Financial accounting model

Authors

Eric Kemp-Benedict, Stockholm Environment Institute

Lineu Rodrigues, EMBRAPA-Cerrados

Scope: Questions and challenges

The purpose of the tool is to convert the outputs of a water planning model like WEAP into variables useful for decision-making by planners and farmers. The tool can also be used in a stand-alone fashion, without links to such models. It can be used in "direct mode" where calculations are performed only once, or in "Monte Carlo mode", where calculations are carried out multiple times and summary statistics are generated.

It is meant to be applied to a small number of farmers located in the same watershed.

The tool is designed for the following purposes:

- Estimate the initial and recurring farm-level costs of water-related infrastructure, including capital investment and amortization, and operational expenses
- Estimate the price and income consequences for farmers of increased production (higher yields, increased planted area) of particular crops

Target group

The tool is targeted at planners, farmers or other stakeholders who wish to explore some of the consequences of certain agricultural or water-related investments in a defined watershed. The use of the model requires a practitioner who is familiar with the agricultural practices used in that watershed.

Requirements for application

The tool is a command-line program.[1] Using it requires some facility with computers, including the editing of text files. The user must provide estimates for a large number of external parameters. Apart from adjusting crop prices as a function of total production, the tool is less a model and more a financial accounting framework. It simply keeps track of financial flows, based on parameter levels supplied by the user.

The following parameters are required for the program. Items marked with an asterisk (*) can be entered either as a constant number or as a formula. Formulas can include random or pseudo-random numbers drawn from uniform, normal, or gamma distributions.

[1] It can be downloaded from http://www.kb-creative.net/sei/SRP/FinancialModel/, with sample files.

Unit input prices

- Irrigation fees (per volume of water) *
- Non-water input prices (per unit of input) *
- Electricity price (per kwh or similar unit) *
- Wage for hired labor (per person-day or similar unit) *

Output parameters (see below for further discussion)

- Reference price by crop
- Reference production by crop
- Production elasticity of price, by crop

Input use

- Non-water input application levels, per ha, by crop
- Planted area, by crop*
- Depth of irrigation water by crop*
- Labor input in person-days per hectare, by crop
- Wage labor fraction, by farm

Production

- Crop yield*

Borrowing and debt

- Borrowing to offset costs of new capital
- Term of loan
- Interest rate on loan

The effect of production on prices

Smallholders are price takers in national and global product markets. In local markets, however, there may be occasions in which increased smallholder production can depress prices. This is particularly true where local markets are thin or poorly integrated (near-term prices have also been seen to respond to changes in production levels in integrated but thin markets as well: Sarris and Hallam 2006). This effect has been noted for lemon production in the Buriti Vermilho, the main producing area in the region and the catchment for which this tool was originally developed. In order the capture price responses to increased production, the tool offers a parameter expressing the percent change in price for each percent change in production (a "production elasticity of price"). Where changes in local output are unlikely to affect prices, or where the size of the effect, if any, is unknown, this parameter can be set to zero.

For crops, when the price varies with the level of production, the following formula is used:

$$\pi = \pi_{\text{ref}} \left(\frac{P}{P_{\text{ref}}} \right)^{-\varepsilon},$$

where π is the price, π_{ref} is the reference price, P is production (total for all farms), P_{ref} is the reference level of production, and ε is the production elasticity of price. With this formula, as production goes up, the price goes down. The formula has the feature that when production is equal to reference production ($P = P_{ref}$), then price is equal to the reference price.

The values for parameters marked with an asterisk in the above list may be specified by a formula, including those using a random number generator for various statistical distributions. This is discussed further in the next section.

Description and application

The accounting framework is implemented as a command-line program. It can be run either in direct mode or Monte Carlo mode. In direct mode, calculations are carried out once and the output values reported. In Monte Carlo mode, calculations are carried out many times, as specified by the user, and summary statistics are provided for output values. These options are discussed in more detail later in this section.

The accounting framework represents a group of farmers individually making decisions about investing in water-related equipment, deciding on planted area for different crops, and hiring labor. When equipment is purchased on credit, principal and interest payments are tracked over time. If water-related technology consumes electricity, this can also be tracked. Labor costs can be estimated, using an exogenous wage rate.

In a typical application of the tool, farmers might invest in new equipment in the initial period, repaying the investment over time. Inputs for the financial model can come from assumed constant values, random numbers from an assumed distribution, or from an external model such as WEAP. Outputs of the financial model can be used to assess the financial viability of an investment or ongoing expense. Model results might show, for example, that with suitable water infrastructure and water allocation, particular cropping patterns can result in reasonably steady income streams, even when rainfall remains scarce over the years.

As mentioned above, the user must supply most of the parameters. Apart for adjusting crop prices as a function of total production, the financial accounting framework is not a model. Rather, it keeps track of financial flows, while the user provides the coefficients needed for the financial calculations.

