**Fertilizer Application**

***a. Source Category Description***

Fertilizer in this category refers to any nitrogen-based compound, or mixture containing such a compound, that is applied to land to improve plant fitness.

The approach to estimate 2014 fertilizer emissions consists of these general steps:

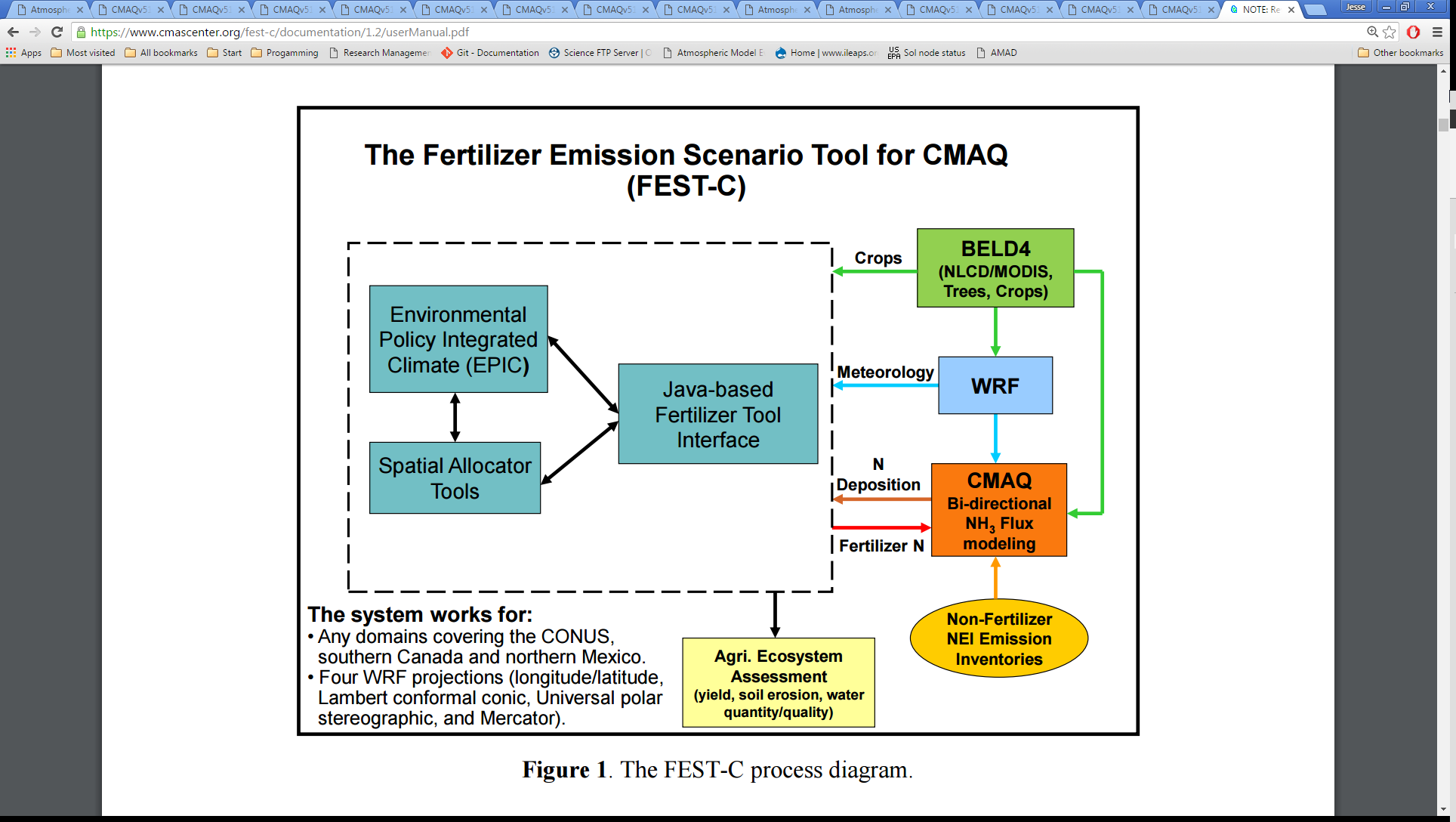
* Run the Fertilizer Emissions Scenario Tool for CMAQ (FEST-C1) and CMAQ2 model with bidirectional (“bidi”) NH3 exchange to produce year 2011 nitrate (NO3) Ammonium (NH4, including Urea), and organic (manure) nitrogen fertilizer estimates and gaseous ammonia NH3 emission estimates respectively.
* Run the Environmental Policy Integrated Climate (EPIC3) modeling system to produce year 2014 NO3, Ammonium (including Urea), and organic (manure) nitrogen fertilizer estimates.
* Compute year 2011 emission factors from the FEST-C outputs to use in estimating year 2014 NH3 emissions.
* All emissions are assigned to one SCC: “…Miscellaneous Fertilizers” (2801700099).

