Model Data

In the REAP model system, we link supply and use projections to regional land use production practices and their corresponding environmental loadings. To establish the linkage, we pooled information from several sources of data, including the baseline data, crop production enterprise database, the National Resources Inventory, and the Agricultural Resource Management Survey (ARMS). The data sources, their use, and the procedures used to integrate them into REAP are outlined below.

Baseline Data

The baseline data provides the market prices and quantities used in setting up the base solution. The baseline data provides projections of agricultural commodity production, prices, trade, and farm income over a 10-year time period. Commodities covered include corn, sorghum, barley, oats, wheat, rice, cotton, soybean and soybean products, milk, beef, pork, chicken, and turkey. Projections contained in the baseline assume the continuation of current farm policies and specific conditions for the economy, weather, and global situation. For more detailed information on the baseline see the ERS Briefing Room (www.ers.usda.gov/Briefing/Baseline/).

The information from the baseline is brought into REAP through files generated by a relational database. We use the database to import the baseline spreadsheets; select the relevant price, supply and use, and policy variable data; and organize it so that it is consistent with REAP naming conventions and GAMS coding requirements. With the database, we generate two files to be called into REAP, one containing the baseline data for crops (buca*mmyy*.gms) and one containing the baseline data for livestock (buli*mmyy*.gms). Both files are located in the model library directory (A1A0LIB). *Mmyy* represents the month and year that the baseline data was published. Baseline files are updated to the most recent baseline data; periodically and current files exist intermittently for baseline data going back to 1992.[6]

REAP calls in the most recent baseline files available by default. The selection of the baseline files, however, is hard coded into the file BGSET.GMS. The baseline call needs to be updated when new baseline files become available. The file BGSET.GMS is in the base model directory.

To change the baseline files being used, all you need to do is to change the name of the baseline files being called in BGSET.GMS. Make sure the desired year exists in the library directory to avoid errors. An example of changing the baseline files used is demonstrated in example 14.

Example 14—Changing from 2001 baseline data to the 2003 baseline

In this example, we are changing the baseline files being used from those containing data from the 2001 baseline data to those containing data from the 2003 baseline data. In this example, the call for baseline files contained in bgset.gms changes from:

---

[6] One needs to be aware that current formulation of REAP, particularly with respect to its representation of farm programs, is not necessarily consistent with the historical baseline files. REAP can be changed fairly easily to accommodate farm programs as they existed in these historical files if so desired.

```
$STITLE SETUP REAP TO MATCH SELECTED BASELINE YEAR YB--calls USDA baseline file
* FILE: <BGSET.GMS>   THIS IS CALLED FROM REAP RUN SETUP FILE: E.G. A1A0A.GMS

* GET BASELINE LIVESTOCK DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BULI0201.GMS %1 %2 %3

* GET BASELINE CROP DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BUCA0201.GMS %1 %2 %3
```

to

```
$STITLE SETUP REAP TO MATCH SELECTED BASELINE YEAR YB--calls USDA baseline file
* FILE: <BGSET.GMS>   THIS IS CALLED FROM REAP RUN SETUP FILE: E.G. A1A0A.GMS
.
* GET BASELINE LIVESTOCK DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BULI0203.GMS %1 %2 %3
.
* GET BASELINE CROP DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BUCA0203.GMS %1 %2 %3
```

In addition, the first time a new baseline file is run, a new table specifying the parameter BSAC will be needed to be changed in the ACRGLY.TBL file in the ENVIR sub-directory. The new BSAC table is created the first time REAP is run with the new baseline file. A code at the bottom of the bucammyy.gms file that automatically aborts the model run when a new baseline file is detected and prints the new BSAC table to use in the listing file.

```
* FILE <BUCA0201.GMS>  <LIBRARY FILE> CALLED FROM BGSET.GMS
.
.
.
ABORT$(ABS(BLCROPT - BSACT) > 0.0001) "**** MUST UPDATE BSAC IN ACRGLY.TBL", BLCROPT, BSACT,
BLCROPA;
```

To update the BSAC table in the ACRGLY.TBL file, copy the BSAC table from the listing over the existing BSAC table in ACRGLY.TBL.

```
*FILE<ACRGLY.TBL> AUGMENTED BY CROPSHR, ROTSHR TABLES AND DERIVATIVES
* ENVIR FORMULATION
.
TABLE BSAC(B,YR) BASELINE ACRES PLANTED 0201 BASELINE
   +         2005       2006       2007       2008       2009       2010
CORN       80.000     80.000     80.500     80.500     81.000     81.000
SORGHUM     9.500      9.600      9.700      9.800      9.900     10.000
```

