MODEL 3: ADDS 2 WATER SUPPLY SCENARIOS

- **OPTIMIZES FARM INCOME FOR FULL AND REDUCED WATER SUPPLY**
- **UPPER BOUND ON LAND IN PRODUCTION BY CROP = 2006 LEVELS**

2 MODELS TOTAL

3.1: FULL (100% OF 2006) WATER SUPPLY

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Optimizing Water Resource Use in the TE Basin - Iraq
Solution Report     SOLVE TE_03 Using NLP From line 197


               S O L V E      S U M M A R Y

     MODEL   TE_03               OBJECTIVE  ag_ben_normal_v
     TYPE    NLP                 DIRECTION  MAXIMIZE
     SOLVER  CONOPT              FROM LINE  197

**** SOLVER STATUS     1 Normal Completion      good
**** MODEL STATUS      1 Optimal                good
**** OBJECTIVE VALUE              8183.1390     good (lower income because of upper bound land constraint)

 RESOURCE USAGE, LIMIT          0.008      1000.000   good
 ITERATION COUNT, LIMIT         5    2000000000       good
 EVALUATION ERRORS              0             0       good
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---- VAR hectares_v land in production by crop-province-scen (1000 Ha - marginal is $US per Ha)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.1-wheat .normal	.	47.4000	47.4000	112.7500
1-Mousil.1-wheat .dry	.	.	47.4000	EPS
1-Mousil.2-cotton.normal	.	0.4500	0.4500	815.9200
1-Mousil.2-cotton.dry	.	.	0.4500	EPS
2-Basra .1-wheat .normal	.	16.9000	16.9000	146.2500
2-Basra .1-wheat .dry	.	.	16.9000	EPS
2-Basra .2-cotton.normal	.	.	.	1146.5000
2-Basra .2-cotton.dry	.	.	.	EPS

Levels:

This Model 3.1 optimizes farm income if there is a normal supply of water, equal to 800 (million cubic meters of water per year). Optimized land in production is shown here with the yellow shaded lines.

Notice the LEVELS shown for the VAR hectares_v, land in production, for each crop and province. For 3.1 you can ignore the un-shaded lines. We will see those later when model 3.2 is run for the dry water supply scenario.

What do these LEVELS say? Remember, our farmers are constrained in this model 3.1 to plant no more than the actual land planted for each crop and province. Look at the GAMS code to see what they actually planted historically. Remember this historical constraint.

Facing that constraint, our income optimizing farmers plant _____ 47.4 (1000 ha) of wheat in Mousil, _____ 0.45 (1000 ha) of cotton in Mousil; _____ 16.9 (1000 ha) of wheat in Basra; _____ 0 (1000 ha) of cotton in Basra. Their optimized land in production equals their historical level for both provinces and both crops.

Marginals:

Notice the very large MARGINALS. How do you interpret them _____?

For wheat land in Mousil, farmers are planning 47.4 (1000) ha. But if unconstrained by history, they want to plant more. If they could plant more, the 1st added (1000) ha of wheat planted in Mousil Province would earn _____ $US 112.75 per Ha. The rest of the MARGINALS have a similar interpretation.

Notice the last line in yellow. Farmers grow zero ha of cotton in Basra. It's what they grew historically (2006). However if they could find a way to grow more cotton in Basra, their 1st added (1000) ha of cotton planted in Basra would bring them an added _____ $US 1146.50. That is a very large amount of added farm income. So the economic value of the first extra Ha of land growing cotton in Basra is _____ $US 1146.50 per Ha.

---- VAR T_hectares_v total land in prodn by province-scen (1000 Ha - marginal is $US per Ha)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.normal	.	47.8500	+INF	.
1-Mousil.dry	.	.	+INF	.
2-Basra .normal	.	16.9000	+INF	.
2-Basra .dry	.	.	+INF	.

Levels: Sums total land in production over crops for each province for the normal water supply scenario.

