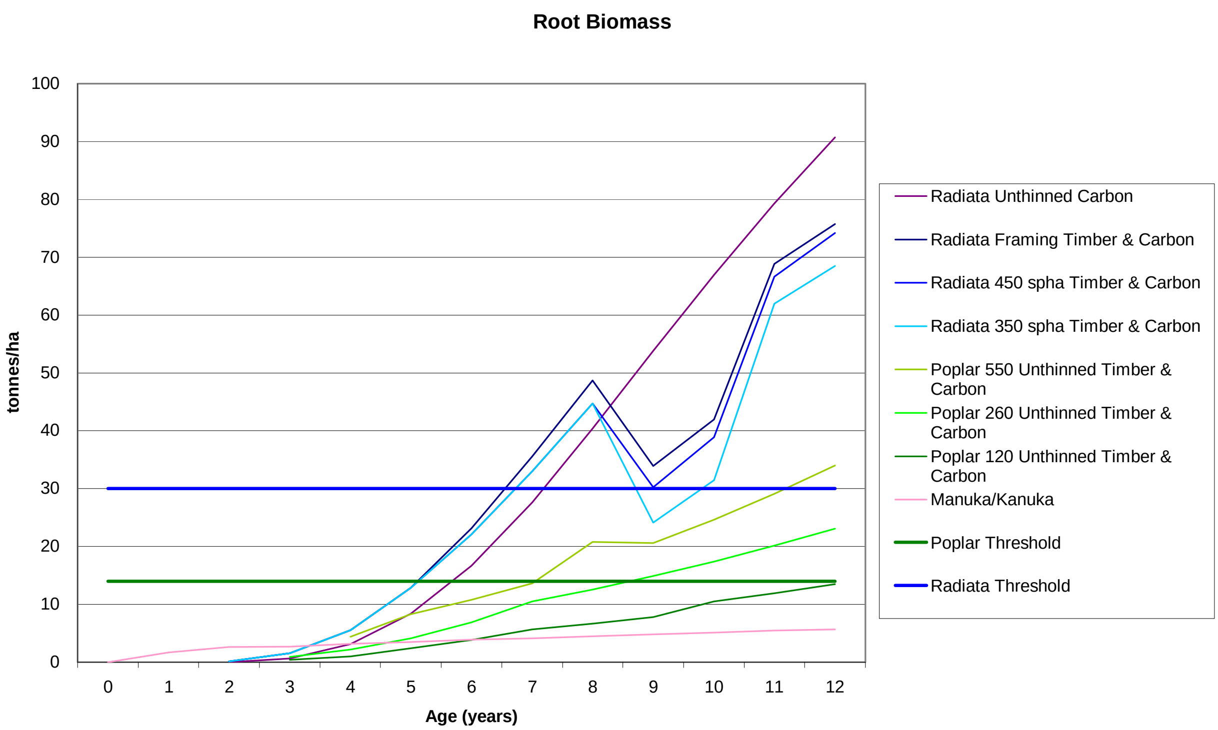
Poplars are well known for their deep root system and their ability to grow from poles. This makes it much easier for the farmer to stabilize soils on slopes and not lose the grazing potential of the pasture by planting poplar poles and protecting the poplar stem with a plastic, expanding sleeve.

However to become effective, calculations suggest that 14 tonnes of root biomass for poplars is required to hold soil on slopes and this occurs at different ages for different stockings of poplar plantings.

For *P.radiata* the threshold has been calculated at 30 tonnes of root biomass per hectare.

Figure 8 shows root biomass for the species where data is available.

Figure 8 : Root Biomass



For poplars, one can see that full root holding capacity occurs at

- age 7 for 550 sph.
- age 9 for 260 sph
- age 12 for 120 sph.

If the slope is already showing signs of erosion, then 12 years is a long risk period before root holding capacity becomes fully effective. However many spaced plantings of Poplar only occur where land has slipped, ie not continuous, and therefore at lower overall per hectare stocking than 120.

