A Qualitative System Dynamics Analysis of the Effects of an Emissions Trading Scheme on the New Zealand Forestry Value Chain

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Prepared for the
28th International Conference of the System Dynamics Society
Seoul, Korea, 25 – 29 July, 2010

ABSTRACT

As part of New Zealand's obligations to the Kyoto Protocol, New Zealand has developed an Emissions Trading Scheme (ETS) as a mechanism to reduce its national greenhouse gas footprint, and to encourage and support global action on climate change. The forestry sector in New Zealand was the first sector to enter the ETS, effective from 1 January 2008. So far many forest owners in New Zealand have been slow to join the scheme. To investigate this situation further, a systems thinking group model building workshop was held to discuss the effects of the ETS on the New Zealand forestry value chain. A qualitative system dynamics analysis was undertaken, whereby a range of relevant issues was generated by a group of stakeholders, and based on these a set of causal variables was identified. These showed a strong bias towards an economic viewpoint of the basic issue being examined. Causal loop diagrams were made from these variables, and the dominant loops were briefly analysed. This paper will discuss some of the insights gained from this project to date.

Keywords: Systems thinking, qualitative system dynamics, New Zealand forestry value chain, carbon sequestration, carbon dioxide, emissions trading.

INTRODUCTION

Carbon trading

On a human timescale, atmospheric carbon dioxide is currently increasing with concerning rapidity. Numerous discussions and schemes have been put forward (MAF, 2008; Maclaren, 2000), and it seems likely that producers of gaseous carbon dioxide will have to purchase allowances if they continue to emit carbon dioxide in the future. The few industries with a capacity to remove carbon dioxide from the atmosphere and sequester it in a stable non-diffusing form are likely to be financially rewarded. Forestry is such an industry, as trees absorb carbon dioxide through the process of photosynthesis, and store it with oxygen and carbon in the form of cellulose and lignin (see Figure 1).

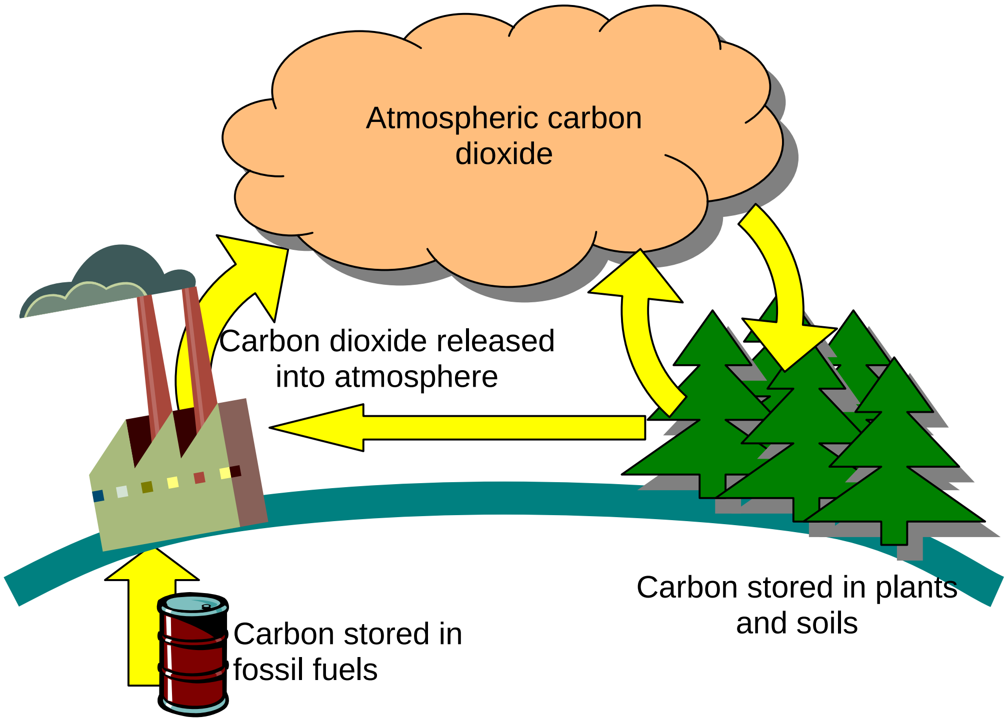

Figure 1. Simplified carbon cycle

A New Zealand (NZ) scheme to reward carbon sequestration – and penalise carbon emissions – is the Emissions Trading Scheme (ETS) (MAF, 2008). Under the ETS, tonnes of carbon dioxide equivalent (CO_2-e) are represented as 'units', and are exchangeable between parties in the form of 'carbon credits'. Emitters of carbon dioxide must purchase credits off of sequesters in order to maintain balanced carbon accounting.

Thus each unit and associated credit has a monetary value, a 'carbon price'. One sequestered tonne of CO_2-e is the carbon stored that has eliminated one tonne of carbon dioxide from the atmosphere (which is 12/44 tonnes of carbon, due to the relative molecular weights of carbon and carbon dioxide). One tonne CO_2-e is worth the carbon price in dollars. Essentially

$$\$ = \text{carbon price} \times \text{tonnes } CO_2\text{-e}$$

This is true whether we are considering a rewarded unit (which is then available to sell for profit), or a penalty unit (for emissions – therefore the emitter must purchase one unit). Figure 2 shows this flow of credits and money.

Much of the proposed legislation is less simplistic. At least in the short term, emissions rulings are using 1990 as an arbitrary datum, meaning that most policies concern relative as opposed to absolute carbon emissions and sequestrations – thus favouring sequestration over stocks. This is like giving someone a speeding ticket for accelerating too hard. This is based on the Kyoto protocol, which New Zealand signed into in 1992. Although this makes no sense to the environment, it at least creates a standard against which legislation may be constructed. Thus under the proposed legislation only forests planted **after** 1990 will be eligible for sequestration monies. Conversely, forests planted **before** 1990 will not be eligible for sequestration monies, but must pay the appropriate fine for any carbon that leaves their site if they chose to deforest and move into another land use. (MAF, 2008).