Becomes

```
TABLE BSAC(B,YR) BASELINE ACRES PLANTED 0203 BASELINE
   +         2007       2008       2009       2010       2011       2012
CORN       80.000     80.000     80.500     80.500     81.000     81.000
SORGHUM     9.500      9.600      9.700      9.800      9.900     10.000
```

If there have been no changes in government programs that would change policy variable names or the manner in which the programs affect producer decisions, then the changes needed to include the new

baseline file is complete. However, when the farm programs represented in the baseline data change, then REAP will need to be reformulated to account for the new programs. Because government farm policy changed from 2001 to 2003, updating REAP to the 2003 baseline required some slight adjustments, primarily in naming conventions for government programs and in the way government program payments and expenditures are calculated in reports.

The major change to farm policy in the 2002 Farm Bill was in the manner in which decoupled income support payments were structured. Prior to the 2002 Farm Bill, decoupled income support payments were fixed in the 1996 Farm Act and called "Production Flexibility Contract (PFC) payments." With the 2002 Farm Bill, we divide the uncoupled income support payments into two parts: a direct payment and counter-cyclical payment. The direct payment was setup similar to the PFC payment. All that was required to incorporate the direct payment into REAP was to add a label for it and substitute this label for PFC in the calculations of government program payments and expenditures. The counter-cyclical payment, however, depends on the difference between the target price and market price or loan rate (whichever is higher), and so required that some additional calculations be added to the code in addition to adding a label for it to the model. Even though the counter cyclical payment was tied to the market price, it was not tied to production since the payment was based on base acreage and program yields that are derived from historical production rather than current production. Actual production of crop was not required to receive the payment. Because both programs were decoupled from production, we assumed that they had no effect on production decisions and could be treated as exogenous variables in the model formulation.

The changes to the model formulation required when the 1996 Farm Bill was enacted, in contrast, were much more extensive. Prior to the 1996 Farm Bill income support payments were tied to both prices and production. The area planted to program crops was limited by base acreage constraints and annual acreage reduction programs. In addition, farmers had limited flexibility to plant oilseeds on a portion of their base acreage.

Crop Production Enterprises

The crop production enterprise database provides data needed to construct crop production activities for REAP and provides the field operation data used to run the EPIC simulations used to generate the environmental indicator coefficients for the cropping systems used in REAP. The database was developed by using information contained in ARMS and literature reviews for each of the 10 Farm Production Regions.

The database includes two types of cropping systems. "Predominant systems" are those systems currently in widespread use. Predominant system coefficients are based upon ARMS[7] estimates, with input costs updated to reflect current input prices and ERS Cost of Production estimates. "Alternative systems" are newer systems that may prove to be less intensive over time in terms of soil erosion and chemical use. There are 623 predominant systems that include rotations of up to 4 crops differentiated by up to 5 tillage practices. The alternative systems include innovative and experimental rotations. These rotations are designed to be less detrimental to the environment. The rotations include using legume crops as a

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[7] The information used in the current database came from the CPS, which is now part of ARMS. See the ERS Briefing Room.

substitute for nitrogen fertilizer and using crop rotation sequences to break up pest life cycles in place of chemical pesticides.

Predominant Systems

The 1992 National Resources Inventory (NRI) and the 1992 Cropping Practices Survey (CPS)[8] were used to define the 62 crop rotations commonly used throughout the United States and the tillage practices commonly associated with them. Rotations were defined based on the number of different REAP crops contained in the cropping history. Records in NRI were divided into regions by overlaying the 26 Land Resource Regions onto the 10 Farm Production Regions. The records were then subdivided again based on whether they were on HEL or NHEL soils. Acreage for each rotation was then recorded.

Tillage practices associated with the rotations and acreage devoted to them were derived from the CPS. Crop rotations as identified through the NRI were used to group the CPS records. ERS definitions pertaining to tillage practices were used to assign tillage practices and acreage associated with each rotation.

All information used to construct predominant systems was obtained from ARMS, primarily the Phase II field practices survey. The Phase II was previously known as the CPS. Because the information used to produce the production systems came from the CPS before its name was changed, we will refer to it as the CPS for the remainder of this section. To create the management files to run EPIC simulations for the predominant systems (and obtain the physical effects of these systems—yields and environmental effects) required obtaining all the management information needed to mimic the complete production cycle of any crop in a rotation. This included information on all field operations from pre-planting to post-harvesting (i.e., what occurred, when it occurred, with what type of equipment, and how frequently) and input levels (i.e., seeding rates, fertilization and liming rates, and pesticide applications) for each crop within a production activity sorted by rotation, tillage practice, and model region.

