dCalifornia Water and Environment Modeling Forum
Promoting Excellence and Consensus in Water and Environment Modeling

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UC DAVIS CENTER FOR WATERSHED SCIENCES

Technical Workshop

Economic Modeling of Agricultural Water Use and Production

(in cooperation with the Center for Watershed Sciences of UC Davis)

Friday, January 31, 2014 UC Davis

Hands-On Examples for Water Modeling in Agriculture

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(Revised February 4, 2014)

Example 1: Model Calibration

Consider the following agricultural production region:

	REGION 1		
Data set	**Alfalfa**	**Vine**	**Corn**
Price ($/Ton)	132	700	250
Yield (Ton/acre)	7	6.5	6
Revenues ($/acre)	924	4550	1500
Cost ($/acre)	681	3478	1000
Observed Resource Use	**Alfalfa**	**Vine**	**Corn**
Irrigated Crop Area (acres)	100	30	200
Applied Water per unit area (ft)	4	1.5	2.5
Applied Water (Acre-ft)	400	45	500
Observed Net Returns ($)	24300	32160	100000

Our objective is to obtain a model that calibrates exactly to the observed data. Our final program should look like:

$$Max \quad profit = \sum_i v_i yld_i x_i - \alpha_i x_i - \frac{1}{2}\gamma_i x_i^2$$

$$\sum_i x_i \leq b$$

where v is the crop i price, y is the yield of crop i, x_i is the decision variable for land, b is the amount of land available in the region, and alpha and gamma are the parameters of the PMP cost function for crop i.

The first step is to solve the linear program

$$\max \ \text{linprofit} = \sum_i XL_i (v_i yld_i - c_i)$$

$$s.t. \quad \sum_i XL_i \le b$$

$$XL_i \le \tilde{X}_i$$

where XL_i is the linear decision variable for irrigated crop area and the rest of the parameters are as defined above. In addition to the limiting resources constraint (second equation) we include a calibration constraint to restrict land use to the observed levels, as described in Howitt (1995).

In the second step we take the shadow value (lambda value here) of the calibration constraint and calculate the parameters of the PMP cost function as:

$\alpha_i = c_i - \lambda_i$ and $\gamma_i = 2\lambda_i / \tilde{X}_i$

In the third step we reformulate the program of the calibrated model as above:

$$Max \quad profit = \sum_i v_i yld_i x_i - \alpha_i x_i - \tfrac{1}{2} \gamma_i x_i^2$$

$$\sum_i x_i \le b$$

Notice the percentage difference at the bottom of the spreadsheet with respect to land. At this point we would say that the model is fully calibrated.

We have successfully replicated the calibrated model in a separate sheet to use it in the examples that follow.

Example 2: An increase in the price of vine crops

We are going to do an exercise in which we increase the price of one of the crops. So we'll copy the calibrated model in a new sheet and change the marginal revenue of the vine crops in the region by 25%. Let's run the experiment and see how the irrigated crop areas change.

Example 3: a 20% shortage of water

In this example we will cut water availability in the system by 20%. We will modify the right hand side of the water constraint. Notice that because the production function is fixed proportions we do not need the water constraint. However, for this example we want to constraint water, therefore we have to add that constraint to the original program and should be:

$$\max \ profit = \sum_i v_i yld_i x_i - \alpha_i - \tfrac{1}{2} \gamma_i x_i$$

$$s.t.$$

$$x_i \le b$$

$$a_i x_i < \overline{W}$$

Where a_i is the amount of water applied per unit area to crop i, and W is the amount of water available in the region.

Example 4: Increased Salinity in Irrigation Water

In this example, we will change the yield of crops as a result of saline water. So let's replicate the calibrated model first. Then, we change the yield parameter so account for the increased salinity. The percentages we used are: alfalfa, 80%, vine 70% and corn 85%. Let's re-run and see the changes in the crop irrigated areas and revenues.

Example 5: Technological improvement

We can see trends in increasing yields for some crop as a result of technological improvements. So let's modify yields again to some degree and see the changes in cropping patterns and revenues. Lets use 20% improvement for alfalfa, 5% for vine and 125% for corn.

Example 6: Climate Change

As a long term scenario, climate change may combine many processes, some physical and some behavioral. In this example we can model the effect of changing crop demands, technology, reductions in available water and reductions in yields. We will modify the parameters to evaluate changes in crop areas and revenues. In our example:

Technological improvement (% of base)	120%	105%	125%
Prices (% of base)	110%	140%	110%
Climate change yield reductions (% of base)	90%	75%	90%

Assume a 27% reduction in available water and a 7% reduction in available land for agriculture.

Example 7: Obtaining Water's shadow value

One of the most interesting aspects of using programing models with bounds on resources is their ability to provide shadow values on these resources. So let's parameterize the right hand side for water and obtain the shadow values. Obtain a water derived demand curve for availability using 50%, 75% and 100% water availability. (Hint: you need the sensitivity reports to obtain the Lagrange multiplier on water).

Example 8: Build a new region.

Let's build a second region from scratch and for that end, let's replicate the first example and modify the parameters to match the table below:

REGION 2				
Data set	**Almonds**	**Vine**	**Vegetables**	
Price ($/Ton)	4234	700	582	
Yield (Ton/acre)	1.1	6.5	6.5	
Revenues ($/acre)	4657.4	4550	3783	
Cost ($/acre)	2627	3478	3200	
Observed Resource Use	**Almonds**	**Vine**	**Vegetables**	Total

Irrigated Crop Area (acres)	150	200	200	<=	550
Applied Water per unit area (ft)	3.1	1.5	2.1		
Applied Water (Acre-ft)	465	300	420	<=	1185
Observed Net Returns ($)	304560	214400	116600		**518560**
	698610	793000	756600		

So let's replicate this all the way to the calibrated model.

Example 9: Water markets

In this example we will explore the potential of water markets to increase net returns to water and management over regions. So let's suppose a drought is in place and we are expecting to reduce water allocations for the two regions in 20%. So let's run a single region optimization for the two models and add up the net returns to land and management. For a first step lets copy Example 8 Tab and rename it Example 9a. Run two optimizations one per region with a 20% water shortage. Sum the objective functions of the two model runs and mark the cell for later comparison with a flexible market based allocation.

Copy the Example 9a spreadsheet and lets allow water trades rename it Example 9b. We need to create a virtual conduit for water. Let's limit the amount of the water transfer to 50% of the region's total supply. We need to add a global net returns to land and management function, modify the regional water constraints, create an equality equation for the water transfers, and set up a constraint to limit the transfer amount. Let's compare the global net returns in this multiregional optimization with the sum of the two individual optimizations.