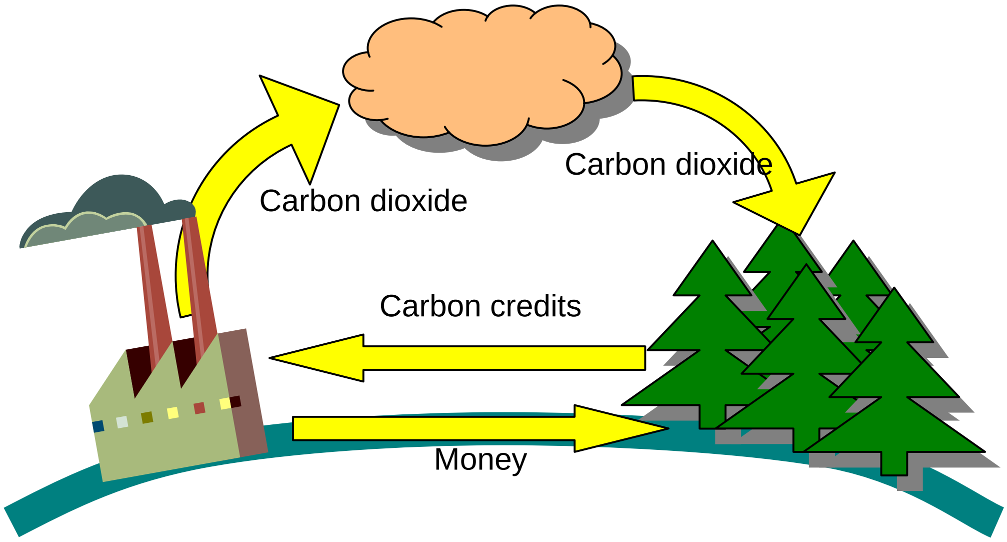

Figure 2. Simplified carbon credit cycle

New Zealand is in the process of developing a comprehensive ETS. Although forestry is already involved in the fledgling program, it will increase in prominence as more emitting sectors – such as power, transport and agriculture – are drafted in over the next ten to twenty years. Many forest owners were initially very hesitant to join the scheme, and the purpose of this study was to use systems thinking techniques to investigate why this was and assess the perceived effects on the New Zealand forestry value chain.

Forestry in New Zealand

New Zealand forestry contributed $5 billion to the national economy in 2008, accounting for about 3.8% of the national gross domestic product (Statistics New Zealand, 2008). Forest covers almost a third of New Zealand, of which 30% is commercially operated planted forest (MAF, 2009). Through highly productive well managed forests New Zealand provides 1.1% of the world's forest products, all from only 0.05% of the global forest resource (MAF, 2009). New Zealand's first major plantations occurred around the early part of the 20th century, as native timber resources were forecasted to run out. Figure 3 shows the expansion of planted exotic forests in New Zealand, although it has to be noted this is alongside a reduction of native forests. Figure 3 shows repeated cycles of growth, although the first net reduction in forest area is seen from 2003 onwards. This reflects a reducing profitability of forestry – driven by rising land prices and falling log prices, leading to deforestation and conversion into pastoral land uses.

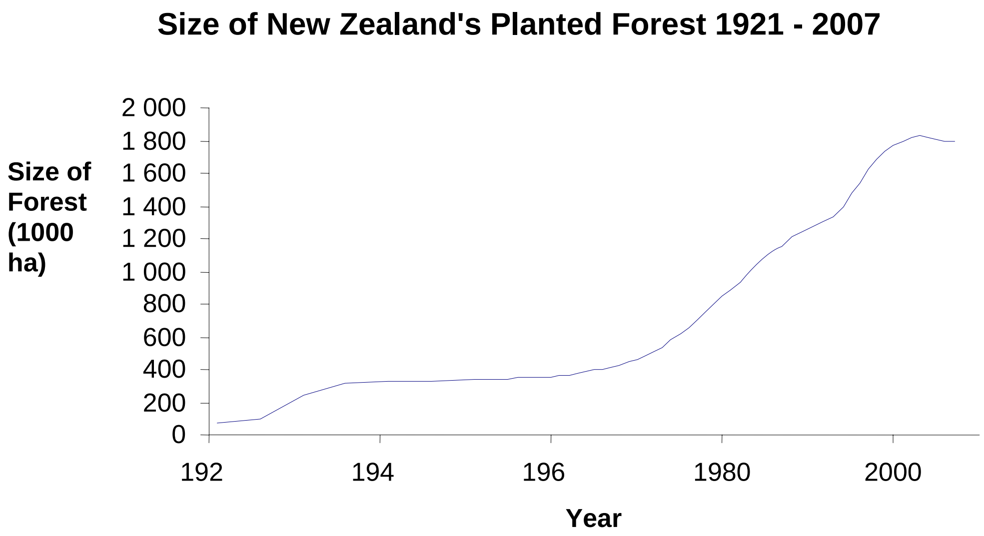

Figure 3. Size of New Zealand's Planted Forests, 1921 – 2007

Figure 4 shows that this deforestation has not greatly affected the net carbon removals. It should be noted that although almost all carbon removals are due to forestry, forestry itself creates some emissions (through harvesting). The net removal is often termed as removals due to Land Use, Land Use Change and Forestry (LULUCF). In 2006 the LULUCF sector consisted of 23.7 Mt CO_2-e of carbon removals from forestry, although other land uses constituted 1.0 Mt CO_2-e of emissions (such as due to liming soil and burning biomass).

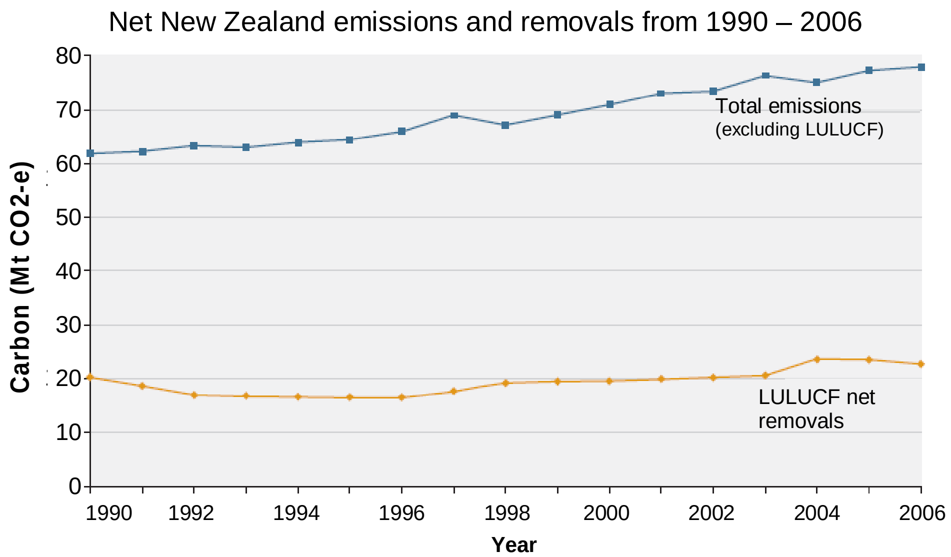

Figure 4. Net New Zealand carbon emissions and removals from 1990 – 2006
(MfE, 2008)

Qualitative system dynamics analysis of effects of ETS on NZ forestry value chain

It is expected that an Emissions Trading Scheme could reverse the current trend for deforestation, and increase the removals through LULUCF (Turner et al, 2008). The purpose of this systems thinking workshop was to investigate the issues that could arise with such a scheme.

