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Standardizing Cropping System Data for Integrated Agricultural Resource Assessment

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Abstract: Approximately 40 percent of the land in the United States is farmland, about 370 million hectares. Farmers cultivate 158 million hectares, making daily decisions to improve the productivity of their land. Through technical assistance program providers and agricultural retail consultants, they use several tools to assess the sustainability of their operations, analyzing soil health, water management, agricultural chemical inputs, energy use, among other concerns. These tools currently provide more than 1 million assessments annually on farm fields across the country, including models and metamodels estimating water and wind erosion, soil organic matter trend, farm fuel use, nutrient and pesticide loss potentials, nutrient balance, PM10 air particulates (dust), soil carbon and nitrogen sequestration. The tools operate from common national soil and climate data. Central to on-farm analysis is the cropping system applied by the farmer. With many programs and initiatives supporting assessments overall, standardizing cropping system data becomes crucial, focused on the farmer's crop rotation, the operations applied on the ground, and the basis for management inputs to the suite of tools. We define a Conservation Resources (CR) cropping system as a series of events, each event having a date and farming operation. An operation may associate to a crop or amendment. From this simple structure, we associate tool-specific input parameter sets to the core entities. The underlying CR database contains ~25,000 cropping system templates across 75 crop management zones, ~550 farming operations, and 118 crops. We provide a suite of data web services fetching data for running the tools.

***Keywords**:* cropping system, data standardization, resource assessment

1.0 Introduction

Approximately 40 percent of the land in the United States is farmland, about 370 million hectares. Farmers cultivate 158 million hectares, making daily decisions to improve the productivity of their land. Through technical assistance program providers and agricultural retail consultants, they use several tools to assess the sustainability of their operations, analyzing soil health, water management, agricultural chemical inputs, energy use, among other concerns.

The Revised Universal Soil Loss Equation (RUSLE2) and Wind Erosion Prediction System (WEPS) models (USDA-ARS, 2013; Wagner, 2013), and the Water Quality Module (WQM) of the Stewardship Tool for Environmental Performance (STEP) expert system (Norfleet et al, 2015) have been deployed as web services operating from common climate, soil, and land management databases. Currently, these services currently support more than 1 million assessments annually on farm fields across the country, estimating water and wind erosion, soil organic matter trend, nutrient loss potentials, pesticide loss potentials and hazards, PM10 air particulates (dust), and farming operation fuel use. Several applications use these services: the USDA Natural Resources Conservation Service (NRCS)

Integrated Erosion Tool, the NRCS Resource Stewardship Evaluation Tool (RSET), the Fieldprint Calculator (FPC) of Field-to-Market (FtM) – The Alliance for Sustainable Agriculture, and FtM member applications using the FPC application programming interface (API). Other models and expert systems (metamodels) deployed as web services are in the pipeline to be integrated with the common databases.

Farm field-level assessment starts with the cropping system devised by the farmer, the sequence of crops grown and the management (farming operations and practices) applied to optimize yield and sustain the productivity of the land. Farm field location enables fetching climate and soil parameter inputs to the model/metamodel services from common data sources. Assessment applications should create cropping system inputs from a common source of crop, operation, and amendment data, thus the emergence of the Land Management Operations Database (LMOD) initially integrating crop rotation data developed for RUSLE2 and WEPS (David et al, 2014). With more models and tools added to the suite of resource assessment web services, and on the way, we have updated and streamlined the LMOD database, and in this paper describe this and an emerging standard for cropping system inputs to the model/metamodel services. Standardized inputs should make it easier for applications having crop rotation builder modules to communicate with these services.

