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CVal: A Spreadsheet Tool to Evaluate the Direct Benefits and Costs of Carbon Sequestration Contracts for Managed Forests

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Abstract

This documentation is meant to accompany CVal, a downloadable spreadsheet tool. CVal was constructed for foresters, other land management advisors, landowners, and carbon credit aggregators to evaluate the direct benefits and costs of entering into contracts for carbon sequestered in managed forests and forest plantations. CVal was designed to evaluate Exchange Forestry Offset (XFO) contracts on the Chicago Climate Exchange (CCX), although the methodology could be adapted for other trading mechanisms and agricultural sequestration projects.

Both the documentation and the spreadsheet tool are downloadable from http://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr180/fpl_gtr180.html. Versions of CVal are available both with and without macros. Although all calculations can be done in the version without macros, the macros version has buttons and automations that make the calculations convenient.

Our general finding is that it is critical in managed forest projects to determine whether carbon accumulated prior to entering the contract can be counted. Depending on the contract year and length, this can triple the revenue from CCX contracts. If it is not possible to count pre-contract year carbon, then it may not be economically worthwhile to enter the program unless it is extended. Other critical variables having a large effect on the overall profitability include the trade price of sequestered carbon, the carbon sequestration rate, and the hurdle rate (the minimum required rate of return on investment) used. Up-front and annual costs are important, but overall profitability is not quite as sensitive to these costs as it is to the previously mentioned variables. Users are expected to enter their own data to evaluate the feasibility of specific projects.

Keywords: Carbon sequestration, carbon valuation, carbon contracts, carbon credits, Exchange Forestry Offset (XFO) contracts, Chicago Climate Exchange (CCX), decision support, discounted cash flow analysis

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Contents

Page

Introduction 1
- Regulated and Voluntary Markets for Sequestered Carbon 1
- Available Tools 2
- Capabilities of CVal 3
- CVal Features 3

CVal Location and Versions 4
- Summary Financial Information 4
- Break-Even Analysis 5
- Cash Flow Inputs 6
- Sensitivity Analyses 7
- Storage Tables 8
- Utility Macros 8
- Implicit Assumptions 9

General Findings 10

Limitations 11

Conclusions 12

References 12

Appendix 1—Selected Financial Terms Used in CVal 14

Apendix 2—CVal's Variables 16

Appendix 3—CVal's Macros 20

Screenshots 22

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Introduction

Regulated and Voluntary Markets for Sequestered Carbon

Sequestered carbon is becoming an increasingly important forest product in the marketplace. The long-run average price for sequestered greenhouse gasses that equate to a tonne of carbon dioxide is around $3.50 in the United States. Carbon markets are developing and can be broadly classified into regulated and voluntary.

In a recent study, Hamilton and others (2008) confirmed 65.0 million tonnes of carbon dioxide equivalent ($MtCO_2e$) transacted on voluntary U.S. markets in 2007. This was more than double the 24.6 $MtCO_2e$ that were transacted in 2006 (Fig. 1). This amount is miniscule against the 2,983 $MtCO_2e$ that were traded on regulated markets in 2007 (Hamilton and others 2008), which is a better indicator of potential market size. In addition, this 2007 regulated market total was itself nearly 80% larger than that in 2006.

The Kyoto Protocol established the framework for a global regulated carbon market and has been signed by 183 countries. Although the United States has not ratified the Kyoto Protocol, several regional, regulated markets have been established. Examples include the California Climate Action Registry and, more recently, the Regional Greenhouse Gas Initiative. Voluntary carbon markets in the United States are prevalent. Ramseur (2007) provided an overview of voluntary carbon offsets. In reviewing literature on carbon offsets and the voluntary market, he found a correlation of offset prices and offset quality.

The voluntary carbon market can be further divided into two components: over-the-counter (OTC) and structured markets. The OTC market is highly fragmented and is based on a deal-by-deal basis. The structured Chicago Climate Exchange (CCX) provides a legally binding mechanism for carbon emission reductions once an entity becomes a member. The CCX is the only exchange platform in the United States for trading forestry offset credits (Ruddell and others 2006).

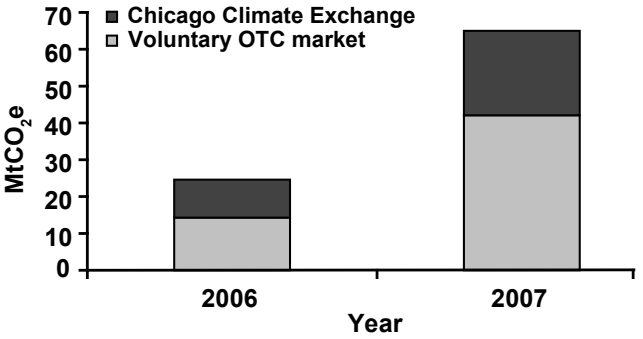

Figure 1—Volume of carbon transacted in voluntary U.S. markets, 2006 and 2007. OTC is over-the-counter.

The CCX is an exchange on which Exchange Forestry Offset (XFO) (also called carbon credits) are bought and sold. A carbon credit is normally quantified in terms of "carbon dioxide equivalent (CO_2e)." CCX contracts are priced in terms of metric tonnes of carbon dioxide equivalent. One metric tonne (1,000 kilograms) is equal to 2,205 pounds or 1.102 short tons. Carbon dioxide equivalent is the standard established by the Intergovernmental Panel on Climate Change (IPCC) to compare greenhouse gases (EPA 2005). **Throughout this document and the spreadsheet CVal, "carbon" and "sequestered carbon" refer to CO_2e.**

CVal, a downloadable spreadsheet tool, was constructed for land owners and managers to evaluate the direct benefits and costs of entering into contracts for carbon sequestered in managed forests and forest plantations. It is best used by an aggregator, professional forester, or project developer with an understanding of realistic cost and benefit ranges and carbon sequestration rates. CVal was designed for XFO contracts on the CCX, although the methodology could be adapted for other project types or standards.

The tool was evaluated using representative data. Although the findings will not apply to all forest tracts, some

generalizations may be made. Users are expected to enter their own data to represent individual projects.

Powerful and flexible, CVal automatically calculates the net benefit (cost) to a landowner of entering into a carbon sequestration contract from cash flows, which are both calculated and graphed. The net benefit (cost) is calculated in terms of discounted values. That is, the cash flows are adjusted by an interest rate for the year in which they occur. In addition, the internal rate of return (IRR) and modified internal rate of return (MIRR) are calculated. Benefits (costs) are calculated both at the beginning of the project, which is the year in which up-front costs are paid, and at the end of the project. Annualized benefits (costs) are shown. Financial break-even analysis of key input variables may be done either with macros or semi-automatically using Excel's built-in tools. Built-in sensitivity analyses are performed on the hurdle rate, the specified counter year in which up-front costs occur, the initial carbon price, and percentage changes in annual, up-front, and end-of-program costs. Storage tables for variables make it easy to return to the original conditions after performing a "What-if?" analysis.

The Chicago Climate Exchange

Although membership in the Chicago Climate Exchange (CCX) is voluntary, once an entity joins, it contractually commits to annual greenhouse gas emission reductions of a specified magnitude compared with its original baseline emissions. Reductions beyond the contracted level can be sold to other CCX members who are in need of additional reductions. A portion of the offset carbon is project-based from landowners who have implemented carbon sequestering practices on their lands.

Individual landowners work through "aggregators" who bundle carbon credits into 100-tonne lots to be traded on the exchange. By enrolling land with an aggregator, the landowner gives the aggregator the rights to the sequestered carbon in exchange for payment. The aggregator chooses when to sell the credits on the CCX market, and within 24 hours of sale receives payment from the CCX. The aggregator makes payments to individual landowners at various times during the year. Payment allocation and disbursement systems vary among individual aggregators.

The CCX began its operations in 2003, completing a "phase 1" in 2006. "Phase 2" is scheduled to run through December 31, 2010, so contracts are legally binding only through that date and final payouts would be expected in 2011. If the CCX continues into a "phase 3," landowners will have the option of being able to either renew their contracts or exit the exchange. CVal's calculations can be extended to value sequestrations for up to seven years beyond the present.

In terms of total value, the transactions in the voluntary markets accounted for $331.8 million in 2007 (Hamilton and others 2008). This represented more than a trebling of the 2006 value; but again, this total was minor compared with the $63.7 billion in total regulated market transactions.

Prices for sequestered carbon are quite volatile, although generally increasing (Fig. 2). A data series for the voluntary U.S. market going back to 2003 is available (Chicago Climate Exchange n.d.a). Daily closing prices for 2003 contracts have ranged from $0.73/tonne on May 7, 2004, to $7.40/tonne on May 30, 2008. Prices fell back to $1.10/tonne on November 17–20, 2008, before recovering somewhat. The most recent price on January 9, 2009, was $1.90/tonne. Still, a contract purchased for $0.98/tonne on the first available date of December 12, 2003, and held until January 9, 2009, would have returned a compound annual increase averaging 3.9% over the period. This compares with an annual compound loss of 3.6% if the same investment had been made in the S&P 500 index for the same period.

Available Tools

The markets for carbon sequestration are significant and growing. Tools are needed that can aid in the smooth and efficient operation of carbon markets. Any tool that can improve information, reduce transactions costs, and make transactions more transparent has the potential to improve market efficiency. Improved market efficiency should lead to more carbon sequestration contracts and increased benefits both for forest owners and potentially for the environment.

Smith and others (2005) presented techniques for calculating average annual net additions to carbon contained in forests and forest products. The tool they created provides average estimates of forest carbon and may be useful when more specific information is not available. Appendix A in Smith and others (2005) contains 51 tables broken down by forest type and region that contain estimates of timber volume and ecosystem carbon stocks for forest land after clear-cut harvest. Forest ages range from 0 to 125 years. However, their report is limited to carbon sequestered and does not cover valuation methodologies.