In *P.radiata*.the root holding capacity threshold is denoted at 30 tonnes of root biomass and this occurs about Age 7 yrs for the thinned regimes. *P.radiata* has a shallower root system and lower tensile strength than *Poplar sp.* hence the greater tonnage required to reach root holding capacity.

To date we have not located any data on eucalypt species but given the tensile strength of eucalypts vs poplars and pines, we suspect that eucalypts will fall between the other two species in terms of tonnage/ha. as soil holding capacity.

From a soil stabilization / soil holding capacity, there is merit in capturing the site as quickly as possible while also capturing carbon credits quickly (McLaren, P. 1996).

Fast growth equates to better soil stability adding to improvement in water quality by reducing erosion and reducing the amount of water available for runoff.

9. DISCUSSION

The results from this study are specific to the McRae site and may change significantly with different soils and environments that encourage other species or regimes. Carbon accumulation is maximized via wood density and growth rate. So exotic species (not likely to be natives) that establish quickly and have moderately high wood density will be favoured for carbon forests.

The costs and loss of biomass from thinning and pruning detracts from the overall tonnage of carbon sequestered and so LEV's are subsequently reduced for regimes including these.

The economic analysis indicates that the unthinned eucalypt regime is best for LEV measure and the timber only regime is the poorest, economically –as measured by LEV. On average, the *P.radiata* volumes estimated and carbon sequestered were less than the eucalypt are but greater than the poplar estimates –a function of both growth rate and wood density.

The low stocking and lower wood density of poplar wood compared to both *P.radiata* and eucalypt make this species a poor proposition for carbon and the general lack of silviculture in farm plantings and lack of continuous wood supply make it a doubtful candidate for timber supply.

Sheep and beef farm option falls behind a number of the pine and eucalypt timber and carbon options but is more economic that poplar and native vegetation land use options. The current Sheep and Beef land use LEV of

$1700 /ha could be considerably improved to in excess of $5000/ha depending on discount rate and carbon price.

Both native scrub regeneration and native forest preservation are slow in growth and therefore bottom of carbon sequestration ability . Their presence can be justified as preservation of biodiversity or in some cases for erosion control. Reverting scrub areas may be left for reasons of erosion control. i.e. more soil loss will occur from animal tracking or clearing and replanting activities than leaving the area fallow.

The only timber only option modeled, *P.radiata*, does not perform as well as the *P.radiata* options with carbon only or timber and carbon, although the sum of cashflows (not compounded) during the 60 year modeling period is fourth largest behind *P.radiata* timber and carbon options . This is because of the time value of money. For a timber only option, revenue is only accrued in years 30 and 60, whereas for options with carbon revenue starts to accrue from age 3 onwards. Added to this, there has been a drop in the price differential between pruned and unpruned logs over the last few years making it harder to make good returns from timber only.

There is no doubt that incomes from carbon credits in trees will provide an alternative income stream, by converting part of a farm into trees, to help smooth fluctuating revenues from farming, with combined soil stability and water quality environmental benefits.

Where farm capital is not available to convert part of a farm to trees, there is an opportunity for farmers to lease the land out under a forestry right to an outside investor and receive an annual income in the form of rent. The level of rent is outside the scope of this document, but can be determined by converting the LEV into an annuity.
A whole farm estate plan is needed to better understand the feasibility of carbon farming with trees. Cash flows and wood flows impact on tax and markets. Affordability will depend on phasing in of new investments and property specific issues and land owner plans.

10. CONCLUSIONS

In this particular study, and using the assumptions made, then the most economic land use for parts of the McRae Trust land is to plant trees for a carbon sequestration objective.

To maintain the objectives laid down in the Trust deed, some mix of farming and forests seems the most likely outcome for future land use.

If the poorer parts of the farm, as denoted by steepness, erosion potential and land use class, are identified and the correct species chosen then the revenues gained from carbon credits could offset the losses from a drop in farm grass area.

Just as forestry land use has changed to dairy production on easier topography in the Central North Island, some of the hill country sheep and cattle properties are in need of better cash flow and more profitable forms of land use.
The carbon credit potential of tree plantations could be considered as one of those possible land uses.