2.0 Methods

The initial version of LMOD grew from the integration of the empirical water erosion model RUSLE2 and wind erosion process model WEPS but taking RUSLE2 management data as the starting point: RUSLE2 chosen because it was the most prevalently used model in 2,800+ USDA county offices. Applications chose from ~27,000 single to multi-year crop rotation templates developed across 75 crop management zones in the United States and Territories, involving 959 crops, 582 farming operations, and 111 residues. Each crop, operation, and residue record contained parameter sets relevant to the RUSLE2 model. Then data stewards matched WEPS parameter sets to these records. Operations and residues matched reasonably well, whereas matching ~300 WEPS crops to 957 RUSLE2 crops often involved a WEPS crop matched to multiple RUSLE2 crops. In several cases for perennial crops, a RUSLE2 crop did not match to a WEPS crop, for example a RUSLE2 second year alfalfa regrowth “crop” translating to “no crop” for WEPS. The primary criticisms came to be LMOD was too RUSLE2 centric with too many crop variants. The variation in crop parameter values among crop variants was not significant enough to justify their number.

The NRCS decision to replace RUSLE2 with the Water Erosion Prediction Project (WEPP) model (Flanagan et al, 2007) provided the opportunity to streamline and update the LMOD data model with the database having fewer crops and residues, and about the same number of operations. WEPP is a process model having a similar lineage to WEPS with some model components having a somewhat overlapping codebase. Both adapted the plant growth component of the Erosion Productivity Impact Calculator (EPIC) model (Sharpley and Williams, 1990). Examining management data for other models and tools supporting or likely to support field-level agricultural resource assessment going forward also revealed reasonable alignment with management data used by WEPS and WEPP. With this analysis, we modelled the next generation database coined Conservation Resources LMOD, or CR_LMOD, developed a new suite of data web services to fetch data for applications, and standard input Javascript Object Notation (JSON) for inserting into input payloads to the WEPS, WEPP, and other resource assessment model/metamodel services.

3.0 The Conservation Resources Land Management Operations Database (CR_LMOD) and Supporting Data Services

With CR_LMOD a cropping system (management) is a series of events, each having a date and a farming operation. If an event has a planting operation, it also has a crop. If an operation puts residue on the ground, for example, compost or mulch, the event has a residue (amendment). Management, event, crop, operation, and residue form the core entities relevant to the current models. The crop, operation, and residue tables have foreign keys to model/metamodel specific tables containing parameter sets needed for simulation. See Figure 1.

CR_LMOD contains ~25,000 managements across 75 CMZs, a slight reduction from the initial LMOD version, removing obsolete records. The database contains roughly the same number of farm operations. However, the number crop records has been sharply reduced to 118, more aligned with

the crops supporting the WEPS, WEPP, STEP-WQM, and other models/metamodels expected to be used for farm field-level resource assessment. Residue (amendment) records were reduced to 16.