Systems thinking

Systems thinking, involving group model building (e.g. see Vennix, 1996; Vennix et al., 1997), embraces a range of facilitating processes, by which stakeholders are encouraged to describe an issue or organised structure in terms of sub-issues and significant features. The idea is to gain an insight into the system as a whole. Many systems are complex, with multiple feedback loops and hidden interactions. Systems thinking tools, using the system dynamics approach, include problem structuring methods, causal loop modelling, dynamic simulation, strategy and scenario analysis, flight management simulators, and organisational learning. These tools provide a language to express, share and analyse the system as a whole. Although these tools are designed to be intuitive, for a full description the reader is directed to, for example, Forrester (1961), Senge (1990), Coyle (1996), Sterman (2000) or Maani and Cavana (2007).

The normal reductionist methodology used to tackle problems – reduce the system down to a very simple set of interactions, quantify and validate – can sometimes miss vital points in more complex systems. By delaying the reductionism to a later point in the decision process, there is the chance to work in a holistic manner on the entire system. This makes it hard to create definite answers, especially quantitative ones, due to the numerous different degrees of freedom held by each participating entity. But by dealing with features qualitatively and approximating the interactions between them we can develop mental models of the systems structure, behaviour and possible archetypes.

The forestry value chain is a conceptual model of the entire forest industry as a linked web. Products and services flow from one contributor to another, and information exchanges keep the system in operation. In itself this is already a 'systems approach', but we can expand the approach and ask how the system will react if brought in contact with other sets of issues or factors. Figure 5 provides a 'rich picture' (Checkland, 1981) of an illustrative forestry value chain, but this is not exhaustive.

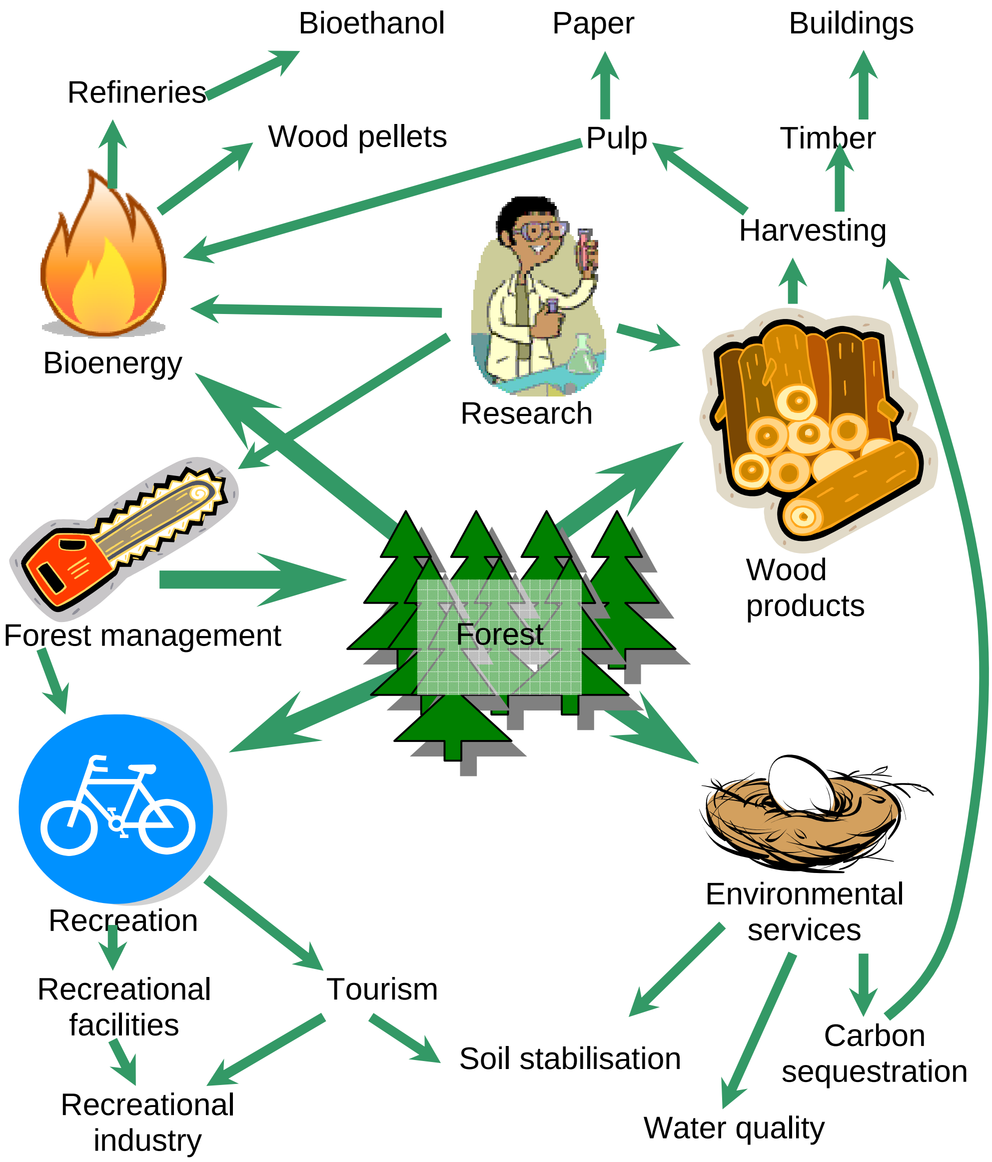

Figure 5. 'Rich Picture' of a simple forestry value chain

METHOD

As discussed above, the general methodological approach used for this study is called systems thinking (e.g. see Senge, 1990; Sterman, 2000; Maani and Cavana, 2007) using the qualitative system dynamics approach (e.g. see Wolstenholme and Coyle, 1983; Vennix, 1996; Coyle and Alexander, 1997; Wolstenholme, 1999).

The overall approach included:

- Initial discussion of problem situation

- Selection of participants for the workshop
- Group model building workshop
- Post workshop activities.

Initial discussion of problem situation

The initial discussion of the problem situation regarding the introduction of the Emission Trading Scheme into the forestry sector in New Zealand is outlined in the Introduction section to this paper.

Following current media interest in the proposed Emissions Trading Scheme (ETS), we phrased the initial organising question as:

"What are the effects of an Emissions Trading Scheme on the New Zealand Forestry Value Chain?"