The Chicago Climate Exchange (n.d.b) produced a set of regional estimates of annual carbon accumulation in live trees and soil organic carbon for afforestation projects. The Iowa Farm Bureau (n.d.) produced an application and sales contract for forestry carbon offsets that contains a carbon offset table based on Birdsey (1996). The Central Minnesota Regional Sustainable Development Partnership (CMRSDP, n.d.) produced a guide for landowners considering enrolling in the Chicago Climate Exchange. CMRSDP's (n.d.) guide also contains an accumulation table for reforestation projects for various forest types that appears to be nearly identical to the Iowa Farm Bureau's (n.d.) table and also has potential income calculations. However, these calculations do not include any costs apart from the CCX and aggregator

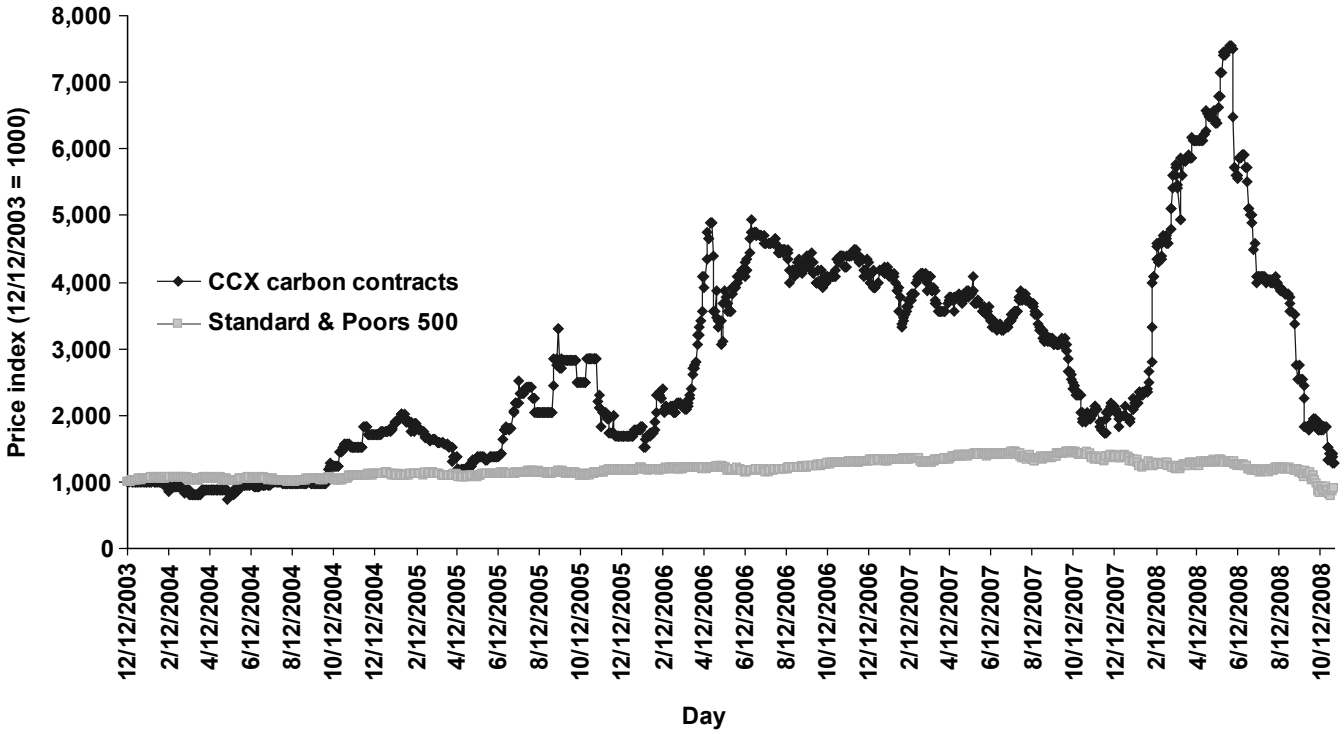

Figure 2—Indices for Chicago Climate Exchange (CCX) daily closing prices for 2003 carbon contracts and the Standard & Poors 500, December 12, 2003, to October 27, 2008.

charges. The CMRSDP example also does not include any allowances for variable sequestration rates or carbon prices. In addition, by simply adding income over the contract life, the CMRSDP implicitly assumes that the time value of money is 0%. Because initial enrollment costs will likely need to be financed, and 0% is not a realistic interest rate, a more sophisticated tool is needed to evaluate the potential profitability (or loss) of these contracts.

Commercial tools are also available. A web-based carbon valuation tool is available by subscription from Point Carbon (n.d.). From its description, this tool is focused on risk and portfolio management of Clean Development Mechanism and Joint Implementation credits under the Kyoto Protocol. Carbon valuation and reporting systems were developed by FORECON EcoMarket Solutions (n.d.) for the U.S. market. However, its solutions are customized and proprietary. The Carbon Finance Unit of The World Bank (n.d.) has a project financial analysis template that includes carbon benefits, but it is structured for large projects extending out 28 years.

Capabilities of CVal

This paper describes a tool that can be used to quickly assess the direct benefits and costs to a forest landowner of entering into a carbon sequestration contract and demonstrates the tool's power and versatility using a sample data set. Whereas general results from sample data are presented, users are expected to enter their own data to determine if entering into a sequestration contract is worthwhile.

The spreadsheet CVal was created to calculate a value for carbon sequestration contracts. The program was set up for contracts traded on the Chicago Climate Exchange, but the general methodology would be applicable for any carbon contracts. Although CCX contracts account for less than a quarter of the value of the voluntary transactions in 2007 (Hamilton and others 2008), the structured contracts make it easier to construct a valuation model and work productively with potential owners of these contracts.

CVal calculates the value of the net benefit or cost of entering into a carbon sequestration contract. A *Summary Financial Information* table also displays the IRR and MIRR on the investment. The average carbon benefit, average cost of trading, and net trading benefit or costs are calculated on a per tonne basis. The per-acre net benefit or cost at the end of the project is also calculated. A chart shows the expected net cash flows per acre over the project life.

CVal should be of interest to foresters and other land management advisors advising owners about entering their forestlands into a carbon sequestration contract, especially under the CCX protocol. The tool should also be of interest to aggregators who accumulate carbon sequestration rights on land parcels so that the rights can be traded.

CVal Features

- Versions with either 1) built-in Visual Basic macros that automate extensive break-even financial calculations and utility functions or 2) without macros to ensure compatibility with all versions of Excel (Microsoft Corp.,

Redmond, Washington), virus-free downloading, operating, and sharing

- Automatic calculation of present value or cost, IRR, MIRR, and ending balance on a per-acre and per-project basis
- A cash flow table showing years in which both outflows and inflows are expected
- Built-in sensitivity analysis on carbon prices, hurdle rates, up-front costs, annual costs, and the year in which up-front costs occur
- Integration with Excel's "Goal Seek" tool to perform break-even analysis
- Extensive graphics showing cash flows, rates of return, and sensitivity analyses
- Built-in warnings and error messages to facilitate error-free calculations
- Extensive annotations in the form of cell comments to explain operations and minimize the need for reference to the user manual

CVal Location and Versions

Summary Financial Information

CVal is constructed with the output of greatest interest to the analyst or landowner, the *Summary Financial Information*, on top (Screenshot 1). (Screenshots start on page 22.)

Note the small red triangles in the upper right corner of some of the cells. These triangles indicate that the cell contains explanatory comments. To see the comments in the spreadsheet, scroll the cursor over a cell containing a comment. It will appear in a yellow box. Alternatively, go to the top menu and select View-Comments to see them all.

In Screenshot 1, the total net benefit (or cost) is the sum of benefits and costs discounted at the hurdle rate back to the contract year, which is the counter year in which the up-front costs occur. The formulation follows basic net present value methodology:

$$\text{Total net benefit (cost) in year } m = \sum_{t=m}^{n} \frac{B_t}{(1+r)^{(t-m)}} - \sum_{t=m}^{n} \frac{C_t}{(1+r)^{(t-m)}}$$

where

B_t is the benefits from sales of the sequestration credits in year t,

C_t the costs of sales of the sequestration credits in year t,

r the discount rate represented by the hurdle rate, in decimal form,

t the counter year in which the benefits or costs occur,

m the contract year, which is the counter year in which the up-front costs are paid, and

n the counter year of the final payout.

The reason for the terms "counter year" and "contract year" is that although CCX contracts can go back to the year 2003 (counter year 1), the contracts are currently scheduled to end in 2010 with final payouts in 2011. If a contract was entered and up-front costs paid in 2008, counter year 6 would be the "contract year" and the valuation year for the net benefits or costs.

The reason that we have not just used absolute years is that the CCX program, currently in Phase 2, may be extended. Having both counter years and absolute years adds flexibility to CVal.

The IRR is a hurdle rate at which the total net benefit (or cost) in the contract year (year m) is \$0:

$$\text{If total net benefit (cost)} = \$0 = \sum_{t=m}^{n} \frac{B_t}{(1+d)^{(t-m)}} - \sum_{t=0}^{n} \frac{C_t}{(1+d)^{(t-m)}}$$

where d is the IRR, in decimal form.

To actually earn the IRR on the entire investment, any intermediate negative or positive cash flows would have to be either borrowed or reinvested at the calculated IRR. This may not be a reasonable assumption if the calculated IRR is very large or very small.

The MIRR is a calculation in which the net costs are discounted back to the contract year using the finance rate and then summed, and the net benefits are compounded out to the end of the project using the hurdle rate, and then summed. At that point, a simple rate of return formula is used to calculate the MIRR.

$$\text{MIRR} = \left(\frac{\text{FV}}{\text{PV}}\right)^{\frac{1}{n-m}} - 1$$

where

FV is the sum of the future value of the benefits compounded to the end of the project at the hurdle rate,

PV the sum of the present value of the costs discounted to the contract year at the finance rate,

m the counter year in which the up-front costs are paid,

n the counter year of the final payout, and

MIRR is calculated in decimal form.

Note that $(n - m)$ is the number of years that the project runs. It is the number of years between the specified contract year (m) in which the initial up-front costs occur and the year of the final project payout (n).

Because reinvestment of intermediate cash flows is assumed to be at the hurdle rate rather than at the project's IRR, MIRR may be more representative than IRR in a project with intermediate cash flows.

Below the *Summary Financial Information* table are the benefits and costs, both per acre and per tract (Screenshot 2).

The calculations for the tract are simply the per-acre calculations times the number of acres in the tract. The benefits and costs are shown valued in the year that the contracts begin and at the end of the contract. They are also shown on an annualized basis, which uses the basic capital recovery formula

$$A = \text{PV} \times \left[\frac{r \times (1+r)^{(n-m)}}{(1+r)^{(n-m)} - 1} \right]$$

where

PV is the total benefits (or costs) valued as of the year in which the initial up-front costs were incurred, and

A the annualized benefits (or costs).

All other variables are as defined previously.

Note in Screenshot 2 that the per-tract net benefit valued as of year 6 (i.e., $504, which is highlighted for this screenshot) is the same as the total net benefit from Screenshot 1. The benefits and costs valuations come from table 3, discussed below. The note in Screenshot 2 drawing attention to the identical annualized net benefits in year 6 and year 9 ($0.74/acre and $185/tract) is one of CVal's conditional advisories that will appear only when the case is true.

To calculate the present value of the benefits and costs, standard discounting methodology is used. That is, benefits, costs, and tonnes of CO_2e are discounted by using the formula

$$\text{PV} = \frac{\text{FV}_t}{(1+r)^{(t-m)}}$$

where

PV is the present value in counter year m of any single benefit or cost or tonne of carbon,

FV_t the future value of the benefit or cost or tonne of carbon in any given counter year t,

r the annual discount rate in decimal form as represented by the hurdle rate, and

m the counter year in which the up-front costs are paid.