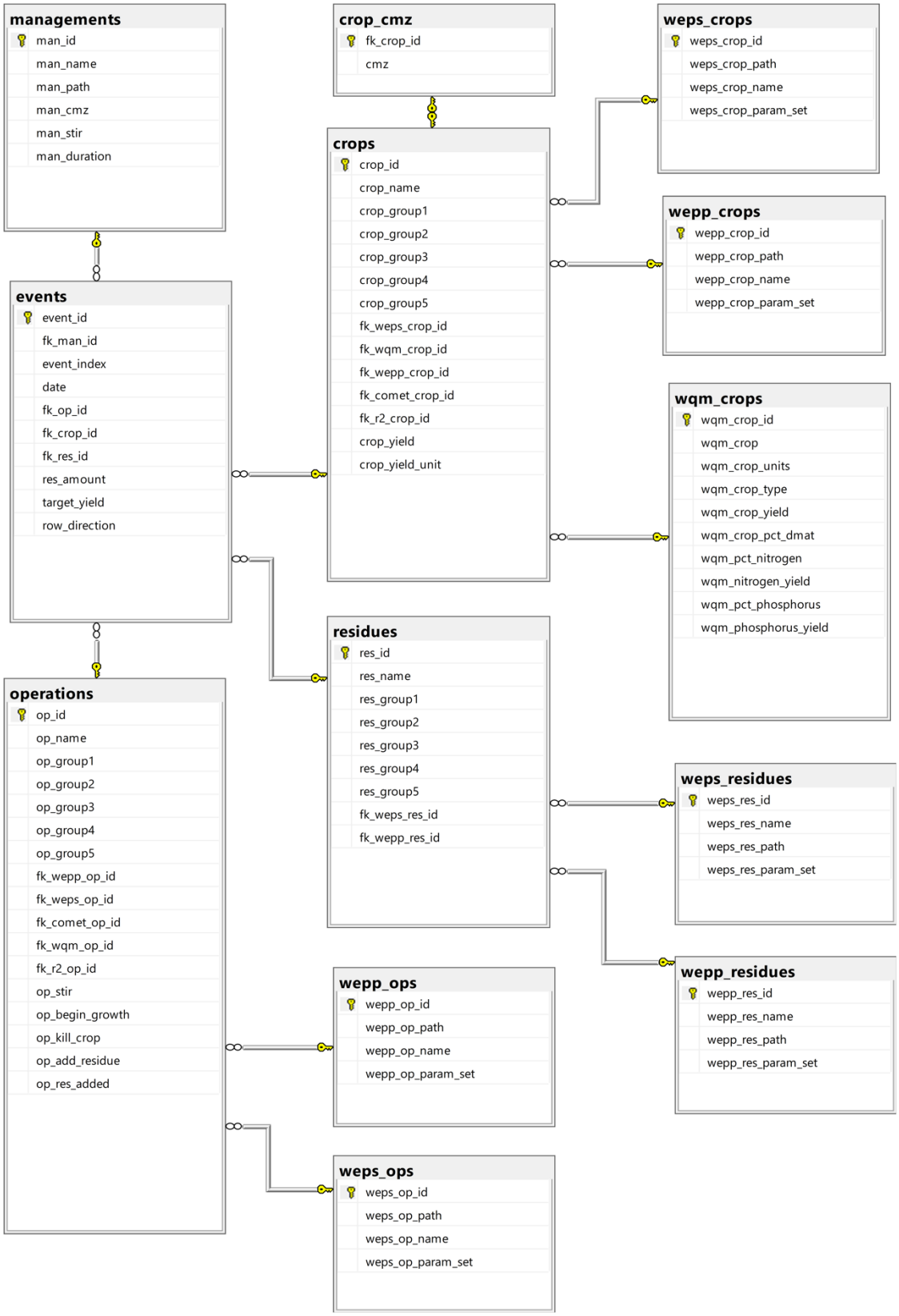

Figure 1. Conservation Resources Land Management Operations Database (CR_LMOD) data tables and elements.

To provide applications access to the data, we updated the suite of web services, deployed as the csip-crlmod service layer. The current service endpoints are:

http://csip.engr.colostate.edu:8092/csip-crlmod/d/management/1.0

http://csip.engr.colostate.edu:8092/csip-crlmod/d/crop/1.1

http://csip.engr.colostate.edu:8092/csip-crlmod/d/operation/1.1

http://csip.engr.colostate.edu:8092/csip-crlmod/d/residue/1.0

The services are built using the Object Modelling System (OMS) and Cloud Services Integration Platform (CSIP) application programming interfaces (APIs) providing data as-a-service (David et al, 2014). CSIP services are RESTful, consuming request JSON populated by an application and returning results as response JSON to the application supporting the business workflow. Figure 2 displays a sample request JSON payload to the csip-crlmod/d/crop/1.1 service.


```
{
"metainfo": {},
"parameter": [{
"name": "id",
"description": "Array containing bigInt identifiers for the objects requested.",
"value": []
},{
"name": "name",
"description": "Array containting strings that exactly match a records name, path excluded.",
"value": []
},{
"name": "keywords",
"description": "Space delimited string containing keywords that match some part of a record's name.
Exclusions can be expressed by putting a minus sign before the term e.g. -corn",
"value": "barley"
},{
"name": "path",
"description": "Array containing strings that exactly match a record's path.",
"value": []
},{
"name": "partial_path",
"description": "Array containing keywords that match some part of a record's path",
"value": []
},{
"name": "limit",
"description": "Maximum number of records to be returned.",
"value": "1"
},{
"name": "offset",
"description": "Number of records to skip before returning the first",
"value": "0"
},{
"name": "names_only",
"description": "True/False to this statement – Return the names of the returned objects, no metadata
or model data.",
"value": "false"
},{
"name": "native_formats",
"description": "True/False to this statement - Return native model formats in the return JSON, not
just names and metadata.",
"value": "false"
}]}
```