This question was selected as it impacts on the whole forestry value chain, and provides a good case-study to examine the dynamics of the system under a change. There are many reports detailing the proposed New Zealand Emissions Trading Scheme. For the impacts on forestry the reader is directed to the MAF policy document "Forestry in the Emissions Trading Scheme" (MAF, 2008).

Selection of participants for the workshop

A number of different stakeholders that could influence, or be influenced by, the introduction of an ETS into the New Zealand forestry sector were identified. These are summarized in the stakeholder map (Freeman, 1984) in Figure 6.

Unfortunately, it was not possible to get representatives from all of these stakeholder groups to attend the workshop. Instead nine representatives were available for the meeting, representing the Ministry of Agriculture and Forestry, Tasman Forest Management Ltd, Catalyst R&D, Scion Research, Victoria University of Wellington and a visiting academic from the business school at Doshisha University, Kyoto, Japan. The stakeholder groups represented at the workshop are indicated by a star symbol on the stakeholder map (Figure 6).

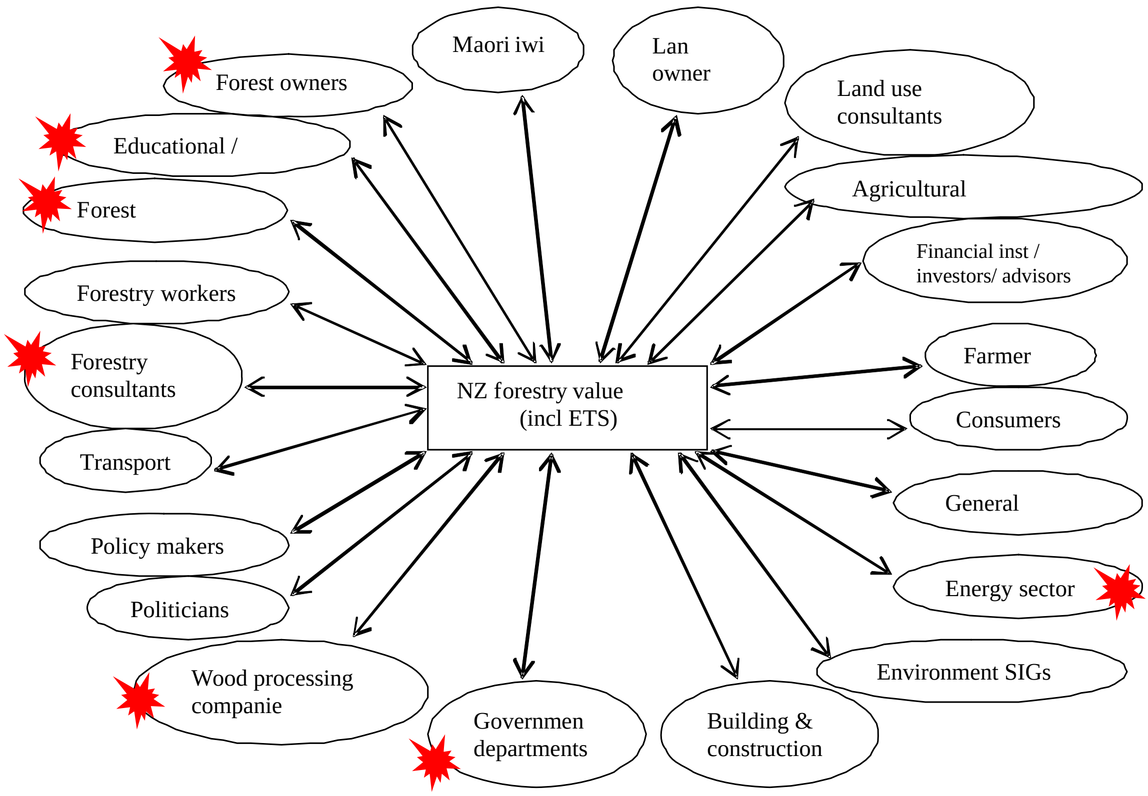

Figure 6. Stakeholder map for the NZ forestry value chain (incl. ETS)

Group model building workshop

The group model building workshop followed the approaches outlined in Cavana et al. (1999 & 2007); Maani & Cavana (2007); Vennix (1996); Kreutzer (1995) and Lane (1993). Hexagon post-it notes were used to record issues and concerns generated by workshop participants (Hodgson, 1994).

None of the participants were financially rewarded for their attendance, showing that they or their companies each had a very strong intrinsic interest in the topic.

The meeting was held over the course of one day, and ran as follows:

- Introductions
- Introduction to systems thinking
- Discussion and rephrasing of organising question

- Listing issues & concepts relating to the organising question
- Grouping issues & naming groups
- Amalgamating groups, assigning each group a small number of variables
- Linking variables, forming an initial causal loop diagram.

During the day the group didn't finish the causal loop diagrams, but these activities will be covered in the results section. Figure 7 shows an early view of the meeting (not all participants present here, 1st co-author taking picture!).

Figure 7 – Photograph from workshop

Post workshop activities

After the workshop, the authors continued analysing the qualitative data collected at the workshop, and further developed the initial causal loop diagram, by adding new variables and connections, and analysing the feedback loops formulated.

RESULTS

Organising question

The first participatory component of the meeting concerned rephrasing the organising statement into a form that the group agreed on. The original statement was:

"What are the Effects of an Emissions Trading Scheme on the New Zealand Forestry Value Chain"

This was discussed and a revised form was 'democratically' agreed upon:

"How will carbon emissions trading effect New Zealand forestry?"

This is similar to the original question, except that the value chain part was omitted. This shows that the term is not in common usage, but the general understanding amongst the group was that '*forestry*' was all parts of the industry, not just forest growing, so the phrase was redundant.

The removal of the word *scheme* was chosen to bring emphasis to the fact that the *'scheme'* as such is as yet undecided, but emissions trading in some form seems likely.

In the follow up to the meeting one of the participants revealed that throughout the meeting he had a separate question in his head *"What are the greenhouse gas impacts of NZ forestry and how can these be enhanced by an ETS?"* This is typical of any group workshop; whilst a common scope is decided by the group each individual will possibly have a slightly different interpretation of it.

Issue generation

The next step was to list issues and concerns around this question – each aspect or factor that should be considered simultaneously to fully assess the problem. The group listed 83 (given in Appendix 1, and photographed in Figure 8) issues or concerns, which clearly shows the necessity for systems thinking as it is humanly impossible to simultaneously and evenly evaluate this many concepts.

The concepts are numbered (on hexagons) in the order they were generated by the participants. Different coloured hexagons were used in this exercise, as sufficient quantities in one colour were not available. However, the two red hexagons (# 73 & 74) reflect strongly held views.