Data to create the crop production enterprise database for the production of corn, soybeans, wheat, cotton, and rice came from the 1992 CPS. The data used for sorghum came from the 1991 CPS. Information on field operations for silage, which was not included in the CPS, was obtained by assuming that silage was corn being harvested for silage. The exception to this was in the Southern Plains, where it was assumed that silage was sorghum being harvested for silage. Accordingly, we assumed that a silage system was managed identically to its "twin" corn or sorghum system, except that silage systems were harvested for silage at the appropriate time. Analogously, EPIC management files for barley and oats were assumed to be similar to wheat managed in a comparable wheat system, with minor modifications (e.g., to ensure that any herbicide applications derived from a wheat system to be used on a comparable barley system were not toxic to barley).

Finally, it was assumed that hay was grown according to established practices for alfalfa in that region. In most regions, it was assumed that alfalfa was established in the summer and fall after the preceding crop

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[8] Not to be confused with the objective function variable CPS.

had been harvested and grown for 4 years, with cuttings two or three times each year. Where alfalfa was not suited to the growing conditions of a particular region, clover or hairy vetch was substituted.

Machinery implement compliments used in each rotation-tillage system were based on the size (horsepower) of the tractor used. The CPS was used to determine the average size (horsepower) of the tractor used in each FPR. A representative implement complement (machinery and equipment) for each FPR was constructed by using the average tractor size in that FPR and information obtained from the publication *Minnesota Farm Machinery Economic Cost Estimates for 1992* (Fuller et al., 1992) and staff of the Rodale Institute Research Center.

Planting information for each crop in a rotation-tillage system was derived from information in the CPS on average seeding rates and planting dates. The type of tillage practice under consideration determined the type of planter for the particular crop. Fertilizer regimes for each crop in a rotation-tillage system were derived from the fertilizer information contained in the CPS. The mean number of fertilizer applications as reported in the CPS for a crop (rounding up or down to an integer, according to convention, but not rounding down to zero) was used to determine the number of fertilizer applications. The mean of CPS for total quantity of nitrogen (N), phosphate (P), and potash (K) were used to determine how many pounds per acre of elemental N, P, and K to apply to each system. Likewise, liming information from the CPS was used to determine lime applications. Also, the most frequently occurring month(s), in the CPS data, were used to set fertilization date(s).

The CPS did not provide necessary information about adjusting the amount of N, P, and K to apply to reflect credits due to manure applications. Yields of some crops in the base systems may have been affected by this omission. The CPS did not contain sufficient information to identify the type of fertilizer used. This is because fertilizer applications can be reported in the survey by type of fertilizer and quantity or by amount of elemental form (N, P, and K) applied or both. As a result, the quantity of each type of fertilizer applied was set so as to equal the quantity of elemental nutrient (N, P, and K) as reported in the CPS.

The appropriate pesticide schedule for a crop (again, by FPR, specific to each crop within a rotation-tillage system) was determined from the mean number of pesticide applications for a particular crop and quantity of active ingredients in the pesticide. To determine which pesticides to apply in the production system, the CPS data was used to determine the first two or three active ingredients in a product mix. The most frequently applied pesticides (active ingredients) for that rotation-tillage system were used as much as possible. Potential complications occurred whenever the number of pesticide applications was greater than one. It was difficult to associate specific pesticides with a particular pesticide application.

Take, for example, a rotation-tillage system where an average of two pesticide applications were reported for a particular crop. The first most frequently occurring pesticide is a herbicide, but this herbicide is a substitute for the second most commonly applied pesticide for the crop. It is conceivable that only one application of a herbicide was being applied for this type of system, but some producers used the first herbicide while others used the second herbicide rather than two applications of herbicide. Also, again suppose that for a rotation-tillage system, there were two pesticide applications reported, and this time, both a herbicide and an insecticide were used. It is difficult to detect from the CPS data whether producers sprayed their fields with a herbicide only once, sprayed their fields a second time with an insecticide, or sprayed their fields twice by using both a herbicide and an insecticide. The typical or representative pesticide application regime for a given system was based on the most frequent pesticide application and the average number of pesticide applications for that crop as observed in the CPS. Information from the CPS was used to determine the application rate of each pesticide (active ingredient) applied in the system and the month(s) of which the most frequent specific pesticide application(s).

Lastly, information from the CPS was used to determine how many field or tillage operations (other than planting, fertilizing, or spraying) occurred for a crop (again, by FPR, specific to each crop within a rotation-tillage system). The mean number of machinery operations reported in the tillage table in the CPS data for that crop (rounding up or down to an integer, according to convention) was used. Further,

information in the CPS was used to determine the most frequently occurring time(s) of field (tillage) operations.