Figure 2. Sample request JSON for the csip-crlmod/d/crop web service

Figure 3 provides the partial sample response JSON payload. Had the input parameter “native formats” been set to “true” the service would have returned spring barley parameter sets for each of the currently supported models.


```
{
"metainfo": {
"status": "Finished",
"cloud_node": "10.1.83.26",
"request_ip": "129.82.52.148",
"service_url": "http://csip.engr.colostate.edu:8092/csip-crlmod/d/crop/1.1",
"csip.version": "$version: 2.2.12 d77d473c01cc 2018-02-13 od, built at 2018-03-06 12:13 by
jenkins$",
"tstamp": "2018-03-21 20:55:21",
"cpu_time": 6,
"expiration_date": "2018-03-21 20:55:51"
},
"parameter": [<inputs>],
"result": [{
                "name": "crlmod",
                "value": {
                "rotations": [],
                "rotationCount": 0,
                "operations": [],
                "operationCount": 0,
                "crops": [{
                                "id": 257,
                                "name": "Barley, spring, grain",
                                "defaultYield": 55,
                                "yieldUnit": "bu/ac"
                        }
```


Figure 3. Partial sample response JSON from the csip-crlmod/d/crop web service.

4.0 Standard Cropping System Data Description.

The concept model for a Conservation Resources (CR) cropping system on a farm field has six primary entities: rotation, management, event, crop, operation, and residue. It derives from “skeleton” XML (.skel) used to exchange management data between desktop versions of the WEPS and RUSLE2 models (USDA-ARS, 2010). Refer to Figure 4 for a sample abbreviated response JSON from the csip-crlmod/d/management service, returning a template for building a crop rotation. In the example, the request specified a no-till spring barley template from crop management zone 1 in the northern Midwest. The request could have been less specific, returning several templates.

A farm field contains one or more crop rotations, typically one, but sometimes more, accommodating alley cropping, vineyards, and other more complex cropping patterns within the field. CR_LMOD supports building a crop rotation by (1) adding operations, crops, and residues to an empty template, or (2) editing one or more management templates retrieved from the database. A management template contains one or more crops, with operation dates spanning one to several years. In the example the operation dates fit within one year, thus a duration of one year.

A management template retrieved from CR_LMOD contains an identifier, path, and name, parameters used for search and choice lists. It also contains a soil tillage intensity rating (STIR) value, the sum of the ratings for each of its operations. However, an array of events primarily characterizes the management. Each event at a minimum must have a date and an operation parameter.