---- VAR uses_crop_v total water use by crop-province-scen (million m^3 - marginal is $US per 1000 m^3)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.1-wheat .normal	.	564.0600	+INF	.
1-Mousil.1-wheat .dry	.	.	+INF	.
1-Mousil.2-cotton.normal	.	8.1000	+INF	.
1-Mousil.2-cotton.dry	.	.	+INF	.
2-Basra .1-wheat .normal	.	228.1500	+INF	.
2-Basra .1-wheat .dry	.	.	+INF	.
2-Basra .2-cotton.normal	.	.	+INF	.
2-Basra .2-cotton.dry	.	.	+INF	.

---- VAR uses_v total water use by scen (million m^3 - marginal is $US per 1000 m^3)

	LOWER	LEVEL	UPPER	MARGINAL
normal	.	800.3100	800.3100	.
dry	.	.	400.1550	.

---- VAR ag_ben_k_v total farm income by crop-province-scen   ($US 1000s - no marginals shown)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.1-wheat .normal	-INF	5344.3500	+INF	.
1-Mousil.1-wheat .dry	-INF	.	+INF	.
1-Mousil.2-cotton.normal	-INF	367.1640	+INF	.
1-Mousil.2-cotton.dry	-INF	.	+INF	.
2-Basra .1-wheat .normal	-INF	2471.6250	+INF	.
2-Basra .1-wheat .dry	-INF	.	+INF	.
2-Basra .2-cotton.normal	-INF	.	+INF	.
2-Basra .2-cotton.dry	-INF	.	+INF	.

LEVELS: Farm Income for each crop and province: 5344 ($US 1000s) for wheat in Mousil, 367 ($US 1000) for cotton in Mousil, 2471 ($US 1000) for wheat in Basra, and nothing for cotton in Basra.

MARGINALS: Should be zero for the objective function

---- VAR ag_ben_v total farm income by scen   ($US 1000s - no marginals shown)

	LOWER	LEVEL	UPPER	MARGINAL
normal	-INF	8183.1390	+INF	.
dry	-INF	.	+INF	.

LEVELS: Farm Income summed over all crops and provinces = 8183 ($US 1000s)

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR ag_ben_no~	-INF	8183.1390	+INF	.
---- VAR ag_ben_dr~	-INF	.	+INF	.

  ag_ben_normal_v total farm income (objective - full water)   ($US 1000s - no marginals shown)
  ag_ben_dry_v   total farm income (objective - reduced water)   ($US 1000s - no marginals shown)

LEVELS: Farm Income for the normal water supply scenario = 8183 ($US 1000s)

3.2: REDUCED (50% OF 2006) SUPPLY

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Solution Report     SOLVE TE_03 Using NLP From line 202


               S O L V E      S U M M A R Y

     MODEL   TE_03               OBJECTIVE  ag_ben_dry_v
     TYPE    NLP                 DIRECTION  MAXIMIZE
     SOLVER  CONOPT              FROM LINE  202

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE             4391.7544    much lower income because water available falls by half

 RESOURCE USAGE, LIMIT          0.055      1000.000
 ITERATION COUNT, LIMIT         5    2000000000
 EVALUATION ERRORS              0             0
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---- VAR hectares_v land in production by crop-province-scen   (1000 Ha - marginal is $US per Ha)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.1-wheat .normal	.	47.4000	47.4000	.
1-Mousil.1-wheat .dry	.	13.7735	47.4000	.
1-Mousil.2-cotton.normal	.	0.4500	0.4500	.
1-Mousil.2-cotton.dry	.	0.4500	0.4500	645.3738
2-Basra .1-wheat .normal	.	16.9000	16.9000	.
2-Basra .1-wheat .dry	.	16.9000	16.9000	18.3403
2-Basra .2-cotton.normal	.	.	.	EPS
2-Basra .2-cotton.dry	.	.	.	943.7395

---- VAR T_hectares_v total land in prodn by province-scen (1000 Ha - marginal is $US per Ha)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.normal	.	47.8500	+INF	.
1-Mousil.dry	.	14.2235	+INF	.
2-Basra .normal	.	16.9000	+INF	.
2-Basra .dry	.	16.9000	+INF	.