Harvest information from the CPS was not used in the analysis. In EPIC simulations, crops were allowed to reach physiological maturity before being killed. Further, crops harvested for grain were allowed to dry in the fields to a specific moisture content, avoiding storage and drying issues and costs.

Alternative Systems

Regional agronomists were asked to complete surveys for alternative systems as part of a study undertaken by the World Resources Institute.[9] The agronomists were asked to complete surveys only for those systems for which there was documented information on all aspects of the systems (i.e., management practices, input levels, and yields). These sources included records of field trials at experiment stations, records from onfarm producer trials, and results of studies published in university experiment station bulletins or peer-reviewed journals. All management information from the completed surveys was used to create the EPIC input files for simulating the biophysical effects (yields and environmental indicators) of the systems. These simulated effects were used in the analysis, but no actual effects were recorded on the survey instrument.

Despite the fact that this database is the most extensive single source of alternative production systems, the coverage is not uniformly comprehensive or representative of all alternatives in each FPR. The unevenness in coverage results from one or more of the following: (1) producers may not have been using many alternative systems in that region when the surveys were completed; (2) producers may have been using alternative systems in that region, but any scientifically gathered or published data for alternative systems in that region may have been limited; and (3) there may have been scientifically gathered or published data for the alternative systems in that region. In general, FPRs, with many alternative systems, have more comprehensive coverage of alternative systems than FPRs with fewer systems.

Crop Production Enterprise Budgets

REAP's production enterprise budgets contain economic items typical of the cost of production budgets (e.g., nitrogen cost, chemical cost, and energy cost) and physical measures of output and input use (e.g., yields, cropland, and irrigation water). They also contain a set of environmental coefficients[10] (e.g., erosion and nitrogen leaching) corresponding to the specific rotation and tillage cropping practices (e.g., soil erosion and nitrogen leaching).

Economic coefficients in the budgets were initially developed by using methods similar to those used in the USDA/Natural Resources Conservation Service's crop budget generator. Ten agronomists in different

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[9] See Faeth (1995) for details.

[10] Environmental indicators are typically reported in physical units. A few such as soil depreciation allowance, soil erosion off-site costs, carbon flux value, and nitrogen flux value are reported in monetary terms.

regions across the United States contributed to the effort. Scientists at RIRC developed a customized budget generator and data-processing procedures to combine the information into budgets and consolidate the budgets into databases suitable for managing the large volume of information.[11]

ERS analysts updated the initial set of crop budgets in several ways. Cost of production estimates are updated to USDA baseline projections of variable cost for the year in which a model scenario is based. The estimates are also updated to be consistent with recent ERS crop cost of production estimates.[12] In addition, the environmental coefficients for each cropping system derived by way of the EPIC biophysical model have been recalculated as part of several update and calibration processes discussed below (see Appendix B).

Livestock Budgets

Budgets for beef, dairy, and swine operations are obtained from cost of production estimates published by ERS.[13] Poultry, slaughtering, and feed ration generation activities are for the most part represented as value added activities with constant returns to scale. Poultry activities have been slightly modified to include energy costs. Energy cost for poultry was obtained from various ERS Situation and Outlook reports. Manure production and nutrient content of animal manure are based on estimates in Kellogg et al. (2000).

Data Reconciliation

We combine information from four databases to derive the base solution in REAP: land use and tillage practices, crop production enterprise, baseline data, and crop yield. The process of combining the information in these databases to obtain a base solution can be thought of as economic calibration and biophysical calibration. Economic calibration is the process of adjusting parameters on behavioral relationships and the production enterprise budgets so that the base solution replicates price, supply, and use as reported in the baseline data. Biophysical calibration is the process of adjusting various parameters in the EPIC model and environmental indicator coefficients in the crop enterprise budgets to be consistent with available information on crop yields, soil erosion, and assumptions about producer behavior, with respect to application of nitrogen fertilizer.

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[11] See Faeth (1995) for details.

[12] These costs are updated periodically by using ARMS data. Future costs of production will be econometrically estimated from farm surveys (see USDA, ERS, 2006).

[13] These costs are updated periodically using ARMS data. Future costs of production will be econometrically estimated from farm surveys (see USDA-ERS, 2006).