Each event operation has an identifier, name, and belongs to a group of similar operations for choice lists or search trees. It has a STIR value, reflecting type and degree of soil disturbance and ground speed. The operation has three Boolean parameters, whether it triggers plant growth, kills live biomass, and involves adding a residue/amendment, such as compost or manure.

```
“result": [{
        "name": "crlmod",
        "value": {
        "rotations": [{
                "duration": 1,
                "managements": [{
                        "id": 27521,
                        "path": "CMZ 01\\a.Single Year Single Crop Templates\\Barley, spring",
                        "name": "spring barley; NT z1",
                        "stir": 2.8,
                        "events": [{
                                "date": "2001-04-20",
                                "operation": {
                                        "id": 20011,
                                        "name": "Fert applic. surface broadcast",
                                        "opGroup1": "Application, agchem, nutrient",
                                        "stir": 0.06,
                                        "begin_growth": false,
                                        "kill_crop": false,
                                        "add_residue": false
                                }},{
                                "date": "2001-04-20",
                                "operation": {
                                        "id": 20211,
                                        "name": "Drill or air seeder, single disk openers 7-10 in spac.",
                                        "opGroup1": "Seeding, drill, other",
                                        "stir": 2.44,
                                        "begin_growth": true,
                                        "kill_crop": false,
                                        "add_residue": false},
                                "crop": {
                                        "id": 257,
                                        "name": "Barley, spring, grain",
                                        "defaultYield": 55,
                                        "yieldUnit": "bu/ac",
                                }},{
                                "date": "2001-06-01",
                                "operation": {
                                        "id": 20044,
                                        "name": "Sprayer, post emergence",
                                        "opGroup1": "Application, agchem, nutrient",
                                        "stir": 0.15,
                                        "begin_growth": false,
                                        "kill_crop": false,
                                        "add_residue": true},
                                "residue": {
                                        "id": 12,
                                        "name": "weed residue; 0-3 mo"
                                }},{
                                "date": "2001-08-05",
                                "operation": {
                                        "id": 20140,
                                        "name": "Harvest, killing crop 50pct standing stubble",
                                        "opGroup1": "Harvest, crops",
                                        "stir": 0.15,
                                        "begin_growth": false,
                                        "kill_crop": true,
                                        "add_residue": false …
                                }}] …
```


Figure 4. Sample abbreviated response JSON from csip-crlmod/d/management web service.

If an operation involves planting, the event includes the crop parameter. A crop has an identifier, name, default yield amount, and yield units. If an operation involves adding a residue, the event includes the residue parameter. A residue has an identifier and name.

An application using this standard core cropping system data should follow the general data flow displayed in Figure 5. The application requests basic management, operation, crop, and residue data from CR_LMOD for populating choice lists. The application user builds a crop rotation, the application requesting additional management template data as needed. The application inserts the crop rotation JSON into the request to the model service (e.g. WEPS or WEPP), also containing other application generated input parameters required by the model. The model service fetches additional model-specific operation, crop, and residue parameters, and with other inputs executes the model simulation, returning results to the application.