Break-Even Analysis

Beneath the benefits and costs table is one of CVal's most powerful features—the break-even analysis (Screenshot 3).

CVal calculates variable values that will result in a financial break-even point. These break-even results are the maximum or minimum values for each variable that will provide the minimum required rate of return on investment (the hurdle rate), provided that the values of the other tabulated variables do not change. In other words, these results are the values at which the net benefit or cost (the net present value) is equal to $0, the financial break-even point. If these break-even results are used as input values for the variables, then investors should earn exactly their desired rate of return on capital as represented by the hurdle rate. The break-even analysis shows how low carbon prices, tract size, or carbon sequestration rates can go or how high up-front or end-of-program costs can be and still provide the minimum desired rate of return. The break-even analysis also shows by what percentage annual costs, up-front costs, and end-of-program costs could rise and still provide the minimum desired rate of return.

To calculate an accounting break even where costs are just covered by revenues, no matter when the costs or revenues occur, the hurdle rate should be changed to 0%.

> *At CVal's financial break-even point, investors will earn exactly their desired rate of return on capital as represented by the hurdle rate. If the hurdle rate is specified as 0%, which is the accounting break-even point, CVal's break-even calculations show input variable values at which investors will just recover their costs over time, but will earn no return on invested capital.*

To test the break-even results, select a value from the break-even table and paste the value into the appropriate cell in the *Cash Flow Inputs* (table 1 of CVal). At the break-even point, the total net benefit should be $0 and the IRR should be equal to the user-specified hurdle rate.

These break-even values are only calculated by specified actions. They must be re-calculated each time an input variable is changed. This can be done automatically using macros, semi-automatically using Excel's built-in "Goal Seek" tool, or manually (not recommended).

The easiest way to find the break-even values is by running a macro. Macros to run a full break-even analysis and individual break-even analyses are pre-installed in the macros version of CVal along with buttons and active areas of the worksheet that simplify running these macros. The complete inactive macro scripts are included in a separate worksheet in the non-macros version of CVal along with instructions on how to copy and install them. For a description of all the break-even macros as well as the utility macros and how to use them, see Appendix 3.

In the macros version of CVal, note the "Run B-E" button to the right of the *Sensitivity Analysis* table (Screenshot 3). Clicking this button automatically runs break-even analyses on all eight variables. Alternatively, macros calculating each of the eight variables can be run individually by clicking in the active area of each variable title in the break-even table. A full break-even analysis is also run when the "Store_Values" macro is run. Each of the macros can also be run by going to the main Excel menu and Tools-Macro-Macros-[Select_Macro_Name]-Run.

Each of these individual break-even values can also be determined semi-automatically with Excel's "Goal Seek" tool. First, to save the initial starting value for the variable from table 1, *Cash Flow Inputs* (Screenshot 4) select the cell containing the variable, copy it, and paste it somewhere for storage (e.g., in table 7, the storage table for temporary values used in break-even analysis). Then select cell G8 (the net benefit or cost) and go to Tools-Goal Seek. Set G8 equal to 0 by changing the cell from table 1 containing the variable of interest. After Goal Seek has found a solution, copy this value and paste it into the appropriate cell in the *Break-Even Analysis* table. To paste the value, go to Excel's Edit-Paste Special-Values. Use this, rather than the general "Paste" command so that you do not change cell formatting. Then if you want to return the initial value, copy the initial starting value for the variable from wherever you stored it, and paste it back into table 1.

To find a break-even value manually, first store the initial starting value for the input variable from the *Cash Flow Inputs* as described in the previous paragraph. Then select the cell containing the variable that is of interest and manually change it until the total net benefit (or cost) in G8 is $0. Then copy the solution and paste it into the break-even table and restore the initial starting value as described in the paragraph above.

Cash Flow Inputs (table 1, table 2, and table 3)

All references to tables in this paper refer to those in CVal, but figure numbers refer to those in this paper.

The input variables in table 1, the *Cash Flow Inputs* (Screenshot 4), are next to the *Summary Financial Information*. By placing these input values here, you may do a quick "what if" analysis. For example, "What is the effect on the net benefit or cost and the rates of return if the _____ [fill in the blank] assumption changes?"). A complete list and description of CVal's input values, along with their initial default assumptions is included in Appendix 2.

Note that three of these variables, "Sequestration rate is …" "Carbon price is …," and "Count pre-contract carbon?" are entered via pull-down selections. Accurate analysis requires accurate specification of input values. Professional assistance may be required to specify the carbon sequestration rate and contract fee structure.

Beneath CVal's summary values, break-even values, and inputs, on what would be page 2 of a print-out of the CVal worksheet, table 2 contains the *Annual per Acre Inputs and Cash Flow Calculations*. The only inputs that are required on this page are the annual carbon sequestration rates and annual carbon prices. Both these inputs are required only if the sequestration rate or carbon price are "Variable" in table 1. The first year's sequestration rate and carbon price equal the rates set in table 1.

For the full and individual break-even analyses to work realistically, it is essential that both the sequestration rates and the carbon prices in subsequent years are entered as functions of the first-year values in table 2. Also, individual up-front costs must be entered as a function of total up-front costs in table 1.

For example, if carbon sequestration rates and carbon prices are both entered as "Constant" in table 1, then the formulas

= "Sequestration_rate" and
= "Initial_carbon_price"

should be entered in the subsequent counter years for the annual sequestration rates and annual carbon prices, respectively. If the carbon sequestration rate or carbon prices have been set as "Constant" in table 1 but they are not constant in table 2, warning messages will appear and the sequestration rates or carbon prices that are different from the first year's values will be highlighted. The macros version of CVal has Fix_Constant_Sequestration_Rates and Fix_Constant_Carbon_Prices, macros that will set formulas in all years equal to the initial year's values. To run these macros, go to Excel's Tools-Macro-Macros-[Select_Macro_Name]-Run.

Table 3, which contains the *Per-Acre Present Value and Ending Balance* calculations, follows the cash flow calculations. The per-acre total net benefit (cost) is the value reported in the *Benefits and Costs* table (Screenshot 2). Table 3 contains more detail on how the total net benefits (costs) figure is calculated. It also contains a discounted value for the carbon, which is used in the calculation of the net trading benefit (or cost) per tonne. The ending balance portion of table 3 is shown (Screenshot 5).

The ending balance calculation shows how much cash would be in hand at the end of the project if the cash flows occurred as projected and if borrowings were at the finance rate and re-investments were at the hurdle rate. The ending balance each year is equal to the previous year's ending balance, plus interest earned, less interest charged, plus the carbon benefit paid, less total costs. Positive beginning balances are carried forward and earn interest at the hurdle rate. Negative beginning balances are carried forward and charged interest at the finance rate. The formula to calculate the ending balance each year is

Ending balance =
[Beginning balance × (1 + r)]
+ Carbon credit benefit paid – total costs

where beginning balance is the ending balance of the previous year and r is the interest rate in decimal form.

If the beginning balance is negative, r is the finance rate of interest. If the beginning balance is positive, r is the hurdle rate.

Ending Balance Notes

- If the hurdle and the finance rates are both set equal to the IRR, the final ending balance will be $0.00.
- If the hurdle and finance rates are identical, the final ending balance may be found using the formula

  Final ending balance = total net benefit (cost) × $(1 + r)^{(n-m)}$

  where total net benefit (cost) is from the initial net benefit (cost) calculation, and

  r is the hurdle rate in decimal form,
  n the counter year of the final payment, and
  m the contract year, which is the counter year of the up-front costs.

  For example, $\$2.33 = \$2.02 \times (1.05)^{(9-6)}$
- A break-even analysis run on the final ending balance and the finance rate will return the IRR. That is, if the finance rate is equal to the IRR, the final ending balance equals $0.

The net trading benefit or cost on a dollar per tonne basis is shown below table 3. The net trading benefit or cost is shown in terms of dollars at the contract year. All benefits and costs as well as tonnes of carbon are discounted back to the beginning of the project to get average figures in dollars per tonne. Discounting is necessary to get a meaningful calculation if the benefits, costs, or amount of carbon traded each year are anything but constant, or if the hurdle rate is anything other than 0%. A tonne of carbon sequestered today is not the same as a tonne of carbon sequestered several years from now because that tonne of carbon today could be sold and the proceeds invested at some interest rate. Therefore, both dollars and tonnes of carbon need to be discounted to get meaningful averages over the life of the project.

The net cash flow per acre graph (Fig. 3) is next to the net trading benefit or cost calculation. This graph shows the net cash flow data coming from table 2.

Sensitivity Analyses

Following on what would be pages 3 and 4 of a printout are four sensitivity analyses. In addition to the break-even sensitivity analysis, CVal automatically conducts a full sensitivity analysis on four key variables: the hurdle rate, the year in which up-front costs occur, the initial carbon price, and costs.

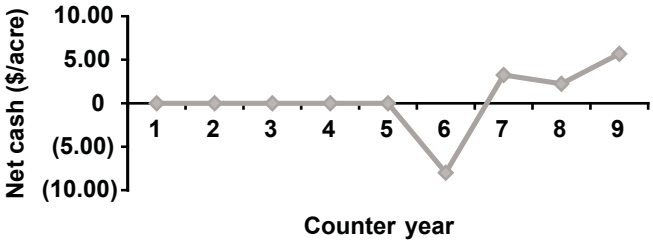

Figure 3—CVal's net cash flow per acre graph.

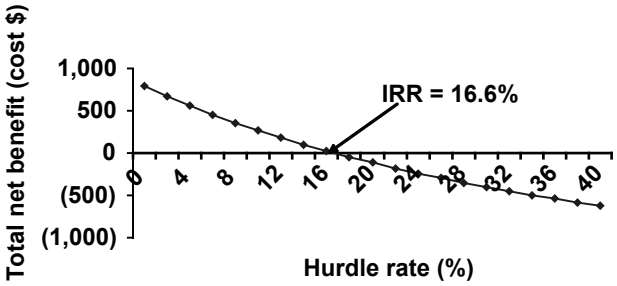

Figure 4—CVal's graph showing the sensitivity of the total net benefit (or cost) to the hurdle rate.

Table 4 shows the sensitivity of the net benefit (cost) to the hurdle rate. To the right of table 4, its results are shown graphically (Fig. 4). Table 4 has three user-entered variables: the mid-point for the hurdle rate graph, the hurdle rate increment, and an IRR test number.

The hurdle rate mid-point and the hurdle rate increment both control the x-axis. To see where the net present value crosses $0, which by definition is the IRR (Fig. 4), adjust the mid-point hurdle rate and the hurdle rate increment until the column with the total net benefit (cost) has both positive and negative values.