Economic Calibration

Economic calibration is to USDA's agricultural baseline for a historical or projected year, including agricultural commodity policies affecting prices and production of crops and livestock, and environmental policies affecting resource use, such as the Conservation Reserve Program (USDA, 2006). National acreage for 10 major field crops is specified by the baseline. Regional acreage allocation is calibrated to crop rotations (up to 4 years). REAP applies several routines to set up a base solution from which to work. The routines enable REAP to replicate production and price estimates as represented in the baseline data for any given year in a manner consistent with available information on the distribution of production activities across the United States. The routines are used to distribute crop and livestock production estimates contained in the USDA baseline to the model regions, adjust crop yields, and update costs of production estimates for production activities. Data sources used during this process include the baseline data, the National Resources Inventory (NRI), ARMS, and production and yield estimates from USDA's National Agricultural Statistics Service (NASS).

To account for data reporting inconsistencies across the REAP data sources, several reconciliation procedures were followed. These procedures are either designed to reconcile baseline projections with historical distribution of production activity or, for the environmental indicators such as soil erosion, reconcile simulation results with levels estimated directly from the NRI.

Information on production for livestock and crop production from NASS estimates are used to apportion the baseline data projections to model the Farm Production Regions. Each region's share of crop production as reported by NASS is applied to the national estimate provide in the baseline projection to allocate crop production among the 10 Farm Production Regions. The regional allocations are then used to specify parameters in cost functions so that REAP validates to the regional production estimates.