Figure 8. Issues as identified by workshop participants

No directive was given to suggest how the issues should be phrased. The group interpretation was that many of the issues were in themselves further questions, such as:

- *Who are the buyers of carbon emissions?*
- *By whom and how will the scheme be administered?*
- *How do we change human behaviours?*
- *Will ETS make a difference – Why bother?*

Or open ended statements such as:

- *Focussing on maximising carbon stocks won't minimise emissions*
- *Management of change*
- *Treatment of other land uses*
- *Consistent understanding – long time frame*

These are hard to quantify – even by the person who phrased them. Only one issue was a physical quantity that could theoretically be measured at a point in time – Total global carbon – although several were management practices with visible physical outcomes, eg:

- *Scattered small forests*
- *Domination of carbon favoured trees*
- *Less silviculture*

- *Increased agroforestry*

Of medium occurrence were issues which can be quantified with economic principles, such as:

- *Bio-energy demand*
- *Demand for wooden houses*
- *Forecasts of carbon prices*
- *Short term reduction in wood supply*

In total, only 15 of the 83 issues (18%) contained an economic indicator word *(supply, demand, price, market, value, cash, market, trade* or *investment.*)

The largest number of issues detailed the ETS policy and inherent risks, such as:

- *Consistent with atmospheric change*
- *Auditing and verification issues*
- *All inclusive – countries and sectors*
- *Payment timing*

Issue grouping

These issues were then grouped into categories (see Appendix 1). The category definitions were not initially decided but allowed to evolve as the discussion progressed. Examples of two groups is provided in Figure 9.

Figure 9. Examples of some initial clusters

After grouping, the categories were debated and a few issues were moved. Then pairs of participants were asked to separate each category into a few groups, from which a small number of variables could be identified for each group. These variables are summarised in Appendix 2.

Variable identification

Of the 26 variables created, 17 contain one or more economic indicator word. Between the issues generation stage and the variable identification stage, the domination of an economic description has increased from 18% to 65%. This is not necessarily a bad thing but it told us two things:

- The majority of participants viewed the ETS as a predominately economic issue.
- The participant group had multifarious qualitative ideas, but when asked to describe them in a quantitative fashion they had a natural tendency towards an economic description (mainly due to a large proportion of the participants had an economic background).

The purpose of this workshop, however, was to create a holistic systems model, rather than a reductionist economics model (which has been done before in numerous papers – (see Turner et al., 2008). If it were the case that the whole system could be modelled in an economic fashion, then nothing would be lost in this narrowing of viewpoint. However, the remaining 35% of variables contain physical measurements (*Area of forests / ha*), social implications (*Public perception of changing land use*), and predicted future behaviour trends (*Change in behaviour over time in emission and sink activities*). This implies that to capture the whole problem described in the initial question we cannot afford to adopt a pure economics perspective. To avoid this bias – and to prevent repetition of previous works – we created a new variable '*Economic viability of forests*' with which we captured all the economic variables. As discovered above, this was expected to be central to the system.

Development of causal loop diagrams

We can link this new variable to the remainder in a causal loop diagram (CLD), as in Figure 10 (constructed with the Vensim computer simulation package (Ventana, 2002)). This diagram is only meant to show the general case. There are exceptions to every rule. For example, increasing the forest area doesn't necessarily mean increasing the carbon sequestered (for example, using some planting techniques it is possible to release more carbon dioxide during planting than would be sequestered in the first ten years) – but *in general* it does. By temporarily ignoring much of the finer detail we can gain a better view of the driving system.

We can see that the economic viability is central to the whole system, but is influenced by public perceptions, attitudes and behaviours. There is a general flow of causality from the left to right, and after the social and economic drivers we start to see physical differences, first in area of forest and amount of measurement, and next in actual carbon emissions and sequestrations.

Figure 10 contains only one feedback loop, a reinforcing loop (R1), linking the *economic viability of forests* with the *area of forests*. As indicated in Figure 3, this was acting as a 'virtuous cycle' until about 2003, but has been operating as a 'vicious cycle' since then, due to the lower perceived economic returns from forestry.

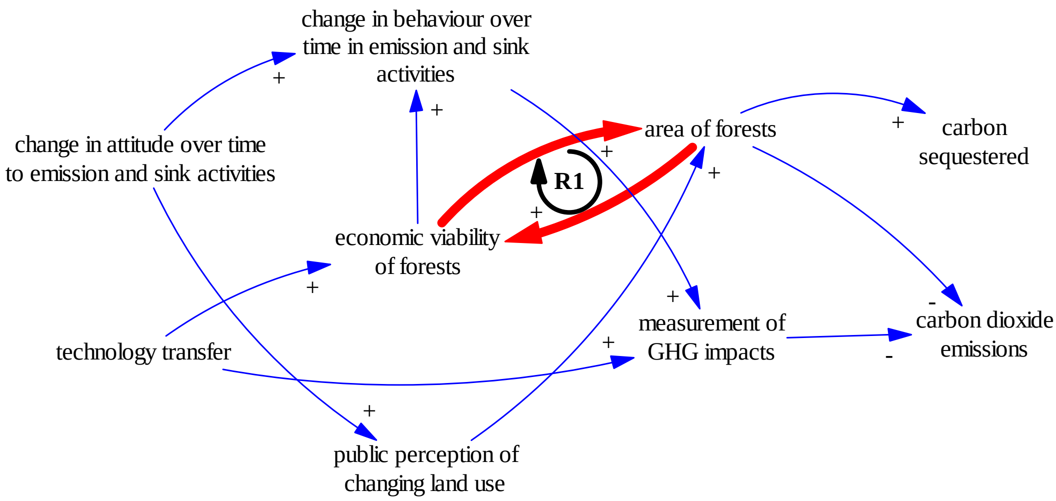

Figure 10. Initial causal loop diagram as developed at the workshop

The lack of feedback loops in Figure 10 is a concern. This is the inherent problem with climate change issues – there is no short-term feedback. A high-volume emitter of carbon dioxide will not immediately feel the repercussions of their actions. Perhaps some decades down the line this may be the case, but this time-scale is often disregarded. This is the reason for climate change policy – to provide an immediate (or thereabouts) reward for carbon sequestration and disincentive to emission. If we add three more variables:

- *Need for reduction in carbon dioxide emissions*
- *Policy restricting industry*
- *Policy encouraging carbon sequestration*

This has the effect of introducing more feedback loops into the diagram (see Figure 11). A very simplistic balancing loop (B1) is highlighted in Figure 11. An increase in carbon dioxide emissions leads to an increase in the need to reduce them. This in turn leads to an increase in policy restricting industry, which brings with it an increase in measurement of greenhouse gas (GHG) impacts. This prominence brings about a reduction in emissions...