The "IRR test number" (cell C94) is a user-entered variable that is used as a starting point for Excel's IRR calculation. This variable is also used in the IRR calculation in the *Summary Financial Information* table. If the IRR calculation returns the #NUM! error, but you can see from the graph (Fig. 4) that the net benefit (cost) curve will cross $0 with some adjustments of the hurdle rate's starting point and increment, then adjusting the "IRR test number" to the approximate hurdle rate where the Net benefit (cost) = $0 should avoid the #NUM! error message. Some adjustment may also be needed to the mid-point of the graph (cell B81) and the increment (cell C92).

Table 5 displays the sensitivity of net benefit (cost), IRR, MIRR, and ending balance to the year that up-front costs occur. Maximum values and the year in which they occur are also provided (Screenshot 6).

To the right of the sensitivity analysis table appears a graph showing the sensitivity of the ending balance and the IRR to the year in which up-front costs occur (Fig. 5).

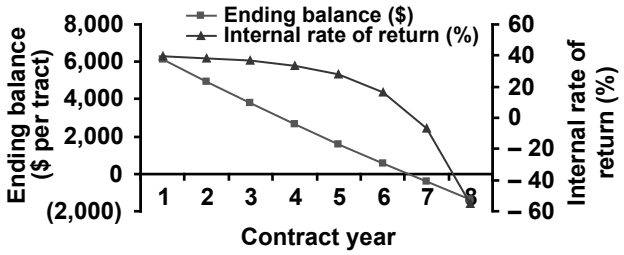

Figure 5—CVal's graph showing the sensitivity of the ending balance and internal rate of return to the year in which the up-front costs occur with no payment given for pre-contract year carbon credits.

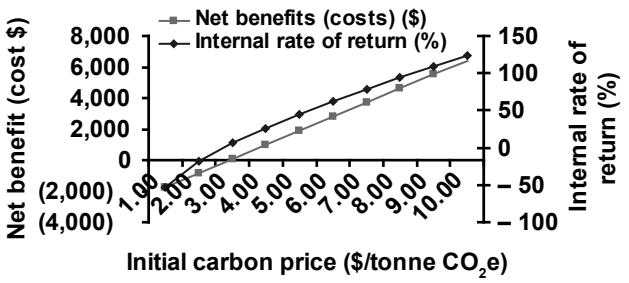

Figure 6—CVal's graph showing the sensitivity of the total net benefits (or costs) and internal rate of return to the initial carbon price.

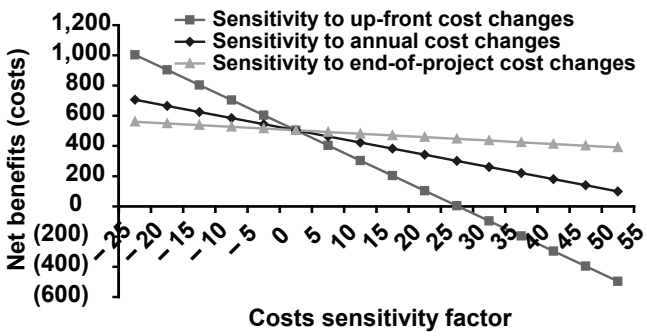

Figure 7—CVal's graph showing the sensitivity of the total net benefits (or costs) to up-front and annual cost changes.

The sensitivity to the initial carbon price of the net benefits (or costs), the IRR, MIRR, and ending balance are found in table 6, (Screenshot 7).

It is important to note that the results in table 6 will be meaningful only if the variables representing carbon prices in the Input table 2 are set as a function of the Initial_carbon_price, which is in Year 2. For example, if carbon prices are set as "Constant" in the Input table 1, the formula, "= Initial_carbon_price" can be entered for the carbon prices (green field) in the Input table 2 for Years 3 to 9. If carbon prices are set as "Variable" in the Input table 1, the prices in Years 3 to 9 in Input table 2 must be set as a function of the initial price (e.g., if prices are expected to increase by 5% per year, the price in Year 3 is made equal to 1.05 × Year 2 price).

Table 6 also has two user-entered variables that control the x-axis in the accompanying graph (Fig. 6). These variables are the mid-point for the initial carbon price and the initial carbon price increment.

Note that if any of the IRR calculations in table 6 shows a #NUM! error message, it will be because at the specified initial carbon price either all of the cash flows are negative or the calculations are outside of Excel's IRR calculation algorithm. To check the reason for the error, first substitute the offending initial carbon price from table 6 into the initial carbon price in table 1 (cell J11). Then check the net cash flows in table 2 (cells O31:O39). If all the cash flows are either $0 or negative, then you have discovered the problem. If at least one of the cash flows is positive, then there may be an interest rate that will make the net benefits (costs) equal to $0. To find this rate, experiment with the IRR test number (cell C94). After you have found the rate that will allow Excel to calculate an IRR, restore the original initial carbon price back into table 1 (cell J11).

CVal's costs are divided into annual costs, up-front costs, and end-of-project costs. The sensitivity of the net benefits (or costs) to changes in costs in each of these groupings is found in table 7 (Screenshot 8). This table also has two user-entered variables to control a central point in the graph and to control the increment change in costs. The central point will probably be 0%. At this point, the costs are calculated as entered in table 1 and the net benefits (costs) are the same as reported in the *Summary Financial Information* table.

A graph of the information in table 7 helps to see which of the cost groupings will have the most significant effect on net benefits (costs) (Fig. 7). The most important cost grouping will have the steepest line.

Storage Tables

CVal's final two tables are storage tables. Table 8 is a storage table for temporary values used in CVal's break-even analysis macros. CVal's break-even macros access this table automatically. It can also be used to manually store starting values so that they may be easily restored following a break-even analysis calculation. Table 9 is used to store and restore user-entered starting values and formulas in table 1, table 2, the *Break-Even Analysis* table, and in the *Sensitivity Analysis* tables (table 4, table 6, and table 7) so that a user can easily try different variables in a "What if?" analysis and then return to the initial conditions.

Utility Macros

CVal's macros version has two buttons at the top of the worksheet: "Store values" and "Restore values." "Store values" runs the "Store_Starting_Values" macro, which first

runs a break-even analysis and then copies the initial values and formulas from table 1, table 2, the *Break-Even Analysis* table, and the user-entered values from table 4, table 6, and table 7 in the sensitivity analysis. The macro then transfers these starting values and formulas into table 9 for storage.

The "Store_Starting_Values" macro runs a full break-even analysis before copying and storing any values so that when the starting values are restored, the values in the break-even analysis table will be correct.

A user may then manually make any modifications to the input variables in table 1 and table 2 doing a "What if?" analysis, and perform any break-even or sensitivity analyses and still easily get back to the initial data set by clicking the "Restore values" button, which runs the "Restore_Starting_Values" macro. The "Restore_Starting_Values" macro copies the macro (or user)-entered values and formulas from table 9 and pastes them into the appropriate cells in table 1, table 2, the *Break-even Analysis* table, and the sensitivity analysis tables.

CVal's macros version has three additional utility macros. Note the similarity between the first two, Fix_Constant_Carbon_Prices and Fix_Constant_Carbon_Sequestration_Rates:

- **Fix_Constant_Carbon_Prices:** If the annual carbon sequestration price is "Constant" (specified in Input table 1), Excel will not automatically fill in the cells in input table 2, unless there is a formula in counter year 3 through counter year 9.

  To ensure constant-price formulas you can run the utility macro or fix the rate manually. To use the utility macro, go to Tools-Macro-Macros-Fix_Constant_Carbon_Prices-Run. This will fill in formulas in counter years 3 through 9, setting the cells equal to the initial carbon price.

  To manually fix a constant carbon price in each of the cells in each of the carbon price cells in table 2 for counter year 3 through counter year 9 enter the formula

  = "Initial_carbon_price"

  This will set the annual carbon prices equal to the initial carbon price entered into table 1.

- **Fix_Constant_Carbon_Sequestration_Rate:** If the annual sequestration rate is "Constant" (specified in input table 1), Excel will not automatically fill in the cells in input table 2, unless there is a formula in counter year 2 through counter year 8.

  To ensure constant sequestration rates, you can run the utility macro or fix the rate manually. To use the utility macro, go to Tools-Macro-Macros-Fix_Constant_Carbon_Sequestration_Rates-Run. This will fill in formulas in counter years 2 through 8 setting the cells equal to the initial sequestration rate.

  To manually fix a constant sequestration rate in each of the sequestration rate cells in table 2, for counter year 2 through counter year 8 enter the formula

  = "Sequestration_rate"

  This will set the annual sequestration rates equal to the initial sequestration rate entered into table 1.

- **Restore_Default_Values:** this macro returns the initial demonstration values that came with CVal. In the version of CVal with macros, the easiest way to run this macro is to click in the active area of cell J8. Alternatively, go to Tools-Macro-Macros-Restore_Default_Values-Run

  The Restore_Default_Values macro can be "worked around" in the version of CVal without macros by using Excel's Scenarios tool and showing both the Default_cash_flow_inputs and the Default_sequestration_and_price scenarios (Tools-Scenarios-[Scenario_name]-Show). This will restore the default values for the variables.

  The problem with the Scenarios tool (in CVal without macros) is that the tool does not restore the initial formulas in the variable cells. It replaces the formulas with absolute values. For example, in table 1 the formulas making the initial up-front costs a function of total up-front costs are replaced with numbers. Similarly in table 2, the formulas for the constant sequestration and carbon prices are replaced with numbers. *This creates misleading and erroneous answers* if the "Goal Seek" tool is subsequently used to run a break-even analysis because only costs that are related to the changing variable by function will be changed in the break-even analysis. See the sections under the Fix_Constant_Carbon_Prices and Fix_Constant_Carbon_Sequestration_Rate macros on how to manually fix the constant formulas if they have been replaced with numbers.

Implicit Assumptions

CVal's main input assumptions were described above and shown in table 1 (Screenshot 4) and table 2.

There are a number of implicit assumptions within CVal's calculations:

- Benefits and costs all occur at the end of each year. This standard assumption in most discounted cash-flow methodology makes calculations much more convenient and has minimal effect on the summary financial information.
- Carbon is not traded until the year after it is sequestered, as required under CCX rules.
- All carbon that is sequestered is traded in the subsequent year. This provides the maximum return for discounted cash flow purposes, assuming constant carbon price.
- The carbon reserve is traded in the year following the end of the contract. This assumes that no catastrophic event,

such as a forest fire or blow down, uses these credits from the carbon reserve.

- Any revenues or fees associated directly with a carbon trade are applied when the trade is made, not when the carbon is sequestered.
- Findings are all pre-tax and on a real basis, which does not include inflation.

General Findings

The sample data set that we ran is not representative of any specific forested tract or of identified market costs or benefits. Still, we believe that the data do represent realistic enough numbers so that we can present generalized results that are worth considering when running an analysis with data for an individual landowner.