Direct Mode Example

A sample input file for direct mode use is shown below. Basic parameters, such as the daily wage, price of water, number of years to run the model, electricity intensity of pumping, and price of electricity, are provided, as well as definitions of crops and farms. Planted area, irrigation water supplied, and yield for each crop are provided in additional files. In this example, a formula is used to represent the daily wage, beginning at 80 “local currency units per day”, and increasing by 0.2 “local currency units per day” for each year the tool runs.

```
wage {80 + 0.2 * $year}       ;# daily wage, local currency
```

```
waterprice 10
nyears 50      ;# 50-year sequence
kWhPerCubicMeter 0.2
PricePerkWh 1

crop RainfMaize -prodelast 0.2 -refprice 0.2 -refprod 10000 \
    -laborintens 1 -pestintens 0.1
crop IrrMaize -prodelast 0.2 -refprice 0.2 -refprod 10000 \
    -laborintens 1 -fertintens 0.1 -pestintens 0.1

farm Farm_A -hirefrac 0.75
Farm_A addcrop RainfMaize -file "FarmArainf.dat"
```

```
Farm_A addcrop IrrMaize -file "FarmAirr.dat"
Farm_A borrow 10000 3 20  ;# Amount, rate as %/year, term (years)

farm Farm_B -hirefrac 0.2
Farm_B addcrop RainfMaize -file "FarmBrainf.dat"

Farm_B borrow 1000 3 10
```

The first few lines of output from this file are shown below. Outputs include estimates of annual and cumulative net income, calculated as crop sales less loan payments, wage labor, non-water inputs, the cost of water, and the cost of electricity for pumping water.

--- FARM Farm_A ---

Year	Cum Income	Net Income	Crop Sales	Loan Pmts	Wage Labor	Non-Wat Inputs	Water	Electricity
0	10349.74	10349.74	34506.74	0.00	24000.00	55.00	100.00	2.00
1	20857.44	10507.69	35396.85	672.16	24060.00	55.00	100.00	2.00
2	27951.31	7093.87	32043.03	672.16	24120.00	55.00	100.00	2.00
3	37704.50	9753.19	34762.35	672.16	24180.00	55.00	100.00	2.00
4	44547.18	6842.68	31911.84	672.16	24240.00	55.00	100.00	2.00
5	56092.32	11545.14	36674.30	672.16	24300.00	55.00	100.00	2.00
6	64319.43	8227.11	33416.26	672.16	24360.00	55.00	100.00	2.00
7	71390.49	7071.06	32320.22	672.16	24420.00	55.00	100.00	2.00
8	80846.54	9456.06	34765.21	672.16	24480.00	55.00	100.00	2.00
9	92950.39	12103.85	37473.00	672.16	24540.00	55.00	100.00	2.00
10	104239.75	11289.36	36718.52	672.16	24600.00	55.00	100.00	2.00
11	116211.88	11972.13	37461.28	672.16	24660.00	55.00	100.00	2.00
12	122790.36	6578.48	32127.64	672.16	24720.00	55.00	100.00	2.00
13	129340.35	6549.99	32159.14	672.16	24780.00	55.00	100.00	2.00

Monte Carlo Mode

A sample input file for Monte Carlo mode is shown below. In this example, statistical distributions are used to represent some of the parameters, and the simulation is run 1000 times. At the end, mean values are reported, as well as the 10%, 50%, and 90% quantiles (note that the 50% quantile is also the median). For the calculations, one variable is available, *year*, which is referred to by prefacing it with a dollar sign, *$year*.

```
montecarlo -N 1000 -quantiles {0.10 0.50 0.90}

wage {rnorm(80, 20) + 0.2 * $year}      ;# daily wage
waterprice 15
nyears 50     ;# 50-year sequence
kWhPerCubicMeter 0.2
PricePerkWh 1

crop RainfMaize -prodelast 0.2 -refprice 0.2 -refprod 10000 \
    -laborintens 1 -pestintens 0.1
crop IrrMaize -prodelast 0.2 -refprice 0.2 -refprod 10000 \

   -laborintens 1 -fertintens 0.1 -pestintens 0.1

farm Farm_A -hirefrac 0.75
Farm_A addcrop RainfMaize -area 150 -irrwater {max(0, 20 - rgamma(7, 0.8))} \
    -yield {max (0, 1100 - rgamma(300, 0.5))}
Farm_A addcrop IrrMaize -area 250 -irrwater 0 -yield {rnorm(650, 100)}
Farm_A borrow 50000 3 20  ;# Amount, rate as %/year, term (years)

farm Farm_B -hirefrac 0.2
Farm_B addcrop RainfMaize -area 75 -irrwater 0 -yield {rnorm(500, 100)}
Farm_B borrow 1000 3 10
```