---- VAR uses_crop_v total water use by crop-province-scen (million m^3 - marginal is $US per 1000 m^3)

	LOWER	LEVEL	UPPER	MARGINAL
1-Mousil.1-wheat .normal	564.0600	564.0600	564.0600	EPS
1-Mousil.1-wheat .dry	.	163.9050	+INF	.
1-Mousil.2-cotton.normal	8.1000	8.1000	8.1000	EPS
1-Mousil.2-cotton.dry	.	8.1000	+INF	.
2-Basra .1-wheat .normal	228.1500	228.1500	228.1500	EPS
2-Basra .1-wheat .dry	.	228.1500	+INF	.
2-Basra .2-cotton.normal	.	.	.	EPS
2-Basra .2-cotton.dry	.	.	+INF	.

Levels

Notice LEVELS of uses_crop_v to each crop for each province. Water use falls off from 564 to 164 (million cubic meters) for wheat in Mousil in the dry scenario compared to full water. But water put to cotton stays the same for in Mousil, wheat in Basra stays the same, and cotton in Basra stays the same as for the normal water supply scenario.

Why did we reduce water applied to wheat in Mousil by so much? _____? Hard question. It's because wheat in Mousil earns the lowest income per ha of any crop or any province. So when water becomes scarce, wheat in Mousil drops out, but other crops and other provinces apply full water to their crops.

Marginals

MARGINALS are zero because there is no constraint on water application to any crop or to any province. But there is a big constraint on total water available. How much did total water fall with drought _____?.

---- VAR uses_v total water use by scen (million m^3 - marginal is $US per 1000 m^3)

	LOWER	LEVEL	UPPER	MARGINAL
normal	.	800.3100	800.3100	.
dry	.	400.1550	400.1550	9.4748

Level

Total water use over crops and scenarios falls from 800.31 (million m3) to 400.15 (million m3). A big drop off. So the MARGINAL value of water rises from 0 to $US 9.47 per 1000 cubic meter.

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---- VAR ag_ben_k_v  total farm income by crop-province-scen     ($US 1000s - no marginals shown)

                                LOWER          LEVEL          UPPER         MARGINAL

1-Mousil.1-wheat .normal        -INF         5344.3500        +INF              .
1-Mousil.1-wheat .dry           -INF         1552.9654        +INF              .
1-Mousil.2-cotton.normal        -INF          367.1640        +INF              .
1-Mousil.2-cotton.dry           -INF          367.1640        +INF              .
2-Basra .1-wheat .normal        -INF         2471.6250        +INF              .
2-Basra .1-wheat .dry           -INF         2471.6250        +INF              .
2-Basra .2-cotton.normal        -INF             .            +INF              .


     VAR ag_ben_k_v  total farm income by crop-province-scen     ($US 1000s - no marginals shown)

                                LOWER          LEVEL          UPPER         MARGINAL

2-Basra .2-cotton.dry           -INF             .            +INF              .

---- VAR ag_ben_v  total farm income by scen                    ($US 1000s - no marginals shown)

              LOWER          LEVEL          UPPER         MARGINAL

normal        -INF         8183.1390        +INF              .
dry           -INF         4391.7544        +INF              .

                           LOWER          LEVEL          UPPER         MARGINAL

---- VAR ag_ben_no~        -INF         8183.1390        +INF              .
---- VAR ag_ben_dr~        -INF         4391.7544        +INF              .

  ag_ben_normal_v  total farm income (objective - full water)    ($US 1000s - no marginals shown)
  ag_ben_dry_v  total farm income (objective - reduced water) ($US 1000s - no marginals shown)
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