Given the input assumptions we chose, the investment in a carbon sequestration contract appears to be a reasonable one. The total net benefit discounted at 5.0% and valued in year 6 is $504. This net benefit is in addition to the required 5.0% rate of return. The investment produces an IRR of 16.6% and a modified IRR of 13.2% when using constant prices of $3.50/tonne CO_2e, a constant sequestration rate of 1.50 MT/acre/year, and finance and reinvestment rates of 5.0%. The net trading benefit is $0.47/tonne CO_2e and the final ending balance at the close of the project in 2011 promises to be $2.33/acre.

The net cash flows were shown (Fig. 3). The default assumption is that the landowner enters into a sequestration contract in year 6 (2008) and that the program finishes out in year 9 (2011). The cash flows are initially negative, as fixed up-front costs required to enter the program are paid. These average $8/acre for the 250-acre tract. If vintage credits were allowed, there would be a large benefit in year 7, when the owners would receive the credit for carbon that was sequestered prior to program entry back to counter year 1. Our default assumption is that such credits will not be allowed for the project, although CVal allows this assumption to be negated. The ending balance remains negative until year 9, the year in which the benefits for the carbon reserve are received.

A break-even analysis run on eight key variables (Screenshot 3) shows that the initial carbon price could drop by about 23% (from $3.50/tonne CO_2e down to $2.95/tonne CO_2e) and the project would still break even (earn the specified hurdle rate). Similarly, the smallest tract size that could be enrolled in the scheme with these assumed input benefits and costs is 204 acres. Sequestration rates, estimated at 1.50 tonne CO_2e/acre/year, could be as low as 1.22 tonne CO_2e/acre/year. The maximum up-front total cost that this project could possibly support is $2,504/tract and the maximum end-of-project costs would be $806/tract. Annual costs could increase as much as 62%, up-front costs could increase as much as 25%, or end-of-project costs could increase as much as 222%, and the project would still break even. It is important to note that if any one of these variables changed to these break-even levels and if there were adverse changes in any of the other variables, the project would not return its desired rate of return as represented by the hurdle rate.

The higher the hurdle rate, the higher the MIRR becomes. For example, doubling the hurdle rate from 5% to 10% increases the MIRR from 13.2% to 14.6%. This is a logical result. The MIRR calculation assumes that positive cash flows are re-invested at the hurdle rate and as funds are re-invested at higher assumed rates, their compounded future value becomes larger, which increases the MIRR.

A counter-intuitive result in this example is that the MIRR is unchanged by the finance rate. This is because annual net cash flows are positive, apart from the initial up-front costs. The result is that the discounted value of the only cash outflow, which occurs at the beginning of the project, is unaffected by the finance rate used.

In contrast to the MIRR, the final ending balance, which is the net benefit (or cost) valued in year 9 (shown in Screenshot 2) is inversely affected by the finance rate used. As the finance rate increases, the ending balance declines. The ending balance is equal to $0 when the finance rate reaches 16.6%, which is the IRR. To test this result, go the CVal worksheet and copy the IRR (cell G9). Select the cell containing the finance rate (M15) and go to Edit-Paste Special-Values. The exact IRR should now be pasted into the finance rate. Now scroll down to the cell containing the calculation of the final ending balance (cell L54). It should be $0.

The year in which up-front costs occur is an important variable affecting the project's overall return. Its effect is linked to whether pre-contract year sequestered carbon can be counted and traded in the year after the up-front costs occur (the year after entering the sequestration program). Whether or not pre-contract year sequestered carbon can be counted is controlled with a "Yes-No" variable in table 1.

If pre-contract sequestered carbon cannot be counted, then it is beneficial to both the ending balance and the IRR to enroll in the program as soon as possible. The contract year is one of the most critical variables affecting the financial returns. Both the IRR and the ending balance decrease the longer enrollment is delayed. This was shown (Screenshot 6 and Fig. 5). Note in this screenshot and figure that counter year 6 is the last year in which enrollment can occur and still provide a positive total net benefit and ending balance. If enrolment occurs after year 6, the ending balance turns negative and the IRR is less than the specified 5.0% hurdle rate.

Under the other initial conditions, including enrollment in year 6, if pre-contract sequestered CO_2e could be counted, the net benefit would jump to $5,236 for the tract and the final ending balance would become $6,061. The IRR would be 170.0%, with a MIRR of 61.2%. In addition, the

minimum initial carbon price would drop to $1.40/tonne CO_2e and the minimum tract size would drop to just 75 acres. In other words, if pre-contract sequestered carbon is available for trading, the financial benefits are vastly improved.

> *...if pre-contract sequestered carbon is not available for trading, it will be financially beneficial to enroll in a sequestration scheme sooner rather than later. An extension of the program will have an immediate positive effect on the financial feasibility of a sequestration project.*

Alternatively, if the CCX program is extended, the financial benefits are improved. If the CCX program is extended two years through to 2012 and the up-front costs still occur in 2008 (now counter year 4), the net benefit becomes $2,095, the ending balance $2,673, the IRR 33.7% and the MIRR 21.2%. The sensitivity analysis shows that the minimum carbon price becomes $2.04/tonne CO_2e and the minimum tract size drops to 128 acres. With five years to accrue benefits, the minimum annual sequestration rate drops to 0.77 tonnes CO_2e/acre.

It is often the case when using discounted cash-flow analysis that financial feasibility is closely linked to both the discount rate and to product prices. This project is unexceptional in this respect. The relationship between total net benefits (or costs) and the discount rate was shown above (Fig. 4). As the discount rate (= hurdle rate) increases, the project's total net benefit decreases. At a hurdle rate of 16.4%, which is the project's IRR, the net benefits are $0 (see also, Screenshot 1). With hurdle rates above this point, the discounted costs are larger than the discounted benefits.

The total net benefits (or costs) and the IRR also appear to be closely linked with the initial carbon price. Both dependent variables are closely correlated with each other. These relationships were shown in Figure 6.

Both the net benefits and the IRR rise and fall rapidly with changes in carbon price. The net benefits turn negative at the break-even carbon price of $2.95/tonne (Screenshot 3).

The maximum total up-front cost is $2,504. That is, if total up-front costs are larger than this amount, the project will not return its required rate of return on investment. It is worthwhile noting that this $2,504 in maximum up-front costs (Screenshot 3) is exactly $504 more than the $2,000 in total initial up-front costs in the default base case. That difference, $504, is also exactly the total net benefit from (Screenshot 1). In other words, the total net benefit shown in the *Summary Financial Information* (Screenshot 1) also represents the maximum amount that total up-front costs could possibly increase with the project still providing at least the required rate of return as represented by the hurdle rate.

The net benefits (costs) are more sensitive to up-front costs than to annual costs and end-of-project costs (Screenshot 8 and Figure 7). This is indicated by the fact that net benefits (costs) both rise and fall more quickly with the same percentage changes in up-front costs compared with annual costs and end-of-project costs. It is also indicated in the break-even analysis (Screenshot 3), which gives cost sensitivity factors of 25% for up-front costs but 62% for annual costs and 222% for end-of-project costs. This smaller percentage for up-front costs indicates a smaller buffer in cost rises before break-even occurs.

Other break-even analyses indicate that the minimum tract size required is 204 acres and the minimum year 1 carbon sequestration rate is 1.22 tonnes CO_2e/acre/year (Screenshot 3). This means that if the number of acres was less than 204, the initial up-front costs would be too large for the project to break even. Similarly if the annual carbon sequestration rate was less than 1.22 tonnes CO_2e/acre/year, the project would not return its required rate of return on investment as represented by the hurdle rate.

Limitations

CVal provides no guarantee that a carbon sequestration contract will be profitable. The program requires a user to enter some forward-looking estimates of prices, costs, sequestration rates, and interest rates. CVal's results will only be as good as are the forecasted benefits and costs.

CVal's analysis covers only the carbon sequestration component of forest management. The results apply only to that component. That is, CVal is a tool for doing an incremental or marginal analysis. CVal does not incorporate the full silvicultural costs and harvest revenues or opportunity costs for possible revenues foregone as a result of entering into a carbon sequestration contract. However, CVal's results could be included with those of other forest management tools to produce numbers for a full comparative analysis.

CVal is not set up to do options analysis. An aggregator might ask, "Given carbon prices today and their variability, am I better off trading today or should I hold off trading until possibly next month or next year?" While CVal can be used to analyze the effect of changing prices on overall returns and can quickly provide the answer to what returns and cash flows would look like if prices did change to a specific level, the program is not designed to provide the value of the option to trade later, given a price variability range.

Apart from possibly delaying entry into the CCX program, which delays the initial cost and payment, and the carbon reserve, which has an effect on the final payment, an inbuilt assumption in CVal is that the sequestered carbon will be traded annually. There is not an option within CVal to delay trading and accumulate annually sequestered carbon for a future year. However, this limitation could be worked around by having the sequestration rate be "variable" (cell

J9), manually entering a 0 for the annual carbon sequestration in one or more years (cells C32:C38) in which carbon would be sequestered but not traded, and then manually adding the carbon that was not traded to the amount sequestered in the next year in which a trade is planned to occur.

CVal is only set up to allow complete calculations through Phase 2 of the CCX, which finishes in 2010. If the program is renewed and extended into a Phase 3 then the current version of CVal would have to be modified slightly. The CCX end-of-program year (cell M17) would have to be changed and the year that up-front costs occur (cell M11) would have to be adjusted. If pre-contract carbon was allowed to be counted, then the sequestration rate would have to be "variable" and the year 1 sequestration rate would have to include all the prior years' carbon going back to 2003. After making these changes, the *Break-Even Sensitivity Analysis* table would have to be re-constructed. These adjustments would work as long as the CCX program was not extended more than seven years beyond the current calendar year. If the program was extended for more than seven years, then the structure of the CVal program itself would have to be modified.

Conclusions

The results of this study show that many variables affect the financial attractiveness to a landowner of entering into a carbon sequestration contract. The year that up-front costs occur is probably the most critical variable affecting overall financial returns. Carbon prices, carbon sequestration rates, and the hurdle rate are also important variables determining overall profitability. Up-front costs are probably going to have a larger effect on overall profitability than on-going verification, re-certification, and trading fees.

CVal is a tool that can be used to quickly analyze variables that affect the benefits and costs of a carbon sequestration project and determine their effect on the project's returns. The tool can be used to show under what conditions a contract is worthwhile to a landowner, and answer "What if?" questions if those conditions change. Break-even analysis shows how much key variables can change while still having the project return at least its minimum desired rate of return.

Finally, just because a carbon sequestration contract may appear financially favorable or unfavorable for a landowner does not mean that it "should" or "should not" be entered into. There may be non-market factors coming into the analysis that have an effect on the decision.