Crop Acreage Reconciliation

Crop acreage allocation is further extended by distributing crop acreage in each Farm Production Region obtained from the general procedure used to assign crop acreage to the Farm Resource Regions among the various crop production enterprise systems in each region. REAP uses three databases to reconcile distribution of crop acreage by rotation and tillage practice, with the national crop acreage estimate from the baseline data projections for any given year. The crop rotation and tillage information is combined with the baseline production data by using a matrix balancing routine to allocate crop acreage in each model region/practice strata as determined by share information from NRI and USDA CPS regional data. Responses in individual region, tillage practice, rotation, and other strata follow nested adjustment functions, which are part of the calibration, and sum to aggregate response. The matrix balancing routine used to achieve this reconciliation is in \REAPgams\a1a0\envir\acrgly.tbl. A fragment of code using this routine is shown in Example 15—Crop acreage matrix balancing routine

```
*    |----------------------------------------|
*    I  QUADRATIC CONSTRAINED MATRIX BALANCING  I
*    |----------------------------------------|

 PARAMETER XACO(BA,U,UR)    BASE PRODUCTION SYSTEM ACREAGE BY MODEL REGION (FROM NRI)
           SRLO(B, U,UR)    BASE              CROP ACREAGE BY MODEL REGION (FROM NRI)
           SRO( B, U )      BASE              CROP ACREAGE BY FARM  REGION (FROM NASS)
           DRLO(BA,U )      BASE PRODUCTION SYSTEM ACREAGE BY FARM  REGION (FROM NRI)

           SXRL(B,BA,U,UR)  CROP ACREAGE SHARE PER UNIT OF PRODUCTION SYSTEM BY SYSTEM BY MODEL REGION
           ARI( B, U )      WEIGHT ON CROP ACREAGE             BY FARM  REGION  DEVNS OF COMPUTED VS NASS
           ARIF             WEIGHT ADJUSTER ON ACREAGE         BY FARM  REGION  DEVNS OF COMPUTED VS NASS
           BRLJ(BA,  UR)    WEIGHT ON PRODUCTION SYSTEM ACREAGE BY FARM  REGION  DEVNS OF COMPUTED VS NRI
           GRLI(BA,U,UR)    WEIGHT ON PRODUCTION SYSTEM ACREAGE BY MODEL REGION  DEVNS OF COMPUTED VS NRI
```

```
          RSR(B,  *, UR)      REPORT OF CROP ACREAGE              BY FARM  REGION
          RDRL(BA, *, UR)     REPORT OF PRODUCTION SYSTEM ACREAGE BY FARM  REGION
          RXAC(BA, *, U, UR)  REPORT OF PRODUCTION SYSTEM ACREAGE BY MODEL REGION
*         DRLO(BA, U, UR)     ROTATION ACREAGE OBTAINED (FROM NRI)
*         BRLI(BA, U, UR)     WEIGHT PLACED ON MODEL REGION CROP ACREAGE DEVIATIONS FROM NRI ACREAGE
          ;
 OPTION XACO: 3: 1: 2,  SRLO: 3: 1: 2,  SXRL: 3: 2: 2,  GRLI: 3: 1: 2;
 OPTION RSR: 3: 2: 1,  RDRL: 3: 2: 1,  RXAC: 3: 2: 2;

XACO(BA, RL, R)        = SUM(T2, ROTAC(BA, T2, RL)$ER2RR(RL, R));
  DRLO(BA, R)          = SUM(RL, XACO(BA, RL, R));
  SRO(B, R)            = ACRG92(B, R);
  SXRL(B, BA, RL, R)    $SUM(T2A, XSB7(B, BA, "NP", "A", "PRD", T2A, RL, R))
                       = SUM(T2, XSB7(B, BA, "NP", "A", "PRD", T2, RL, R))
                       / SUM(T2A, 1$XSB7(B, BA, "NP", "A", "PRD", T2A, RL, R)) ;

  ARIF               = 1;
*                              DEVIATION WEIGHT CALCULATIONS
*                              WEIGHTS: INVERSES IMPLIES CHI-SQUARE MINIMAND FOR CONSTRAINED MATRIX
PROBLEM
*                                    EQUAL TO 1 IMPLIES CONSTRAINED LEAST SQUARES
  ARI(B, R)             $SRO(B, R)
                       = 1 / SRO(B, R);
  BRLJ(BA, R)           $DRLO(BA, R)
                       = 1 / DRLO(BA, R);
  GRLI(BA, RL, R)       $XACO(BA, RL, R)
                       = 1 / XACO(BA, RL, R);

  DISPLAY XACO, DRLO, SRO, SXRL, ARI, BRLJ, GRLI;

 POSITIVE VARIABLES
          XAC(BA, RL, R)      ACREAGE OF PRODUCTION SYSTEM BY MODEL PRODUCTION REGION
          SR(B, R)            ACREAGE OF CROP PLANTED IN FARM PRODUCTION REGION
          DRL(BA, R)          ACREAGE OF CROP SYSTEM ACREAGE BY FARM PRODUCTION REGION
          ;
 VARIABLE  DEVFN             QUADRATIC CONSTRAINED MATRIX DEVIATION FUNCTION
          ;
 EQUATIONS OBJCHIS          CHI-SQUARE OBJECTIVE FUNCTION
*         OBJCLSQ           CONSTRAINED LEAST-SQUARES OBJECTIVE FUNCTION
          SCROP(B, R)        CROP ACREAGE BALANCE BY FARM REGION
          NCROP(B)           NATIONAL BASELINE CROP ACREAGE BALANCE REQUIREMENT
          DSYSTEM(BA, R)     PRODUCTION SYSTEM BALANCE BY FARM REGION
          XACP(BA, RL, R)    PRODUCTION SYSTEM BY MODEL REGION POSITIVE CONSTRAINT
          {REQUIRE ALL SYSTEMS > O
                                              ACREAGE}
          ;
 OBJCHIS..    DEVFN =E=   SUM((B, R)$SRO(B, R),  ARIF * ARI(B, R) * SQR(SR( B, R) - SRO(B, R)))
                     + SUM((BA, R)$DRLO(BA, R),      BRLJ(BA, R) * SQR(DRL(BA, R) - DRLO(BA, R)))
                     + SUM((BA, RL, R)$XACO(BA, RL, R), GRLI(BA, RL, R) * SQR(XAC(BA, RL, R)- XACO(BA, RL, R)));
SCROP(B, R)$SRO(B, R)..

                  SR(B, R)$SRO(B, R)      =E= SUM((BA, RL)$XACO(BA, RL, R), XAC(BA, RL, R) * SXRL
( B, BA, RL, R));

 NCROP(B)$BSAC(B, "%1")..
                  BSAC(B, "%1")          =E= SUM(R$SRO(B, R), SR( B, R));

 DSYSTEM(BA, R)$DRLO(BA, R)..
                  DRL(BA, R)$DRLO(BA, R) =E= SUM(RL$XACO(BA, RL, R), XAC(BA, RL, R));
```

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```
XACP(BA, RL, R)$XACO(BA, RL, R)..
                XAC(BA, RL, R)$XACO(BA, RL, R) =G= MIN(.05, .05 * XACO(BA, RL, R));

MODEL QCM_CHIS2 RECONCILE CROP AND ROTATION SYSTEM ACREAGE BY FARM PRODUCTION REGION /
 OBJCHIS, SCROP, NCROP, DSYSTEM, XACP /;

 OPTION LIMROW            = 10;
 OPTION LIMCOL            = 10;

 SOLVE QCM_CHIS2 USING NLP MINIMIZING DEVFN;

 RSR(B, "RCHI-2",    R)    = SR.L(B,R);
 RDRL(BA, "RCHI-2",   R)   = DRL.L(BA,R);
 RXAC(BA, "RCHI-2",RL,R)   = XAC.L(BA,RL,R);