FEST-C reads land use data from the Biogenic Emissions Landuse Dataset (BELD) version 4, meteorological variables from the Weather Research and Forecasting (WRF4) model, and nitrogen deposition data from a previous or historical average CMAQ simulation. FEST-C model outputs are discussed in greater detail in the “NH3\_Fert\_Fact\_Sheet\_v2.docx” included in the zip file “*2014\_Fertilizer\_Application\_v1.0\_22apr2016.zip*” available at:

<ftp://ftp.epa.gov/EmisInventory/2014/doc/nonpoint/>

A comprehensive flowchart if the complete EPIC/FEST-C/WRF “bidi” modeling system is illustrated in Figure 1.

**Figure 1.** “Bidi” Modeling system used to compute 2014 fertilizer emissions

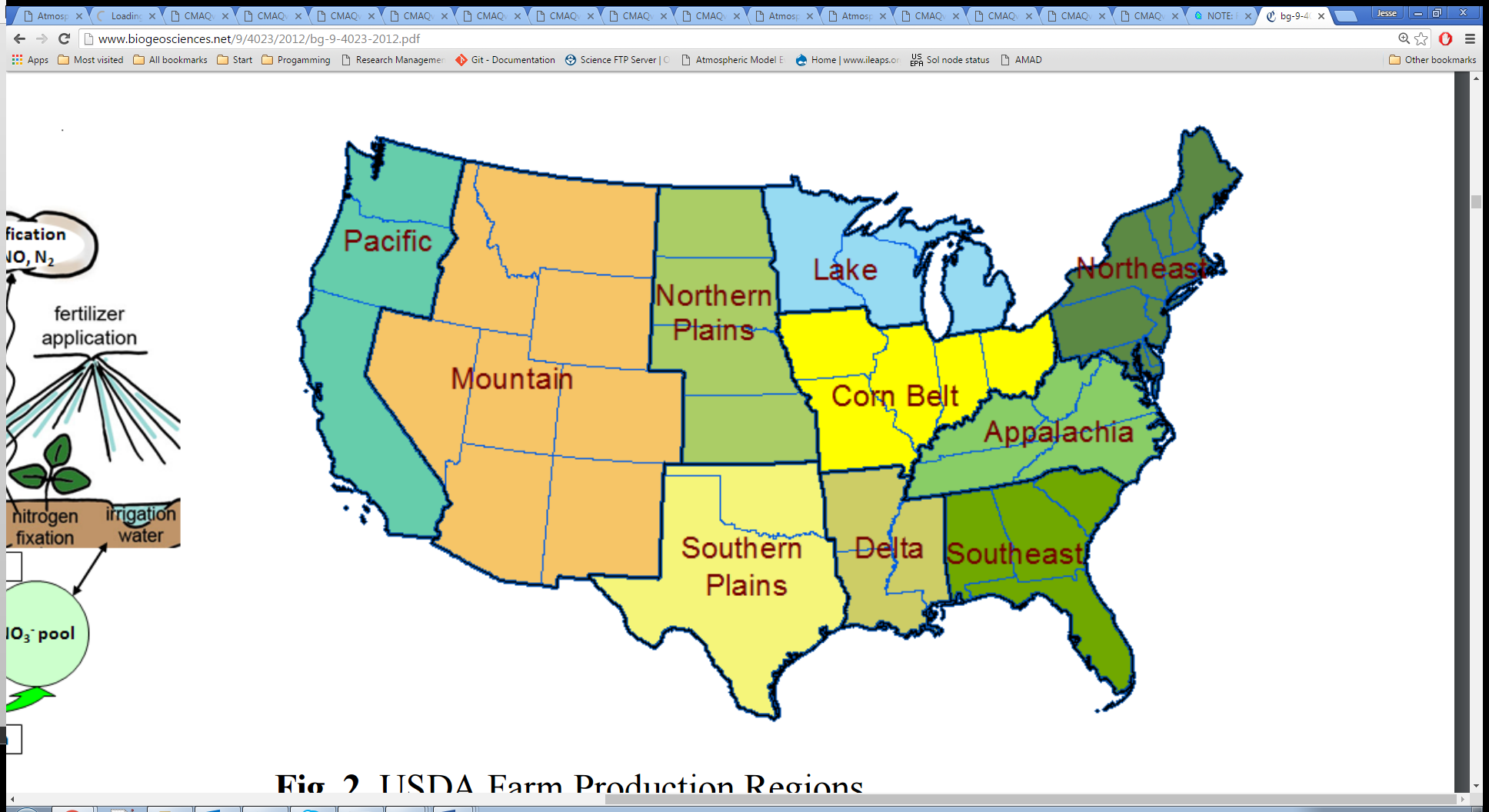


***b. Activity Data***

The following activity parameters were input into the EPIC model:

* Grid cell meteorological variables from WRF (see Table 1)
* Initial soil profiles/soil selection
* Presence of 21 major crops: irrigated and rain fed hay, alfalfa, grass, barley, beans, grain corn, silage corn, cotton, oats, peanuts, potatoes, rice, rye, grain sorghum, silage sorghum, soybeans, spring wheat, winter wheat, canola, and other crops (e.g. lettuce, tomatoes, etc.)
* Fertilizer sales to establish the type/composition of nutrients applied
* Management scenarios for the 10 USDA production regions (Figure 2)

**Figure 2.** USDA farm production regions used in FEST-C simulations5



Grid cell meteorological variables were generated by the WRF meteorological model. WRF was run on a national 12km rectangular grid for the year 2014. The meteorological parameters in Table 1 were used as EPIC model inputs.

**Table 1.** Environmental Variables needed for an EPIC simulation

| EPIC input variable | Variable Source |
| --- | --- |
| Daily Total Radiation (MJ m2 ) | WRF |
| Daily Maximum 2-m Temperature (C) | WRF |
| Daily minimum 2-m temperature (C) | WRF |
| Daily Total Precipitation (mm) | WRF |
| Daily Average Relative Humidity (unitless) | WRF |
| Daily Average 10-m Wind Speed (m s-1 ) | WRF |
| Daily Total Wet Deposition Oxidized N (g/ha) | CMAQ |
| Daily Total Wet Deposition Reduced N (g/ha) | CMAQ |
| Daily Total Dry Deposition Oxidized N (g/ha) | CMAQ |
| Daily Total Dry Deposition Reduced N (g/ha) | CMAQ |