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Appendix 1—Selected Financial Terms Used in CVal

Annual costs are costs that occur each year, including the aggregator's fee, verification costs, and annual re-certification costs.

IMPORTANT! The annual costs in CVal **should not** include inflation.

Annualized benefits (costs) are the *net benefits (costs)* annualized over the number of years from the contract year to the end of the program using the *hurdle rate* and an annuity formula. This spreads the *net benefits (costs)* over the number of years the project is in place.

Benefits and costs are measured in CVal in terms of cash flows.

Benefits are equal to the price of CO_2e each year ($/tonne) times the amount of CO_2e traded in each year (tonnes). CVal has an in-built assumption that the cash benefits are received in the year after the carbon is sequestered.

Costs are equal to *up-front costs* (in the *contract year* only), plus *annual costs*, plus *end-of-project costs* (in the final year only)

See also: annualized benefits (costs)
net benefits (costs)

IMPORTANT! The benefits and costs in CVal **should not** include inflation.

Break-even analysis is an analysis in which a specified input variable is changed until the *financial break-even point* is reached.

Cash flow is the sum each year of the benefits less the costs in that year. When each cash flow is discounted using the *hurdle rate* and then summed, the result is the *net benefit (cost)*.

Contract year is the year in which the *up-front costs* are paid. This is the start of the project.

Ending balance is a measure of project profitability. The ending balance each year is equal to the beginning balance plus interest earned at the *hurdle rate* on positive beginning balances (or less interest charged at the *finance rate* on negative beginning balances) plus the carbon credit benefit paid, less total costs.

See also: final ending balance

End-of-project costs are costs (if any) required in the final year of the project. In CVal, the end-of-project costs includes the ending inventory cost.

IMPORTANT! The end-of-project costs in CVal **should not** include inflation.

Final ending balance is a measure of project profitability. Final ending balance is the *net benefit (cost)* that would be expected at the end of the project if the cash flows and reinvestments occurred as predicted. If the final ending balance is positive, the project will be expected to earn a rate of return greater than its *hurdle rate*. If the final ending balance is negative, the project will be expected to earn a rate of return less than its *hurdle rate*. If the final ending balance is $0, the project will be expected to earn exactly its *hurdle rate*.

See also: ending balance

Finance rate is used in the calculation of the modified internal rate of return MIRR and the ending balance. Finance rate is the cost of borrowed money invested in the project.

IMPORTANT! The finance rate in CVal **should not** include inflation.

Financial break-even is a break-even point at which the *net benefits (costs)* valued in the *contract year* are exactly $0. Note that at the financial break-even point, a project's rate of return will be exactly equal to its *hurdle rate*.

Hurdle rate is the interest rate that investors require for the investment to be worth the risk. It may represent the cost of equity capital or the return expected on the next best alternative investment with similar risk.

The hurdle rate is used to calculate total *net benefit (cost)*. The hurdle rate is also used as the reinvestment rate in calculation of the *MIRR* and as the reinvestment rate for positive balances in calculation of a project's *ending balance* and *final ending balance*.

IMPORTANT! The hurdle rate in CVal **should not** include inflation.

Internal rate of return (IRR) is an interest rate that, if used to discount the net cash flows (benefits minus costs), will cause their sum to be $0. If the IRR is used as both the *hurdle rate* and the *finance rate*, the final ending balance will also be $0.

If IRR is used as a measure of an investment's return, its calculation implicitly assumes that any intermediate cash flows will be borrowed or re-invested at the calculated IRR.

Modified internal rate of return (MIRR) is a measure of return on investment. MIRR's calculation assumes that any negative intermediate cash flows will be borrowed at the assumed *finance rate* and any positive cash flows will be re-invested at the assumed *hurdle rate*.

Net benefit (cost) is a measure of project profitability. Benefits and costs are both adjusted by the *hurdle rate* and the year in which they occur. Net benefits (costs) at the start of the project are equal to its net present value. Net benefits (costs) at the end of the project are equal to its final *ending balance*.

Sensitivity analysis factor can be used to increase or decrease a specified input variable by an entered percentage.

Up-front costs are the initial costs required to enter into a sequestration program to allow sequestration credits to be sold. In CVal, up-front costs consist of initial inventory cost, management plan cost, certification cost, and other up-front costs. It is assumed in CVal that these up-front costs occur in the *contract year*, which is in the year before any carbon trading can occur.

Appendix 2—CVal's Variables

Most of CVal's variables are entered in table 1: *Cash Flow Inputs*. Depending on the options selected, annual sequestration rates and annual carbon prices may need to be entered in table 2: *Per Acre Inputs and Present Value Calculations*. Other variables not included in either of these tables include the tract name, which is entered at the top of the spreadsheet, and starting points and incremental changes for the sensitivity analyses, which are entered in the sensitivity analysis tables. The main input variables follow in their order of appearance in the tables on the CVal worksheet.

Tract size: Up-front costs tend to be fixed, regardless of the tract size. For that reason, the relationship between the tract size and the net benefit or cost is not strictly linear.

Default: 250 acres

Year 1 carbon sequestration rate (tonnes CO_2e/ac/yr): The CCX bases its contract prices in terms of metric tonnes (1 tonne = 2,205 pounds av).

Default: 1.50 tons CO_2e/ac/yr and "Constant"

Sequestration rate is… "Constant" or "Variable." Like the carbon price, the sequestration rate may be "Constant" or "Variable." If it is "Constant," the Year 1 rate should remain unchanged throughout the project life (a warning will appear if it varies). If it is "Variable," the Year 1 rate should be different for at least one year in the project life (a warning will appear if it is constant).

Default: Constant

Carbon reserve pool factor: Each year that carbon is sequestered, the CCX requires that 20% be placed into a "Carbon Reserve Pool" to act as an insurance against catastrophic losses. If a catastrophic loss occurs, the landowner's carbon liability may be limited to this reserve. If the landowner decides to harvest, the liability extends to the amount harvested.

Although the landowner retains ownership of this reserve, it may not be traded until the final year. In this spreadsheet's cash flow and rate of return calculations, it is assumed that the entire carbon reserve pool is traded in the final year.

Default: 20%

Initial carbon price applies to the second counter year because carbon is traded in the year after it is sequestered, so the earliest that carbon could be traded is counter year 2.

Default: \$3.50/tonne CO_2e

Carbon price is…: "Constant" or "Variable." Like the carbon sequestration rate, the price may be "Constant" or "Variable." If it is "Constant," the Initial carbon price should remain unchanged throughout the project life (a warning will appear if it varies). If it is "Variable," the Initial carbon price should be different for at least one year in the project life (a warning will appear if it is constant).

Default: Constant

Aggregator's fee is an annual cost percentage multiplied by the carbon credit benefit each year. It is incurred when carbon is traded.

Default: 10%

Verification fee is a cost per tonne that is multiplied by the carbon actually traded each year.

Note: except for the final year, this does not include the carbon in the reserve.

Default: \$0.25/tonne CO_2e

Annual re-certification cost: This annual fee is the cost for the tract to remain in the certification program.

Default: \$0/tract

Trading fee is the per-tonne fee charged by the Chicago Carbon Exchange (CCX), multiplied by the carbon actually traded each year.

Note: except for the final year, this does not include the carbon in the reserve pool.

Default: \$0.20/tonne CO_2e

Other annual costs is a catch-all placeholder to accommodate other ongoing costs not explicitly incorporated into this model.

Default: \$0.00/acre

Up-front costs sensitivity factor (UFCSF) makes it easy to run a sensitivity analysis on all the up-front costs. The up-front costs consist of the

- Initial inventory cost
- Management plan cost
- Certification cost
- Other up-front costs

Normally the UFCSF is set at 0%. Then all four up-front costs are calculated as specified in this cash flow inputs table. Further examples may clarify how this number works.

- If the UFCSF is 10%, all four up-front costs are increased by 10%.
- If the UFCSF is – 20%, all four up-front costs are decreased by 20%.
- If the UFCSF is – 100% (that is, negative 100%), there are no up-front costs.

A break-even value for the UFCSF is included in the *Sensitivity Analysis* table, and table 7 contains a sensitivity analysis for this variable.

Note that for the UFCSF to work correctly, the up-front costs in table 1 (cells M7:M10) must be entered as a function of the total up-front costs (cell M19).

Default: 0%

Annual costs sensitivity factor (ACSF) makes it easy to run a sensitivity analysis on all the annual costs.

The annual costs consist of the

- Aggregator's fee
- Verification fee
- Annual re-certification cost
- Trading fee
- Other annual costs

Normally, the ACSF is set at 0%. Then all five annual costs are calculated as specified in table 1. Further examples may clarify how this number works.

- If the ACSF is 10%, all five annual costs are increased by 10%.
- If the ACSF is – 20%, all five annual costs are decreased by 20%.
- If the ACSF is – 100% (that is, negative 100%), there are no annual costs.

A break-even value for the ACSF is included in the *Sensitivity Analysis* table and table 7 contains a sensitivity analysis for this variable.

Default: 0%

End-of-project costs sensitivity factor (EOPCSF) makes it easy to run a sensitivity analysis on both end-of-program costs. The end-of-program costs consist of the

- Ending inventory cost
- Other end-of-project costs

Normally the EOPCSF is set at 0%. Then both end-of-project costs are calculated as specified in this cash flow inputs table. Further examples may clarify how this number works.

- If the EOPCSF is 10%, both end-of-project costs are increased by 10%.
- If the EOPCSF is – 20%, both end-of-project costs are decreased by 20%.
- If the EOPCSF is – 100% (negative 100%), there are no end-of-project costs.

A break-even value for the EOPCSF is included in the *Sensitivity Analysis* table, and table 7 contains a sensitivity analysis for this variable.

Note that for the EOPCSF to work correctly, the end-of-project costs in table 1 (cells M12:M13) must be entered as a function of the total end-of-project costs (cell M20).
Default: 0%

Initial inventory cost is the total cost of doing the initial inventory. One of the initial up-front costs, it is on a per-tract basis.

Default: = total_up-front_costs × 50% or $1,000/tract

Management plan cost is the cost of writing the management plan for the forest tract. A management plan is required for certification and thus for carbon trading. It is one of the initial up-front costs and is on a per-tract basis.

Default: = total_up-front_costs × 50% or $1,000/tract

Certification cost is the initial forest certification costs. Forest certification is required for CCX forest carbon offset trading and is one of the initial up-front costs on a per-tract basis.

Default = total_up-front_costs × 0% or $0/tract

Other up-front costs is a catch-all placeholder to accommodate one-off costs that have not been explicitly incorporated into this model. It is one of the initial up-front costs and is on a per-tract basis.