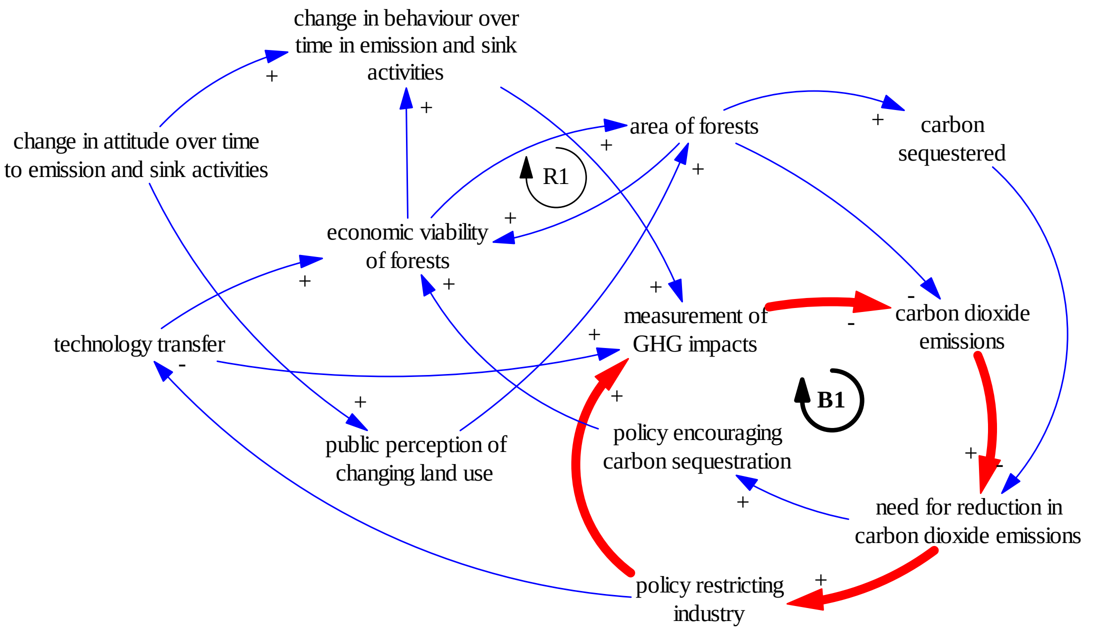

Figure 11. CLD with policy additions and balancing feedback loop (B1)

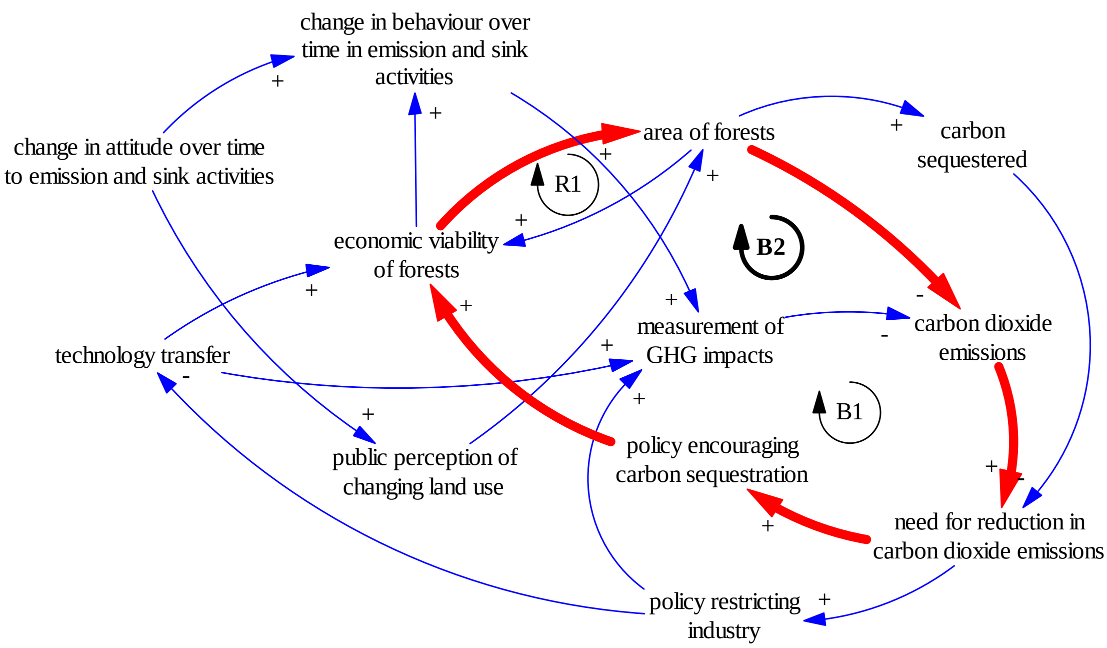

Figure 12. CLD with second balancing feedback loop (B2)

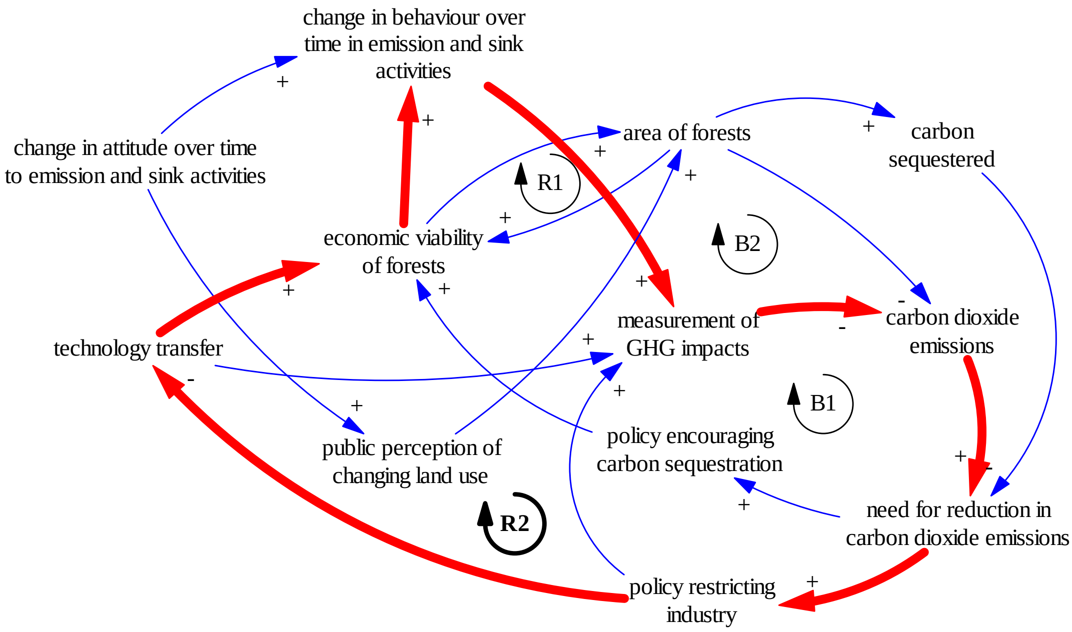

Figure 13. CLD with reinforcing feedback loop (R2)