Further Work

In view of the number of questions raised by this study further work is recommended on differing sites and locations. Economic analyses like this project are best extended to cover the whole estate and for a considerable time periods so that cash flow and product flow considerations are addressed.

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12. APPENDICES

Appendix 1 – Total Carbon Yield (t CO_2/ha)

Age	Radiata Unthinned Carbon	E. fastigata Unthinned Carbon	E. Fastigata 600 Timber & Carbon	E. Fastigata 450 Timber & Carbon	Radiata 450 sph Timber & Carbon	Radiata Framing Timber & Carbon	Radiata 350 sph Timber & Carbon	Poplar 550 Unthinned Timber & Carbon	Poplar 260 Unthinned Timber & Carbon	Poplar 120 Unthinned Timber & Carbon	Manuka/Kanuka	Native Forest
0	0	0	0	0	0	0	0	0	0	0	1	0
1	0	0	0	0	1	1	1	0	0	0	21	3
2	1	3	3	3	3	3	3	2	1	1	49	6
3	4	25	25	25	8	8	8	11	7	4	69	9
4	16	71	71	71	31	31	31	31	20	10	87	12
5	38	135	135	135	69	69	69	57	37	19	100	15
6	74	210	246	274	120	126	120	87	57	29	110	18
7	122	289	304	316	184	196	184	118	77	40	117	21
8	180	368	381	393	247	267	246	149	97	50	124	24
9	245	444	446	449	279	294	264	179	117	60	128	27
10	313	518	513	512	317	329	290	209	136	70	133	30
11	381	588	575	569	362	370	325	237	155	80	136	33
12	448	657	637	627	411	415	365	264	173	89	140	36
13	516	723	697	683	463	464	410	290	191	98	144	39
14	583	787	755	737	516	514	458	315	208	107	148	42
15	651	849	812	790	570	565	508	339	225	115	151	45
16	718	909	867	842	625	617	559	362	241	124	155	48
17	786	967	920	892	679	669	610	385	257	132	159	51
18	853	1,023	971	940	733	721	662	406	272	140	163	54
19	920	1,077	1,021	987	787	772	713	426	287	148	167	57
20	985	1,128	1,068	1,031	839	822	763	446	301	155	171	60
21	1,050	1,178	1,114	1,074	890	871	812	464	314	162	175	63
22	1,112	1,225	1,157	1,115	940	918	860	482	327	169	179	66
23	1,173	1,269	1,198	1,154	987	963	905	500	340	176	183	69
24	1,232	1,312	1,237	1,191	1,032	1,006	949	516	351	183	187	72
25	1,288	1,351	1,274	1,226	1,075	1,047	991	532	363	189	192	75
26	1,343	1,389	1,308	1,258	1,117	1,086	1,031	547	373	195	196	78
27	1,397	1,423	1,340	1,289	1,158	1,125	1,070	561	384	201	200	81
28	1,450	1,456	1,370	1,317	1,197	1,163	1,109	574	394	206	204	84
29	1,502	1,485	1,397	1,343	1,236	1,200	1,146	587	403	211	209	87