DISPLAY "QUADRATIC CONSTRAINED MATRIX ADJUSTMENTS", RSR, RDRL, RXAC;
```

Cost of Production Reconciliation

Crop and livestock production activity costs can be updated to the most recently available cost of production estimates obtained from the ARMS survey if desired. Costs can be updated by using a set of matrix balancing routines that adjust individual line item budget expenditures in the REAP budgets to ensure that average costs as reported for these items by crop and region by ERS match REAP estimates. The routines for updating are in \REAPgams\a1a0lib\bucaxx96.gms for crops and \REAPgams\a1a0lib\bulixx96.gms for livestock production activities.

Demand and Supply Response Calibration

Demand and supply parameters are calibrated to replicate demand and supply response embodied in FAPSIM supply and demand effect multipliers. The multipliers represent the supply and demand response obtained when a single commodity is subjected to a supply or demand shock over a 10-year period. All other prices and quantities are allowed to vary in response to the shock. The multipliers are similar to elasticities except that they rely on the total derivative, not the partial derivative. Most supply and demand elasticities reported in the literature are derived by using the partial derivative, where all other prices and quantities are held constant. Export demand and import supply parameters were derived from elasticities contained in the Partial Equilibrium Agricultural Trade Simulator (PEATSim) model (Abler, 2006).

On the supply side, several sets of parameters need to be calibrated, including the elasticities of transformation used in specifying the CET functions for crop rotations and tillage practices. These elasticities were calculated by using a search algorithm that loops through a range of possible values and calculates the change in production with respect to a price shock for each commodity for each set of elasticity values. The set of elasticity values that comes closest in replicating the FAPSIM supply multipliers are used in the model formulation. Currently, the transformation elasticities are set at -2. The results from the search algorithm indicate that crop supply response is sensitive to the magnitude of the transformation elasticity on the CET function used to control substitution among crop rotations. Crop supply response was largely unaffected by the magnitude of the transformation elasticity used on the CET functions that control substitution among the tillage practices.

Biophysical Calibration

Biophysical calibration is accomplished by running regional specification of soil type, weather conditions, crop systems, and management practices through EPIC biophysical simulations. A representative soil was selected for each region from the NRI and SOILS5 databases by using a multidimensional measure of similarity to regional average Universal Soil Loss Equation (USLE) variables capturing slope, hydrological, and erodability characteristics (Wischmeier and Smith, 1978). Representative weather

conditions are estimated from distributional information (mean and variance) on temperature and rainfall from the National Oceanic and Atmospheric Administration (NOAA) combined with information on location of crop production. Average crop yields are estimated for the model regions from county yield data for the 10 crops.

Each crop system is specified as a sequence of crops, with dated field operations including planting, cultivation, fertilizer and pesticide application, and harvesting. Biophysical model biological parameters are validated in each production region so that simulated yields calibrate to regional yields and to ensure the yield-nitrogen response is consistent with observed nitrogen application rates and rational economic behavior on the part of producers.

Once the biophysical model has been calibrated, the environmental loading coefficients used by REAP for each combination of crop, rotation, tillage, drainage (tile drained or not), and region are derived. To more closely replicate the long-term effects of a particular set of practices, EPIC is first used to simulate the evolution of soil condition over 60 years of weather conditions for each set of practices. After that period of priming the soil, the soil condition is fixed, and the coefficients for nitrogen leaching, soil erosion, and so forth are calculated. These parameters represent the average annual results over a number of years; the specific number varies, depending on the number of crops in rotation and the number of years in the rotation, but is usually equal to 7 years' worth of results per crop.

Onsite phosphorus and nitrogen runoff estimated by using EPIC are calibrated to in-stream measurements made by the U.S. Geological Survey (Smith et al., 1997). The transport coefficients for phosphorus and nitrogen are used to estimate the quantity of sheet and rill erosion and pesticides that also run off into surrounding water bodies. Pesticide leaching and runoff are measured by the quantity of the active ingredient and then normalized to reflect toxicity and half-life (Barnard et al., 1997).

An interface called I_EPIC is used to manage the multiple EPIC runs necessary for calibration and generation of REAP environmental parameters. I_EPIC was developed and is maintained by Iowa State University. In order to increase the transparency of input, I_EPIC uses Microsoft Access databases as its input files rather than the more cryptic text-based input files used directly by EPIC. When input modifications are required, these databases can easily be opened and edited, then reloaded into I_EPIC. I_EPIC generates the text-based input files required by EPIC, and then translates EPIC's output into pre-formatted output tables in the same Microsoft Access database.