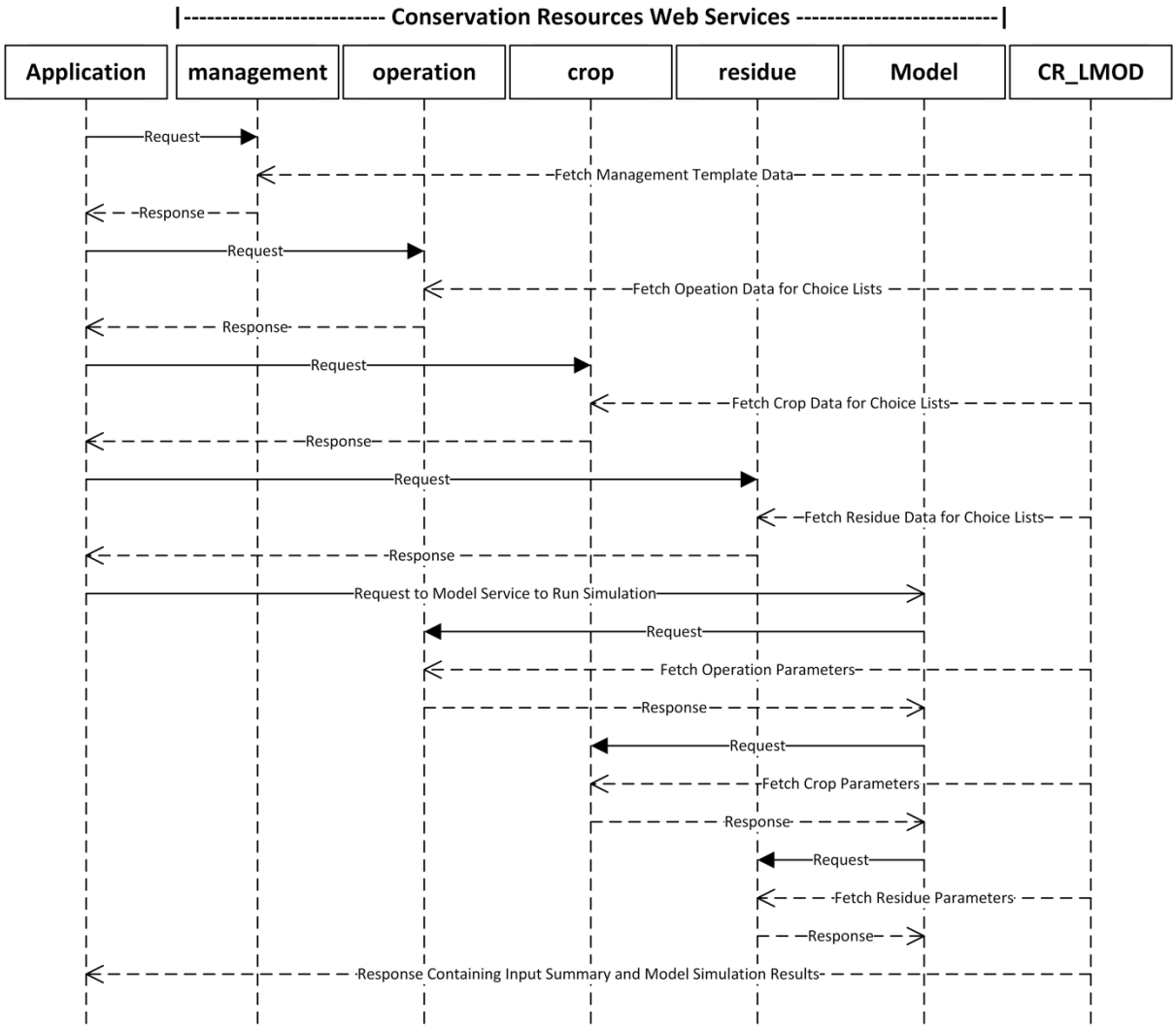

Figure 5. Generalized data flow involving a software application using CR_LMOD data and services.

5.0 Discussion

Currently, CR_LMOD and its data services support the Integrated Erosion Tool (IET) deployed to NRCS county offices. IET computes representative water and wind erosion rates on farm fields, as well as soil organic matter trend, PM10 air particulates, and farming operation fuel use. IET runs the CR WEPP and WEPS model services deployed to the agency data center, using common databases for climate, soil, as well as common cropping system data discussed in this paper. NRCS typically updates ~300,000 conservation plans annually, involving assessments of ~1.5 million farm fields. While not all assessments require model simulations, these numbers provide a general indication of

the service load for capacity management purposes. Each model service simulation involves approximately 5 service requests for CR_LMOD data.

CR_LMOD data and services also support WEPS and WEPP simulations for the soil conservation metric of the national-scope FtM Fieldprint Calculator (https://fieldtomarket.org/our-program/fieldprint-platform/). FtM member organizations using their own applications request erosion model simulations through the FPC API calling CR model and data services, and farmers can directly use the FtM FPC application to do the same. Current service load averages ~1,000 model simulations per day, with periodic batch requests for 20-40 thousand simulations a day for short periods.

Progress continues to integrate other models and metamodels with CR_LMOD data and services. STEP-WQM relies on a crop table containing nitrogen and phosphorus grow-out parameters for nutrient balance calculations, a table added to CR_LMOD mapped to records in the parent crop table. Similar integration continues to map crop data for the Daily CENTURY (DayCent) model (Parton et al, 1998) to CR_LMOD to support assessment of greenhouse gas emissions and carbon sequestration. WEPP, WEPS, and the Soil and Water Assessment Tool (SWAT) model (Gassman et al, 2007) plant growth sub-models have a common lineage, prompting recent discussion enabling SWAT access to CR_LMOD data and services.

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