Other feedback loops are shown in Figures 12 and 13, although it should be apparent that there are additional loops that combine parts of these three. The polarity of a loop can be determined by a summation of the polarity signs on each arrow. Negative loops (negative feedback, or balancing loops) act to keep a system in a steady state. Positive (or reinforcing) loops tend to continually increase in prominence, unless kept in check by a negative feedback loop (for a full description of causal loops see, e.g., Maani and Cavana, 2007; Sterman, 2000).

The feedback loop (R2) in Figure 13 is reinforcing, but utilises the weak link between '*policy restricting industry*' leads to a reduction in '*technology transfer*'. This link is of a much weaker confidence than others (for example increasing '*area of forests*' leads to increasing '*carbon sequestered*', which is still is not entirely accurate, but can be given a much higher confidence rating), which means the entire loop can be considered fairly weak.

The balancing loop (B2) in Figure 12 is negative, but much stronger. This loop suggests that a policy encouraging carbon sequestration will increase forests and sequestration, and hence reduce the need to sequester more (this last link is the weakest). This means that unless a run-away positive feedback loop (for example transport creating sufficient emissions to negate the impact of increased forest area of CO_2 emissions) keeps the need to reduce high, then the encouraging carbon policy will be sufficient. Unfortunately, it is likely that other industries exogenous to this system will do just that, and there will be a perpetual need for a reduction in CO_2 emissions.

This alludes to the fact that the most crucial variable in the model is the '*need for reduction of carbon dioxide emissions*'. This should perhaps be obvious – if there were no need there would be no issue – but it is borne out diagrammatically by the fact that all feedback loops (B1, B2 & R2) pass through this point, and if any other systems were to be endogenised then they would probably join here. Unfortunately, this variable is also the most undetermined. Many would argue that there is no need as climate change is not occurring, whilst others claim that it is so late that the time when there was potential to take mitigating actions has since passed. These could be modelled with another public perception – as eventually most long-term policies will follow (or sway) public opinion. This is where development into a full system dynamics model would be most useful – to explore these possible scenarios and alternative policies.

CONCLUSIONS

This paper is a summary of the systems thinking workshop and related activities, and provides the basis for further research in this area. The major results are:

The key issue in the question *"How will carbon emissions trading effect New Zealand forestry?"* is the '*need for a reduction in carbon dioxide emissions*'. Clearly if there can conclusively be proved to be no need to reduce emissions, then carbon trading will be of zero value and the scheme will have a null impact. If the need is proven to be dire, then the impact will be great.

Central to the scheme is the importance of economic analyses. These are impacted by public perceptions and future events, but it is clear that for a scheme to have a beneficial impact it must be economically sound.

The major physical quantities that New Zealand forestry and the Emissions Trading Scheme are concerned with are the area of forests, the amount of carbon sequestered and the amount of carbon dioxide emitted.

It is interesting that the majority of talk centred around carbon dioxide, not the generic term 'greenhouse gasses'. If we had included farming within the system boundaries – which creates a lot of methane and nitrous oxide, two potent GHGs – then it is likely this would have been expanded out. On the whole these results are reaffirming not groundbreaking, but show that logical steps taken in a short time frame with an 'informed' small group can lead to some convincing and useful answers.

Finally it must be noted that the participants to the group model building workshops did not represent all the stakeholder groups that have an interest in the Emissions Trading Scheme and forestry value chain in New Zealand. The results discussed in this paper are indicative only, as the causal loop diagrams have not been fully validated. However, the insights gained from these workshops and subsequent analyses have demonstrated very clearly the power of systems thinking, and qualitative system dynamics in particular, to examine complex issues such as the introduction of an Emissions Trading Scheme in

New Zealand. The project has provided a very useful communication tool and has generated considerable interest amongst stakeholders and hopefully commitment for ongoing work in this area.

ACKNOWLEDGEMENTS

The authors would like to thank Scion Research Ltd for supporting this research project. They are also most grateful to all the participants for their open and generous contributions at the group model building workshop. However, the interpretations and opinions in this paper are those of the authors.

REFERENCES

Cavana, R.Y., Boyd, D. and Taylor, R. (2007). A systems thinking study of retention and recruitment issues for the New Zealand Army electronic technician trade group, *Systems Research & Behavioral Science*, 24(2): 201-216.

Cavana, R.Y., Davies, P.K., Robson, R.M. and Wilson, K.J. (1999). Drivers of quality in health services: different worldviews of clinicians and policy managers revealed. *System Dynamics Review*, 15(3): 331-340.

Checkland, P.B. (1981). *Systems thinking, systems practice*. Wiley, Chichester.

Coyle, R.G. and Alexander, M.W.D. (1997). Two approaches to qualitative modelling of a nation's drug trade. *System Dynamics Review*, 13(3): 205–222.

Coyle, R.G. (1996). *System Dynamics Modelling: A Practical Approach*. Chapman & Hall, London.

Forrester, J.W. (1961). *Industrial Dynamics*. MIT Press, Cambridge, Mass.

Freeman, R. E. (1984). *Strategic Management: A Stakeholder Approach*. Pitman Publishing, Boston, MA.

Hodgson, A.M. (1994). Hexagons for systems thinking. In *Modeling for Learning Organisations*, (Morecroft, J.D.W. and Sterman, J.D., eds), Productivity Press, Portland, OR.

Kreutzer, D.P. (1995). FASTBreakTM: a facilitation approach to systems thinking breakthroughs. In *Learning Organisations: Developing Cultures for Tomorrow's Workplace*, (Chawla, S. and Renesch, J., eds). Productivity Press: Portland, OR.

Lane, D.C. (1993). The road not taken: observing a process of issue selection and model conceptualization. *System Dynamics Review*, 9(3): 239–264.

Maani, K.E. and Cavana, R.Y. (2007). *Systems Thinking, System Dynamics: Managing Change and Complexity*. 2nd ed. Pearson Education (NZ), Auckland.

Maclaren, J. P. (2000). Trees in the Greenhouse. *Forest Research Bulletin No. 21*. Forest Research Institute, Rotorua.

