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$EOLCOM //
$TITLE Optimizing Water Resource Use in the TE Basin - Iraq
$OFFLISTING OFFUPPER

OPTION LIMROW = 0, LIMCOL = 0;

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* ---------------------------------------------------------------------------------
*  Model 2 Simple Farm Management
*  Adds a SET for province (2 provinces: Mousil-Basra)
*  Expands water supply to 800 million cubic meters (2006 use level for both 2 provinces)
* ---------------------------------------------------------------------------------

$OFFTEXT

****************************************   Section 1 ***********************************
*                                           Sets                                       *
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```
SETS

i    province

/
  1-Mousil
  2-Basra
/

k    crop

/  1-wheat
   2-cotton
/


************************************  Section 2 ******************************************
*                                          Data                                           *
*******************************************************************************************

table  Bc(i,k)    crop water demand (ET) (1000s cubic meters per Ha = 10ths meters depth)

                 1-wheat          2-cotton
 1-mousil          11.9              18.0
 2-Basra           13.5              21.4

*Bc(i,k) =  0.5 * Bc(i,k)

table    Yield_p(i,k)   Crop Yield - proportional to ET (tons per Ha)

               1-wheat         2-Cotton
1-Mousil        1.39              2.32
2-Basra         1.57              2.75


* economic data

parameter   Price_p(k)   Crop Prices ($ US per ton)

/1-Wheat        225
```

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 2-Cotton       906
/

table Cost_p(i,k)     Production Costs Excluding water ($US per Ha)

                1-wheat     2-cotton
1-Mousil          200         1286
2-Basra           207         1345

parameter Wat_supply_p     total water available (million cubic meters per year)

/800/

Parameter Net_revenue_p(i,k)  calculated net revenue per unit land ($ US per Ha)
;

Net_revenue_p(i,k) = Price_p(k) * Yield_p(i,k) - Cost_p(i,k);

*****************************  SECTION 3 ********************************************
*                              Variables                                            *
*********************************************************************************
positive variables

hectares_v    (i,k)   land in production by crop-province   (1000 Ha - marginal is $US per Ha)
T_hectares_v  (i  )   total land in prodn by province       (1000 Ha - marginal is $US per Ha)
uses_crop_v   (i,k)   total water use by crop-province      (million m^3 - marginal is $US per 1000 m^3)
uses_v                total water use                       (million m^3 - marginal is $US per 1000 m^3)

variables
ag_ben_k_v    (i,k)   total farm income by crop            ($US 1000s - no marginals shown)
ag_ben_v              total farm income (objective)        ($US 1000s - no marginals shown)

*****************************   Section 4  ******************************************
*                              Equations                                            *
*********************************************************************************
Equations

// equations declared (named)

T_hectares_e   (i  )  total land in production by province   (1000 Ha - marginal is $US per Ha)
```

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Uses_crop_e    (i,k)  total water use by crop - province     (million m^3 - marginal is $US per 1000 m^3)
uses_e                total water use                       (million m^3 - marginal is $US per 1000 m^3)

ag_ben_k_e     (i,k)  total farm income by crop - province   ($US 1000s - no marginals shown)
ag_ben_e              total farm income (objective)         ($US 1000s - no marginals shown)
;

// equations defined (using above names with algebraic formulas)

T_hectares_e (i  ).. T_hectares_v (i  )  =e=  sum(k, hectares_v     (i,k));          // sums land in prodn over crops
Uses_crop_e  (i,k).. uses_crop_v  (i,k)  =e=  Bc(i,k) * hectares_v  (i,k);          // total water use by crop-province
uses_e            .. uses_v              =e=  sum((i,k), uses_crop_v(i,k));         // total water use summed over crops-prov
ag_ben_k_e   (i,k).. ag_ben_k_v   (i,k)  =e=  net_revenue_p(i,k) * hectares_v(i,k); // total farm income by crop-province
ag_ben_e          .. ag_ben_v            =e=  sum((i,k), ag_ben_k_v (i,k));         // objective fn total farm income

*************** Section 5 ************************************************************
*  Labels and defines all models used                                                 *
*  Each model has one objective                                                       *
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model TE_02 /all/ ;                                        // uses all equations above

*********************************  Section 6   ***************************************
*                                 BOUNDS                                             *
*  Bounding shows a positive shadow price for each limiting resource                 *
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uses_v.up = wat_supply_p;   // upper bound on total water available, avoids unbounded solution
*hectares_v.lo('1-mousil','1-wheat') =  10; // food security requirement
*uses_crop_v.lo('wheat')  = 100;            // lower bound on water assigned to wheat

*************** Section 7 ************************************************************
*                SOLVE THE MODEL                                                     *
**************************************************************************************

solve TE_02 using nlp maximizing ag_ben_v;  // uses nonlinear programming solver

*************** Section 7 ************************************************************
*                THE END                                                             *
**************************************************************************************
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