30	1,553	1,512	1,422	1,366	1,274	1,236	1,183	600	412	216	213	90
30	1,553	1,512	601	583	579	560	536	271	198	108	213	90
31	1,602	1,541	518	502	499	482	461	232	169	91	217	93
32	1,648	1,567	450	436	432	418	400	200	145	78	221	96
33	1,692	1,592	411	399	379	367	350	182	131	70	225	99
34	1,734	1,616	404	394	351	340	326	177	125	67	229	102
35	1,773	1,639	423	414	346	337	324	183	127	68	233	105
36	1,811	1,660	496	515	360	358	341	196	134	71	238	108
37	1,848	1,682	520	525	391	397	375	212	144	75	242	111
38	1,882	1,702	569	575	428	442	412	230	155	81	246	114
39	1,915	1,721	609	607	435	445	408	250	166	86	250	117
40	1,946	1,740	655	650	453	461	415	269	179	93	254	120
41	1,976	1,758	699	689	481	484	433	290	192	99	258	123
42	2,004	1,775	745	731	514	515	460	310	205	106	262	126
43	2,031	1,791	791	773	553	550	492	330	218	112	267	129
44	2,056	1,808	837	816	594	589	530	350	232	119	271	132
45	2,079	1,823	883	859	639	631	570	369	245	126	275	135
46	2,117	1,838	929	902	684	675	613	389	259	133	279	138
47	2,150	1,853	975	944	731	719	658	407	272	140	283	141
48	2,186	1,867	1,019	986	779	765	703	426	285	147	287	144
49	2,221	1,881	1,062	1,027	827	810	749	444	298	154	291	147
50	2,257	1,894	1,105	1,067	874	856	795	461	311	161	295	150
51	2,294	1,908	1,146	1,105	921	900	840	478	323	167	300	153
52	2,331	1,921	1,185	1,142	966	943	884	494	335	173	303	156
53	2,368	1,934	1,223	1,178	1,010	985	927	510	346	180	308	159
54	2,407	1,946	1,259	1,212	1,053	1,025	968	525	357	186	311	162
55	2,446	1,959	1,293	1,244	1,093	1,064	1,007	539	368	192	315	165
56	2,485	1,971	1,325	1,274	1,133	1,101	1,045	553	378	197	319	168
57	2,526	1,984	1,355	1,302	1,171	1,138	1,083	567	388	203	323	171
58	2,568	1,996	1,383	1,329	1,210	1,174	1,120	580	397	208	327	174
59	2,610	2,009	1,408	1,353	1,247	1,210	1,156	592	406	213	331	177
60	2,654	2,022	1,432	1,376	1,283	1,245	1,191	604	414	218	335	180

Appendix 2 – Annual Cashflows ($/ha)

Year	E. fastigata Unthinned Carbon	E. Fastigata 450 Timber & Carbon	E. Fastigata 600 Timber & Carbon	Radiata Unthinned Carbon	Radiata Framing Timber & Carbon	Radiata 450 spha Timber & Carbon	Radiata 350 spha Timber & Carbon	Radiata 350 spha Timber	Poplar 550 Unthinned Timber & Carbon	Poplar 260 Unthinned Timber & Carbon	Poplar 120 Unthinned Timber & Carbon	Native Forest	Manuka/Kanuka
0	-596	-596	-596	-708	-708	-708	-708	-687	-341	-341	-341	-378	-378
1	-1,582	-1,582	-1,582	-1,418	-1,418	-1,418	-1,418	-1,416	-1,147	-780	-603	-299	-299
2	-754	-754	-754	-564	-564	-564	-564	-562	-438	-438	-438	-299	-299
3	218	218	218	-206	-126	-126	-126	-267	103	32	-32	-115	65
4	586	586	586	-50	133	133	133	-263	251	130	20	-165	-75
5	871	871	861	98	386	-649	-649	-1,298	333	169	20	-206	-116
6	1,109	1,814	1,311	381	758	656	656	-263	302	254	84	-165	-75
7	1,192	524	805	602	1,002	-43	-43	-1,183	325	269	91	-165	-75
8	1,181	1,146	1,154	785	568	-532	-557	-1,677	323	268	90	-165	-75
9	1,139	785	931	902	214	297	60	-263	310	121	86	-165	-75
10	1,046	854	921	913	324	377	160	-263	251	69	39	-206	-116
11	1,039	793	893	957	472	556	362	-263	273	100	75	-165	-75
12	995	805	881	951	552	619	460	-263	254	91	71	-165	-75
13	954	761	838	947	603	668	544	-263	234	82	66	-165	-75
14	917	746	814	948	637	691	596	-263	215	74	-77	-165	-75
15	839	674	730	909	545	595	519	-334	155	23	-122	-206	-116
16	845	692	752	953	670	716	653	-263	180	56	-85	-165	-75
17	808	663	720	952	673	718	664	-263	163	47	-89	-165	-75
18	771	634	688	946	668	712	664	-263	146	38	-93	-165	-75
19	732	603	654	934	655	698	656	-263	131	28	-97	-165	-75
20	651	529	567	875	593	636	598	-263	74	-24	-143	-206	-116
21	652	536	582	893	610	652	617	-263	101	8	-106	-165	-75
22	610	501	544	864	580	622	589	-263	86	-2	-110	-165	-75
23	568	464	505	830	546	588	557	-263	72	-13	-115	-165	-75
24	524	427	465	793	511	550	522	-263	59	-23	-120	-165	-75
25	438	347	373	710	432	470	443	-263	4	-74	-166	-206	-116
26	435	350	383	725	448	485	460	-263	33	-42	-128	-165	-75
27	390	310	341	707	432	468	443	-263	21	-51	-133	-165	-75
28	344	270	299	689	415	450	426	-263	9	-60	-137	-165	-75
29	299	230	257	671	328	362	337	-334	-2	-69	-141	-165	-75
30	109	-34	-5,142	78	14,508	18,222	19,559	30,589	1,866	-4,842	-2,676	-410	-320
31	196	-2,967	-3,008	-551	-2,820	-2,867	-2,758	-1,416	-2,655	-1,747	-1,155	-245	-155
32	147	-1,723	-1,759	267	-1,718	-1,757	-1,672	-562	-1,103	-963	-770	-245	-155
33	218	-909	-940	521	-1,198	-1,231	-1,157	-267	-570	-502	-387	-169	-79