The following operators can be used in formulas for expressing area, yield, depth of irrigation water, and other parameters marked with an asterisk: +, -, *, /, and **. The last operator means "raised to the power of". The available functions that can be used in formulas include:

Function	Description
abs(*x*)	Absolute value of *x*
acos(*x*)	Inverse cosine of *x*
asin(*x*)	Inverse sine of *x*
atan(*x*)	Inverse tangent of *x*
atan2(*y*, x)	Alternative inverse tangent, specifying *x* and *y* separately
cos(*x*)	Cosine of *x*
cosh(*x*)	Hyberbolic cosine of *x*
exp(*x*)	Exponential function (Euler's constant *e* raised to the power of *x*)
log(*x*)	Natural logarithm of *x*

Function	Description
log10(*x*)	Log base 10 of *x*
max(*x*, *y*, …)	Maximum of *x*, *y*, …
min(*x*, *y*, …)	Minimum of *x*, *y*, …
runif(*min*, *max*)	A uniformly-distributed random number between *min* and *max*
rnorm(*mu*, *sd*)	A normally-distribution random number with mean *mu* and standard deviation *sd*
rgamma(*mu*, *cv*)	A gamma-distributed random number with mean *mu* and coefficient of variation *cv*
sin(*x*)	Sine of *x*
sinh(*x*)	Hyberbolix sine of *x*
sqrt(*x*)	Square root of *x*
tan(*x*)	Tangent of *x*
tanh(*x*)	Hyberbolic tangent of *x*

The "random-number" generating functions (actually pseudo-random number generators) "runif", "rnorm", and "rgamma", can be used in Monte Carlo mode to produce different outputs on each run.

In the preceding example, the yield for the irrigated crop on Farm A, in spite of irrigation, is taken to be somewhat uncertain, with the yield equal to

yield = max(0, 1100 - rgamma(300, 0.5))

This has a curve like that shown in Figure 1 in which most of the distribution is at relatively high values for the yield, but there is a chance for very low yields.

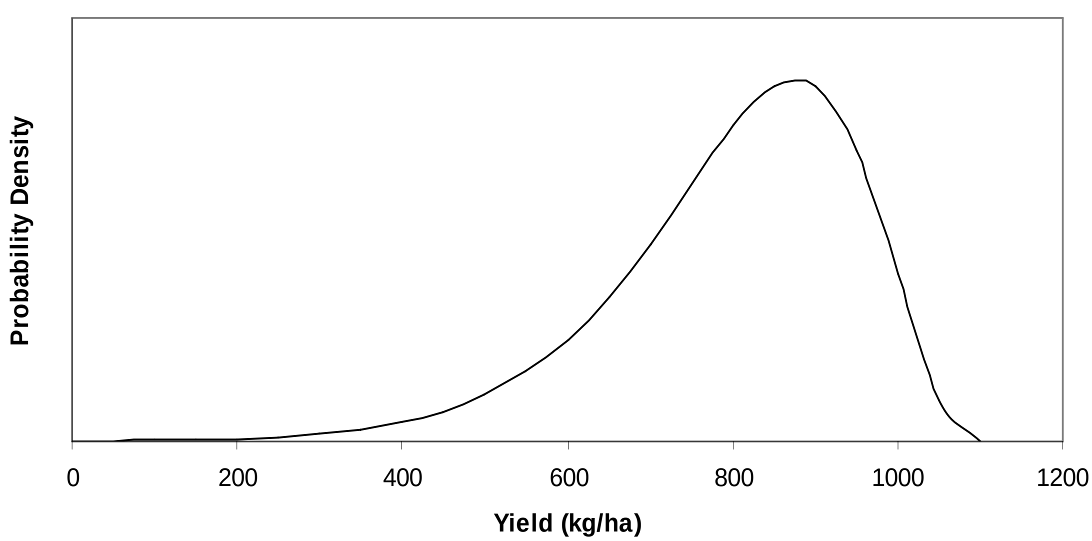

Figure 1: Probability density for different yields on Farm A

The outputs in Monte Carlo mode are harder to show, because each line is wider than in direct mode. The same variables are reported as for direct model. For each variable the mean and quantiles are reported, where the specific quantiles can be specified by the user. For convenience, only the first few lines and columns in the output file are shown below.

For this run, quantiles at the 10%, 50%, and 90% level were specified. As can be seen in the output file, for the first four years of operation, in more than 10% of the simulated cases the cumulative income to the farmer was negative. However, after that point cumulative income is positive in more than 90% of the cases. In this simulation, then, the farmer may want to ensure enough resources to weather at least four years of losses. Note that in all years, in over 10% of the simulated cases, there is a loss of income in that year. However, the net trend is toward increasing income in most of the runs.