Default = total_up-front_costs × 0% or $0/tract

Contract year (Year that up-front costs occur) is the year in which the initial inventory, management plan, certification, and other up-front costs are incurred. It is assumed to be the year in which a contract with an Aggregator is entered. It also specifies the year in which PV (Present Value) is calculated.

NOTE: Some landowners might have paid up-front costs before entering a carbon contract. These are sunk costs and should not be considered in the evaluation of the present contract unless they could somehow be recovered if the contract is not entered.

Default: 6

Ending inventory cost is the cost (if any) of doing a closing inventory prior to the final carbon payout.

Note that entering this variable as a function to total_end_of_project_costs will allow the use of "Goal Seek" to find the maximum end-of-project costs that would still return the required rate of return as represented by the hurdle rate.

Default: total_end_of_project_costs × 100%

Other end-of-project costs is a catch-all placeholder to accommodate other end-of-project costs that have not been explicitly incorporated into this model.

Note that entering this variable as a function to total_end_of_project_costs will allow the use of "Goal Seek" to find the maximum end-of-project costs that would still return the required rate of return as represented by the hurdle rate.

Default: total_end_of_project_costs × 0%

Hurdle rate is the interest rate that investors require for this investment to be worth the risk. It may represent the cost of capital or the next best alternative investment with similar risk.

The hurdle rate is used to calculate the total net benefit. It is also used as the reinvestment rate in the calculation of the MIRR.

IMPORTANT! The hurdle rate **should not** include inflation. Since inflation is not included into costs and revenues in this worksheet model, inflation should not be incorporated into the hurdle rate. In economic terms, this hurdle rate is a real (not a nominal) rate of return.

To change a nominal interest rate (including inflation) into a real rate, use the formula

Real rate = [(1 + Nominal rate)/(1 + Inflation)] – 1,

where all interest rates are in decimal form.

For example,

Nominal rate is 9.2%
Inflation rate 4.0%
Real rate [(1 + 0.092)/(1 + 0.040)] – 1
Real rate 0.050 = 5.0%

Default: 5.0%

Finance rate is used in the calculation of the modified IRR. It is the cost of borrowed money invested in this project.

IMPORTANT! Like the hurdle rate, the finance rate **should not** include inflation. See the hurdle rate for an example of how to convert a nominal interest rate, which includes inflation, into a real interest rate without inflation.

Default: 5%

Count pre-contract carbon? "No" or "Yes"

If "No," then the sequestered carbon stocks in years prior to certification will not be counted or available for trading.

If "Yes," then tonnes of sequestered carbon from the pre-contract years back to the starting year will be summed and available for trading in the year after certification. The Chicago Climate Exchange (CCX) now allows credits for new managed forest offset projects only from the year in which there was a forest inventory conducted.

Default: "No"

End-of-project year: CVal is set up to begin calculations seven years before the end-of-project year because the CCX began trading in 2003 and Phase 2 of its protocol extends to 2010.

CVal can be modified to perform calculations for an end-of-project year up to seven years after the present time. In other words, if the present year is 2008, the latest end-of-project year could be 2015. However, the end-of-project year should not be later than the date the current protocol is set to expire.

Default: 2010

Total up-front costs (M19) is a variable that can be used with "Goal Seek" to determine the magnitude of up-front costs that will make the total net benefits = $0.

The total up-front costs equal the sum of initial inventory cost, management plan cost, certification cost, and other up-front costs; that is, the sum of cells M7–M10. Total_up-front_costs (in cell M19) should be entered as a value, rather than by formula.

IMPORTANT! If the value for total_up-front_costs is initially set at $0, then the IRR and MIRR will be undefined. In addition, the Maximum up-front costs sensitivity factor found by running a break-even sensitivity analysis using macro or "Goal Seek" will be meaningless.

If the user then wants to determine what total up-front cost will make the total net benefit = $0, cells M7–M10 should be set as a function of total_up-front_costs. Goal Seek can then be used to set NPV = $0 by changing total_up-front_costs.

For example, if Initial inventory and Management plan both make up 50% of total_up-front_costs, with Certification and Other up-front costs both being $0, M7 and M8 should both be temporarily specified as " = total_up-front_costs × 0.5" and M9 and M10 should both be "0," or "= total_up-front_costs × 0.0". Next, use Tools-Goal Seek and Set cell G8 (the total net benefit) to value 0 by changing cell M19 (total_up-front_costs). Combining the values for cells M7 and M8 will give the total up-front cost that breaks even (i.e., total net benefit =$0).

IMPORTANT! If you do this, make sure that the percentages for the four up-front costs add up to 100% (e.g., 50% Initial inventory, 50% Management plan, 0% Certification cost, and 0% Other up-front costs).

Resetting the default cash flow inputs in Tools-Scenarios will restore $1000 values to initial inventory and management costs. The Scenarios tool cannot restore formulas. After running the Scenarios tool, the "total up-front costs" variable will have no dependents, and Goal Seek will not work with this variable.

Resetting the default cash flow inputs using the "Restore_Default_Values" macro will avoid this problem.

Default: $2,000

Total end-of-project costs (M20) is a variable that can be used with "Goal Seek" to determine the magnitude of end-of-project costs that will make the total net benefit = $0.

The total end-of-project costs equal the sum of Ending inventory and Other end-of-project costs; that is, the sum of cells M12–M13. Total_end_of_project_costs should be entered as a value, rather than by formula.

IMPORTANT! If the value for total_end_of_project_costs is initially set at $0, then the Maximum end-of-project costs sensitivity factor found by running a break-even sensitivity analysis using macro or "Goal Seek" will be meaningless.

If the user then wants to determine what total_end_of_project_costs will make the total net benefit = $0, cells M12:M13 should be set as a function of total_end_of_project_costs. Goal Seek can then be used to set total net benefit = $0 by changing total_end_of_project_costs.

For example, if ending inventory makes up 100% of total_end_of_project_costs, with Other end-of-project costs being 0%, M9 should both be temporarily specified as

"= total_End_of_project_costs × 100%" and M10 should be either "0" or

"= total_End_of_project_costs × 0%". Next, use Tools-Goal Seek and *Set cell* G8 (the total net benefit) *To value* 0 *By changing cell* M20 (total_end_of_project_costs). Combining the values for cells M9 and M10 will give the total end-of-project cost that breaks even (i.e., total net benefit = $0).

IMPORTANT! If you do this, make sure that the percentages for the two end-of-project costs add up to 100% (e.g., 100% Ending inventory and 0% Other end-of-project costs).

NOTE: Resetting the default cash flow inputs in Tools-Scenarios in the non-macros version of CVal will restore $250 values to Ending inventory and $0 to Other end-of-project costs. The Scenarios tool cannot restore formulas. After running the Scenarios tool, the "total end-of-project costs" variable will have no dependents, and Goal Seek will not work with this variable. Resetting the default cash flow inputs using the "Restore_Default_Values" macro will avoid this problem.

Default: $250

Appendix 3—CVal's Macros

This spreadsheet file contains macro scripts that may be useful for a user. They are optional and located on the worksheet tab labeled "Macro Scripts." CVal comes in two versions – with and without macros. The CVal spreadsheet was constructed without macros because macros can carry viruses and because not all versions of Excel support macros. Everything that these scripts do can be done without macros. However, using macro scripts may make certain repetitive operations easier. The CVal version with macros has the following scripts pre-installed. In addition, this version has buttons on the CVal worksheet to make it easier to run a full break-even analysis and to store and re-store user-entered input values.

The macros are divided into two groups: break-even macros and utility macros. Following the descriptions of the macros is a section on using these macros scripts.

Break-Even Macros

The break-even macros all use Excel's built-in "Goal Seek" tool to find values for the variables that would still provide the minimum desired rate of return. That is, the macros find the values that will make the net benefits (costs) = $0.

- **Min_Carbon_Price** finds the minimum initial carbon price. Note that for this macro to provide meaningful results, it is important that the carbon prices in all years in table 2 be entered by formula as a function of the first year's price.
- **Min_Tract_Size** finds the minimum tract size given the fixed up-front costs that occur regardless of tract size.
- **Min_Sequestration_Rate** finds the minimum carbon sequestration rate. Note that for this macro to provide meaningful results, it is important that the carbon sequestration rates in all years in table 2 be entered by formula as a function of the first year's sequestration rate.
- **Max_Up-front_Costs** finds the maximum up-front costs that could be paid. Note that for this macro to provide meaningful results, it is important that the four up-front costs in table 1 be entered by formula as a function of the total up-front costs.
- **Max_End_of_Project_Costs** finds the maximum end-of-project costs that could be paid. Note that for this macro to provide meaningful results, it is important that the two end-of-project costs in table 1 be entered by formula as a function of the total end-of-project costs.
- **Max_Annual_Costs_Sensitivity** finds maximum percentage that annual costs could increase.
- **Max_Up-front_Costs_Sensitivity** finds the maximum percentage that up-front costs could increase. Note that for this percentage to be meaningful, total up-front costs cannot be $0.
- **Max_End_of_Project_Costs_Sensitivity** finds the maximum percentage that end-of-project costs could increase. Note that for this percentage to be meaningful, total end-of-project costs cannot be $0.
- **Breakeven_Analysis** automatically runs break-even analyses to find the minimum carbon price, the minimum tract size, the minimum sequestration rate, the maximum up-front costs, the maximum end-of-program costs, the maximum annual costs sensitivity, the maximum up-front costs sensitivity, and the maximum end-of-program costs sensitivity. The macro pastes the results into the Break-even analysis table and restores the original user-entered variables into the input tables.

  Note that for results from this macro to be meaningful, formulas must be entered in table 1 for the up-front costs and end-of-program costs and in table 2 for the carbon prices and carbon sequestration rates, as discussed in the individual break-even analysis macros above.

Utility Macros

- **Store_Starting_Values** stores the user-entered starting input values in table 8, the *Storage Table for Starting Values*. These values include user-entered variables in table 1 and table 2, the user-entered variables in the sensitivity analysis tables, and the variables from the break-even analysis table. For the latter reason, Store_Starting_Values first calls and automatically runs the break-even analysis macro before storing any values. In the CVal version with macros pre-installed, the Store_Starting_Values macro may be run using the "Store values" button above table 1.
- **Restore_Starting_Values** restores the starting values from table 8, the "Storage Table for Starting Values." Note that the restored values include those in the break-even analysis table. In the CVal version with macros pre-installed, the Restore_Starting_Values macro may be run using the "Restore values" button above table 1.
- **Restore_Default_Values** restores the default variable values that originally came with the spreadsheet, including those in the break-even analysis table.
- **Fix_Constant_Carbon_Prices** fixes the annual carbon prices in table 2 if they are supposed to be constant but there was some warning message indicating otherwise.
- **Fix_Constant_Carbon_Sequestration Rates** fixes the annual carbon sequestration rates in table 2 if they are supposed to be constant but there was some warning message indicating otherwise.