EPIC requires extremely detailed information about soil conditions, other site conditions (such as slope and weather), and sequence and timing of field operations in order to run. Creation of the data-rich input databases used by I_EPIC is therefore the most time-intensive step in the process of calibrating the model and generating the environmental effect parameters. As mentioned earlier, soil and weather information were originally compiled from external data sources, while field operations were compiled by USDA and WRI from existing data.

I_EPIC supports several versions of EPIC, including version 0509, which was used to generate the most recent set of environmental parameters used by REAP. More information on EPIC is at http://www.brc.tamus.edu/epic/. More information on I_EPIC is at http://www.public.iastate.edu/~elvis/i_epic_main.html.

Crop Yield Reconciliation

Crop production in REAP is calibrated to baseline data projections by adjusting crop yields in the crop production enterprise systems. This is accomplished by distributing projected crop production to the Farm Resource Region by using each region's share of crop production as derived from crop production information reported by NASS. The regional crop production results for each crop are then compared with each simulated yield for a Farm Resource Region to form a crop-specific index in each Farm Resource Region, which is then used to adjust yields in each production enterprise system so that simulated

production matches projected production for each crop in each Farm Resource Region. This routine is in a1a0\bgcaxa.gms.

Environmental Indicator Reconciliation

The erosion estimates in the budgets are calibrated to meet erosion information obtained from the NRI by obtaining the soils erosion estimate by REAP model region from the 1992 NRI. The erosion coefficients in the REAP budgets are then used to calculate REAP estimates of cropland erosion in each region. An erosion index for adjusting REAP erosion coefficients are constructed by dividing the NRI estimates by the REAP soil erosion estimate for each model region. A similar routine is used to calibrate wind erosion. The code for this is in a1a0\envir\evactga.gms.

Box 1—History of Model's Development

The U.S. Mathematical Programming Regional Agricultural Sector Model (USMP) (now Regional Environment and Agriculture Programming Model (REAP), an agriculture sector analysis model, grew out of innovations in optimization, economic modeling, and computing in the 1970s and 1980s. Following Duloy and Norton's (1973 and 1975) application of separable programming, the Economic Research Service (ERS) began sector model efforts in 1981 to support analysis of 1981 and 1985 farm legislation. Robert House built the initial USMP sector model based on the Duloy and Norton model. In 1982, House reformulated USMP as a nonlinear system enabling direct solution of USMP's quadratic demand and Positive Math Programming (PMP) supply system, based on Howitt's (1995) PMP methodology.

From the mid-1980s to late 1980s, crop commodity programs and endogenous acreage program participation were added to the model. The addition of the Conservation Reserve Program followed, along with incorporation of and calibration to the USDA multiyear baselines. In these years, USMP contributed to ERS food and agricultural public and staff analyses, including the 1981 and 1985 Farm Bills.

Terry Hickenbotham collaborated on USMP enhancements and analyses in the 1980s, including GATT trade liberalization and analyses of the new triple base provisions of the 1990 Farm Bill. In 1991, W. Terry Disney joined the USMP effort. Disney rebuilt the livestock sector, and Mark Peters developed comprehensive feed grain and wet/dry milling components that supported 1990's ethanol analyses. A joint project with the World Resources Institute (WRI) and the Rodale Institute (including Paul Faeth and John Westra of WRI, and Kim Kroll and Jim Reynolds of the Rodale Institute) was initiated to add environmental indicators and alternative tillage and rotation cropping systems to the model, facilitating conservation and environmental policy analysis.

House and Peters enhanced these by integrating constant-elasticity crop supply to manage the numerous regional, tillage, fertilizer application, and multiyear rotation alternatives. House and Peters integrated calibrated estimates of crop yield and alternative nitrogen application rates and other physical indicators by using the EPIC crop biophysical model. Howard McDowell enhanced the environmental indicator measures and analysis and linked GIS information with USMP analyses.

After 2000, Keith Paustian and Mark Sperow of the Natural Resource Ecology Laboratory of Colorado State University helped to develop carbon sequestration implications of changes in U.S. crop and forestry land uses; Robert Johansson and Jonathan Kaplan of ERS helped to incorporate the environmental implications of animal production; Suzie Greenhalgh, Mindy Selman, and Elizabeth Marshall of WRI helped to develop watershed applications and biofuel components for the model.

In 2006, the model was renamed "REAP" to reflect the importance of the region-specific interaction between the environmental and economic components of the model, which are currently being revised by researchers at WRI (Elizabeth Marshall, Suzie Greenhalgh, and Mindy Selman), ERS (Scott Malcolm), and the Louisiana State University Agricultural Center (John Westra).