Year	Cum Income	Net Income ... --- FARM Farm_A ---
0	[8242.40 : -4001.03 8277.74 19774.51]	[8242.40 : -4001.03 8277.74 19774.51] ...
1	[13148.33 : -4504.34 13256.79 28748.63]	[4905.94 : -7228.83 5120.48 16236.84] ...
2	[18198.47 : -2740.41 18582.53 38551.58]	[5050.13 : -7265.13 5156.69 16931.10] ...
3	[22642.86 : -627.36 22776.21 45756.51]	[4444.39 : -7375.96 4770.51 15268.26] ...
4	[27472.22 : 431.03 27624.23 53513.03]	[4829.36 : -7540.00 4705.24 16527.80] ...
5	[31735.71 : 2455.42 31995.16 60731.84]	[4263.48 : -7538.39 4189.43 15645.60] ...
6	[36103.95 : 4478.05 36402.15 68036.66]	[4368.24 : -7814.37 4316.45 16469.74] ...
7	[40583.20 : 6639.90 40318.37 73728.25]	[4479.25 : -6997.72 4527.37 15528.26] ...
8	[44837.28 : 9565.67 44192.03 80686.60]	[4254.08 : -7301.01 4379.70 15555.70] ...
9	[49115.35 : 11963.88 49725.63 85652.62]	[4278.07 : -8022.20 4227.81 15333.39] ...
10	[53693.74 : 15488.48 54093.18 92027.33]	[4578.39 : -7016.62 4610.26 17218.28] ...
11	[58015.67 : 17331.78 58663.08 101561.74]	[4321.93 : -7522.02 4287.10 16493.51] ...

Lessons learned

The accounting model was designed with the Buriti Vermelho watershed in mind, but has not yet been applied to that watershed.

Recommendations

This tool can be used for simple "what-if" calculations, or for calculations using outputs of a water allocation model like WEAP. If pricing decisions are likely to be made during the project, then preliminary figures can be put into this tool and used for a rapid assessment of the viability of different investment options. This can be done either by setting fixed values, preparing input files in another program (such as Excel), or running the program in Monte Carlo mode and using the built-in random-number generators.

One possibility is to use the tool near the beginning of a project for a quick assessment and then return to it with more and more detailed inputs over the course of the project. Note that in Monte Carlo mode the tool is really only intended for quick assessment, and not for making final decisions – see the discussion in the next section. As a result of using the tool in Monte

Carlo mode, it may be decided that a detailed study is needed to resolve possible issues, or that a less-intensive study would suffice.

Limitations

This tool has several limitations. It is best used for a quick evaluation of the viability of different pricing interventions under different yield, planting area, and irrigation scenarios.

Not Principally a Model

The tool is (mainly) an accounting framework, and not a model. There is only one modeled aspect, and that is that prices depend on overall production. This modeling element was included because otherwise the outputs could be misleading, since an increase in production would otherwise translate into increased income in a one-to-one ratio, which is not a likely result. However, there are other potentially important aspects of the system that have not been modeled. In particular, no account is taken of behavioral modifications or strategic behavior that might arise as a result of the outputs (for example, switching crops, or shifting to an alternative income source). This must be supplied by thinking critically about the outputs of the scenarios and of this tool, or by using a separate tool. Also, competing demands for water are not taken into account. The tool takes the irrigation water allocation as given.

Independent Probabilities in Monte Carlo Mode

There is no connection between one random number and another when running in Monte Carlo mode. For example, if a random-number generator is used to generate yields on two different fields on the same farm, there will be no correlation between the two fields in any given year – they will be calculated independently. For this reason, it is important not to end an analysis with this tool. It is good for quick assessment to address the question, “How much should we worry about project viability in light of variability in yields, wages, and other external variables?” If a substantial fraction of runs produces a net loss in income, then it is worthwhile doing a detailed study of potential interactions between fields, farms, and access to irrigation water. If, on the other hand, most of the runs produce a net positive income, and that result is robust with different assumptions, then less-intensive follow-up analysis may be adequate.

Not a High-End Monte Carlo Tool

The random number generator that underlies the different pseudo-random numbers used in Monte Carlo mode is a decent, but limited, linear congruential generator. For very large numbers of variables and iterations the possibility of correlations between early and late numbers in the pseudo-random number sequence begins to be a concern. Also, for very large numbers of iterations and variables, the tool will start to run slowly. High-end Monte Carlo tools use more sophisticated techniques for generating sequences of pseudo-random numbers. The benefit to the approach taken for this tool is speed, as the generator used is quite fast. Since the tool is meant for a quick assessment, this choice was deemed appropriate.

Contacts and links

The developer of the program is Eric Kemp-Benedict to be reached at erickb@sei-us.org .