To use these macro scripts

For CVal with macros pre-installed…

- For a full break-even analysis select the "Run B-E" button to the right of the *Sensitivity Analysis* table. This runs

the Breakeven_Analysis macro, which finds the minimum initial carbon price, the minimum tract size, the minimum year 1 carbon sequestration rate, and the maximum total annual and up-front costs that would still provide the minimum desired rate of return on investment (i.e., the hurdle rate).

- For individual break-even analyses, click the "hot" areas in the titles above each variable in the *Break-Even Analysis* table.
- To store user-entered starting values, including those from the *Break-Even Analysis* table and user-entered variables from the sensitivity analyses, select the "Store values" button above table 1.
- To restore user-entered starting values, including those from the break-even analysis table and user-entered variables from the sensitivity analyses, select the "Restore values" button above table 1.
- To restore the original sample values that came with the CVal program, select the "hot" area in the "Click here to restore original values" box that is just below the *Cash Flow Inputs* title.
- To run these or any other installed macros, go to Tools-Macro-Macros-[Select_Macro_Name]-Run

For CVal without macros pre-installed…

- First set up a "Do nothing" macro. To do this, go to Tools-Macros-Record New Macro. Use the default to store the macro in "This workbook." The default macro name (e.g., "Macro1") is also fine. Give the macro a short-cut keyboard combination, if you wish. Then go back into Tools-Macros-Stop Recording. There will now be a "Do nothing" macro set up that you can edit.
- Open the "Do nothing" macro. To do this, go to Tools-Macros-[Select_Macro_Name]_Edit.
- Now click the Macro Scripts worksheet and copy the full macro script or scripts that you want to be able to run beginning with the "Sub" cell and ending with the "End Sub" cell (the parts between the grayed areas). If you want to copy all the macros, begin with the Break_Even_Macros title and copy all the way down to the bottom of the macro scripts.
- Paste this full macro script over the existing macro script in the "Do nothing" macro in the macro editing box.
- Close the macro editing box and return to Microsoft Excel. To do this, hit the red X (close) button in the upper right corner of the macro editing box, or go to File-Close and Return to Microsoft Excel on the macro editing worksheet.
- Run the macro by *first opening the CVal worksheet page*. Then go to Tools-Macro-Macros-[Select_Macro_Name]-Run

Summary financial information for Peavey Pines	
Total net benefit at 5.0% valued in year 6 :	**$ 504**
Internal rate of return :	**16.6%**
Modified internal rate of return* :	**13.2%**

*MIRR at a finance rate of 5.0% and a reinvestment rate of 5.0%.

NOTE: Pre-contract sequestered CO2e IS NOT included in the benefits.

Screenshot 1—CVal's summary financial information.

Benefits and costs discounted at the hurdle rate of 5.0%				
	---------- Total ----------		--- Annualized over 3 years ---	
	Per acre	Per tract	Per acre	Per tract
Benefits valued as of year 6	$ 14.16	$ 3,540	$ 5.20	$ 1,300
Costs valued as of year 6	(12.14)	(3,036)	(4.46)	(1,115)
Net benefit valued as of year 6	**$ 2.02**	**$ 504**	**$ 0.74**	**$ 185**
Net benefit valued as of year 9	**$ 2.33**	**$ 583**	**$ 0.74**	**$ 185**

NOTE: Per acre and per tract annualized net benefits valued at year 6 and year 9 are identical because the hurdle rate and finance rate are identical at 5.0%

Screenshot 2—CVal's benefits and costs table.

Break-even sensitivity analysis for Peavey Pines Run B-E

Minimum initial carbon price ($/tonne CO_2e)	Minimum tract size (acres)	Min. yr. 1 carbon sequestration rate (tonnes CO_2e/ac/yr)	Maximum total up-front costs ($/tract)	Maximum total end-of-project costs ($/tract)	Maximum annual costs sensitivity factor	Maximum up-front costs sensitivity factor	Maximum end-of-project costs sensitivity factor
$ 2.95	**204**	**1.22**	**$ 2,504**	**$ 806**	**62%**	**25%**	**222%**

WARNINGS!
These values only change by running a "Breakeven_Analysis" macro.
The maximum total up-front and end-of-project costs macros require formulaic specification of up-front costs in Table 1. The minimum price and sequestration rate macros require formulaic specification of price and carbon sequestration rate in Table 2. The full break-even analysis macro requires all four formulaic specifications.
If there are no up-front or end-of-project costs, their respective sensitivity factors will be meaningless.

Screenshot 3—CVal's break-even sensitivity analysis table.

1. CASH FLOW INPUTS					
	Click on Tools-Scenarios-Default-Show to restore default values				
Tract size	250	acres	Initial inventory cost	$ 1,000	per tract
Year 1 carbon sequestration rate	1.50	tonnes CO_2e/ac/yr	Management plan cost	$ 1,000	per tract
Sequestration rate is…	Constant		Certification cost	$ -	per tract
Carbon reserve pool factor	20%		Other up-front costs	$ -	per tract
Initial carbon price	$ 3.50	per tonne CO_2e	Contract year (Year that up-front costs occur)	6	(counter year)
Carbon price is…	Constant		Ending inventory cost	$ 250	per tract
Aggregator's fee	10%		Other end-of-project costs	$ -	per tract
Verification fee	$ 0.25	per tonne CO_2e	Hurdle rate	5.0%	
Annual re-certification cost	$ -	per tract	Finance rate	5.0%	
Trading fee	$ 0.20	per tonne CO_2e	Count pre-contract carbon?	No	
Other annual costs	$ -	per acre	End-of-project year	2010	
Up-front costs sensitivity factor	0%				
Annual costs sensitivity factor	0%		Total up-front costs	$ 2,000	per tract
End-of-project costs sensitivity factor	0%		Total end-of-project costs	$ 250	per tract
WARNINGS FOR THE INPUT TABLE (below):					

Screenshot 4—CVal's main user-entered input variables.

Year	Counter year	Beginning balance ($/acre)	Interest earned (Interest charged) ($/acre)	Carbon credit benefit paid ($/acre)	Total costs ($/acre)	Ending balance ($/acre)
2003	1		$ -		$ -	$ -
2004	2	$ -	$ -	$ -	$ -	$ -
2005	3	$ -	$ -	$ -	$ -	$ -
2006	4	$ -	$ -	$ -	$ -	$ -
2007	5	$ -	$ -	$ -	$ -	$ -
2008	6	$ -	$ -	$ -	$ (8.00)	$ (8.00)
2009	7	$ (8.00)	$ (0.40)	$ 4.20	$ (0.96)	$ (5.16)
2010	8	$ (5.16)	$ (0.26)	$ 4.20	$ (1.96)	$ (3.18)
2011	9	$ (3.18)	$ (0.16)	$ 7.35	$ (1.68)	**$ 2.33**

Screenshot 5—CVal's ending balance calculations from table 3 with final ending balance highlighted.

5. Sensitivity of Total net benefits (costs), IRR, MIRR, and ending balance to the specified counter year in which up-front costs occur for Peavey Pines

Year	Specified counter year	Total net benefits (costs) at 5.0%	Internal rate of return	Modified IRR at 5.0% finance and 5.0% reinvestment rates	Ending balance at 5.0% finance and 5.0% reinvestment rates
2003	1	$ 4,154	39.4%	20.8%	$ 6,137
2004	2	$ 3,508	38.5%	21.3%	$ 4,936
2005	3	$ 2,822	36.8%	21.6%	$ 3,782
2006	4	$ 2,095	33.7%	21.2%	$ 2,673
2007	5	$ 1,323	27.9%	19.2%	$ 1,608
2008	6	$ 504	16.6%	13.2%	$ 583
2009	7	$ (365)	-6.8%	-5.1%	$ (402)
2010	8	$ (1,286)	-55.0%	-55.0%	$ (1,350)
NOTE: Pre-contract sequestered CO2e IS NOT included in the benefits.					
	Maximum:	$ 4,154	39.4%	21.6%	$ 6,137
	Maximum in year:	1	1	3	1

Screenshot 6—CVal's sensitivity analysis table for the year in which up-front costs occur.

6. Sensitivity of Total net benefits (costs), IRR, MIRR, and ending balance to the initial carbon price for the Peavey Pines project beginning in counter year 6

	Initial carbon price ($/tonne CO_2e)	Total net benefits (costs) at 5.0% ($/tract)	Internal rate of return (%)	Modified IRR at 5.0% finance and 5.0% reinvestment rates (%)	Final ending balance at 5.0% finance and 5.0% reinvestment rates ($/tract)
	$ 1.00	$ (1,772)	-52.7%	-43.2%	$ (2,051)
	$ 2.00	$ (861)	-17.8%	-13.0%	$ (997)
	$ 3.00	$ 49	6.2%	5.8%	$ 56
	$ 4.00	$ 959	26.4%	19.6%	$ 1,110
	$ 5.00	$ 1,869	44.8%	30.8%	$ 2,164
	$ 6.00	$ 2,779	61.9%	40.4%	$ 3,217
	$ 7.00	$ 3,690	78.3%	48.8%	$ 4,271
	$ 8.00	$ 4,600	94.0%	56.3%	$ 5,325
	$ 9.00	$ 5,510	109.4%	63.2%	$ 6,378
	$ 10.00	$ 6,420	124.4%	69.5%	$ 7,432
				Initial carbon price increment:	**$ 1.00**

NOTE: Pre-contract sequestered CO2e IS NOT included in the benefits.

Screenshot 7—CVal's sensitivity analysis table showing financial measures as a function of the initial carbon price.

7. Sensitivity of net benefits or costs to percentage changes in the annual, up-front costs and end-of-project costs for Peavey Pines

Cost sensitivity factor	Net benefits (costs) with annual cost changes	Net benefits (costs) with up-front cost changes	Net benefits (costs) with end-of-project cost changes
-25%	$ 706	$ 1,004	$ 561
-20%	$ 666	$ 904	$ 549
-15%	$ 625	$ 804	$ 538
-10%	$ 585	$ 704	$ 527
-5%	$ 544	$ 604	$ 515
0%	$ 504	$ 504	$ 504
5%	$ 463	$ 404	$ 493
10%	$ 423	$ 304	$ 481
15%	$ 382	$ 204	$ 470
20%	$ 342	$ 104	$ 459
25%	$ 302	$ 4	$ 447
30%	$ 261	$ (96)	$ 436
35%	$ 221	$ (196)	$ 424
40%	$ 180	$ (296)	$ 413
45%	$ 140	$ (396)	$ 402
50%	$ 99	$ (496)	$ 390
		Sensitivity factor increment:	**5%**

Screenshot 8—CVal's sensitivity analysis table showing net benefits (costs) as a function of the cost sensitivity factors for annual costs, up-front costs, and end-of-project costs.

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