34	193	-328	-354	490	-744	-773	-709	-263	-319	-328	-293	-165	-75
35	135	87	54	411	-367	-1,426	-1,370	-1,298	-174	-241	-267	-206	-116
36	158	1,142	617	419	112	-11	38	-263	-12	-115	-181	-165	-75
37	143	-54	208	386	447	-617	-575	-1,183	57	-66	-154	-165	-75
38	127	648	640	355	90	-1,027	-1,015	-1,677	93	-38	-139	-165	-75
39	113	355	487	325	-199	-130	-334	-263	113	-22	-130	-165	-75
40	57	483	537	255	-32	8	-180	-263	81	-53	-166	-206	-116
41	86	472	561	271	164	238	69	-263	127	-4	-120	-165	-75
42	74	527	593	242	286	343	206	-263	128	1	-116	-165	-75
43	64	520	589	216	372	429	324	-263	126	5	-114	-165	-75
44	53	537	598	189	437	483	406	-263	122	7	-112	-165	-75
45	2	493	542	121	371	415	354	-334	74	-34	-153	-206	-116
46	35	534	589	405	519	560	510	-263	110	7	-111	-165	-75
47	28	526	579	343	542	582	539	-263	102	5	-111	-165	-75
48	20	515	565	380	554	593	556	-263	94	1	-112	-165	-75
49	14	499	546	368	555	595	561	-263	85	-4	-114	-165	-75
50	-33	438	473	342	507	546	516	-263	34	-51	-158	-206	-116
51	3	457	500	389	534	574	546	-263	66	-16	-118	-165	-75
52	-1	432	472	401	514	553	527	-263	56	-23	-121	-165	-75
53	-5	404	442	411	489	528	503	-263	46	-30	-124	-165	-75
54	-7	374	410	424	460	498	474	-263	36	-38	-128	-165	-75
55	-51	301	325	396	388	424	402	-263	-16	-88	-173	-206	-116
56	-11	309	341	452	409	445	423	-263	16	-54	-135	-165	-75
57	-12	275	305	467	398	434	411	-263	6	-61	-138	-165	-75
58	-12	239	267	484	386	420	398	-263	-4	-69	-142	-165	-75
59	-11	203	229	500	302	335	313	-334	-14	-77	-145	-165	-75
60	228	476	-4,640	742	15,141	18,848	20,203	31,385	2,228	-4,454	-2,262	69	159