MAF, (2008). *Forestry in the Emissions Trading Scheme*. Ministry of Agriculture & Forestry, Wellington. Policy document available online at www.maf.govt.nz/sustainable-forestry/ets/guide/ets-guidelines.pdf [Website sourced March 2009]

MAF, (2009). *New Zealand Forest Industry Facts and Figures 2008/2009*. Ministry of Agriculture & Forestry, Wellington. Information leaflet, available online at http://www.maf.govt.nz/statistics/forestry/other-forestry-releases/facts-figures

MfE, (2008). *New Zealand's Greenhouse Gas Inventory 1990 – 2006, An Overview*. Ministry for the Environment, Wellington. Available online at www.mfe.govt.nz

Paul, T., Kimberley, M. and Beets, P. (2008). Indicative forest sequestration tables. MAF contract report by Scion found online at http://www.maf.govt.nz/climatechange/reports/sequestration/Indicative-Forest-Sequestration-Tables.pdf.

Senge, P.M. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organisation.* Doubleday Currency, New York.

Statistics New Zealand, (2008). *Gross Domestic Product: December 2008 quarter*. Statistics New Zealand, Wellington. Found online at http://www.stats.govt.nz/products-and-services/hot-off-the-press/gross-domestic-product/gross-domestic-product-dec08qtr-revised.htm?page=para005Master

Sterman, J.D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill, Boston.

Turner, J. A., West, G., Dungey, H., Wakelin, S., Maclaren, P., Adams, T., Silcock, P. (2008). *Managing New Zealand planted forests for carbon – a review of selected management scenarios and identification of knowledge gaps*. Report by Scion for the Ministry of Agriculture and Forestry. Scion, Rotorua.

Vennix, J.A.M., Andersen, D.F. and Richardson, G.P. (eds). (1997). Group model building. *System Dynamics Review*, 13(2): 103–201.

Vennix, J.A.M. (1996). *Group Model Building: Facilitating Team Learning Using System Dynamics*. Wiley, Chichester.

Ventana. 2002. *Vensim 5 User's Guide*. Ventana Systems, Harvard, MA.

Wolstenholme, E.F. and Coyle, R.G. (1983). The development of system dynamics as a methodology for system description and qualitative analysis. *Journal of the Operational Research Society*, 34: 569–581.

Wolstenholme, E.F. (1999). Qualitative vs. quantitative modelling: the evolving balance. *Journal of the Operational Research Society*, 50: 422–428.

APPENDIX 1

ISSUES/CONCEPTS GENERATED AND GROUPED BY THEME

Issues (Grouped)

Cash flow NPV

6 Land value change
33 Consistent with atmospheric change
9 Better cash flows
15 Change in value of different forest types
19 Diversified forest values
38 Forestry investment schemes
57 Impact of applying financial tools (e.g. discount rate) to natural resource management

Market competitiveness / efficiency

8 Carbon trade market – fair, strong and big enough
23 Carbon market structure and standards
39 Who are the buyers of carbon emissions?

49 By whom and how will the scheme be administered?

Measure GHG Impacts - Political, atmospheric

42 Verification
30 Auditing and verification issues
12 Obligations and rights
28 Equity of application
2 Focussing on maximising carbon stocks won't minimise emissions
4 Scope of scheme
65 All inclusive – countries and sectors

Change in attitudes and behaviours over time to emissions and sink activities

83 How do we change human behaviours?
73 Will ETS make a difference – Why bother? (Strong view)
64 Consistent understanding – long time frame
82 Management of change
54 Public perception of forestry and forest products
55 Kids dreams and lifestyle

Wood Supply

17 Impacts on wood flows
24 Scattered small forests
36 Short term reduction in wood supply
31 Domination of carbon favoured trees

Costs \$ / tonne CO_2 or m^3

56 Logistics of forest planting expansion
79 Carbon costs of shifting wood overseas
3 More affordable small scale harvesting
40 Hill country harvesting

CO_2 stocks and emissions

13 Longer rotations
21 Less silviculture
23 Diverse silvicultural regime
74 Adaptation and mitigation – design of forests (Strong view)
1 More diverse tree species
34 Increased agroforestry
29 Fast growing species

Supply capacity – labour, capital, technology

80 Transportation technologies
27 Expertise shortage
72 Workforce capacity
81 New technologies in foresting
47 Technical tools and capability

Public perception of changing land use

69 Impacts on biodiversity
45 Change in forest usage
70 Sustainable land use
5 Shift to sink land uses
10 Treatment of other land uses

Demand, supply and price of wood based products and ecosystem services

37 Alternative use of carbon stock
59 Change in comparative advantage (int. trade terms)
43 Bio-energy demand
7 Effects on market and trade
52 Low emission substitute products
78 Demand for fibre
66 Multi-functionality of forests
16 Forest services vs. timber industry
46 Demand for wooden houses
11 Emphasis on diverse products

Technology Transfer

63 Increased technology transfer in harvesting
62 Tech transfer and education

Risks affecting demand for carbon trading

35 Expected stability and longevity of scheme
78 Analysing and modelling risk and uncertainty
32 Forecasts of carbon prices
44 Forecasting demand for carbon
75 Other sequestration strategies (e.g. photoplankton)
51 Risk of ETS

Risks affecting supply of carbon trading

61 Sustaining financial crisis
18 Cascading uses
22 Insurance of carbon stock
50 Paradigm shift
48 Efficiency
60 Forest growing – lack of flexibility
20 Payment timing
77 Total global carbon
26 International forestry
47 Liability complication
53 Agency risk (intermediatary)
71 Actual climate change
68 Fire – destruction of forests
14 Quantifying liability
58 Corruption and fraud
67 Exit strategy (after ETS?)

APPENDIX 2

VARIABLES

- Number of new markets
- Supply of ecosystem services
- Supply of tradable carbon (tonne / yr)

Qualitative system dynamics analysis of effects of ETS on NZ forestry value chain

- Carbon trading price ($ / tonne)
- Carbon Sink (CO_2 tonne / ha)
- Demand for carbon trading (tonne / yr)
- Area of forests / ha
- Carbon dioxide emissions
- Wood supply
- Demand for wood based products
- Wood price ($ / tonne)
- Supply wood based products
- Costs ($ / tonne / h)
- Number of new markets per annum
- Risks affecting demand for carbon credits
- Market competitiveness / efficiency
- Risks affecting supply of carbon credits
- Change in attitude over time to emission and sink activities
- Public perception of changing land use
- Measure GHG impacts – political, atmospheric
- Technology transfer
- Cash flow NPV ($ / ha)
- Forest services price
- Change in behaviour over time in emission and sink activities
- Demand for ecosystem services
- Supply capacity – labour, capital, technology