| Daily Total Wet Deposition Organic N (g/ha) | CMAQ |

Initial soil nutrient and pH conditions are based on the 1992 USDA Soil Conservation Service (CSC) Soils-5 survey. The EPIC model then is run for 25 years using current fertilization and agricultural cropping techniques to estimate soil nutrient content and pH for the 2014 EPIC/WRF/CMAQ simulation.

The presence of crops in each model grid cell was determined through the use of USDA Census of Agriculture data (2012) and USGS National Land Cover data (2011). These two data sources were used to compute the fraction of agricultural land in a model grid cell and the mix of crops grown on that land.

Fertilizer sales data and the 6-month period in which they were sold were extracted from the 2006 Association of American Plant Food Control Officials (AAPFCO). AAPFCO data is used to identify the composition, e.g. urea, nitrate, organic, etc., of the fertilizer used the amount applied is estimated using the modeled crop demand. This data is useful in making a reasonable assignment of what kind of fertilizer is being applied to which crops.

Management activity data refers to data used to estimate representative crop management schemes. The USDA Agricultural Resource Management Survey (ARMS) was used for this purpose. This data covers 10 USDA production regions, and provides management schemes for irrigated and rain fed hay, alfalfa, grass, barley, beans, grain corn, silage corn, cotton, oats, peanuts, potatoes, rice, rye, grain sorghum, silage sorghum, soybeans, spring wheat, winter wheat, canola, and other crops (e.g. lettuce, tomatoes, etc.).

***c. Emission Factors***

The emission factors were derived from the 2011 FEST-C outputs. Total fertilizer emission factors for each month and county were computed by taking the ratio of total fertilizer NH3 emissions (short tons) to total nitrogen fertilizer application (short tons).

***d. Emissions***

12 km by 12 km gridded NH3 emissions were mapped into a county shape file polygon if the grid level centroid falls within the bounds of the county level polygon. With additional time and resources, spatial allocator technique could be refined to allow for more accurate county-level estimates.

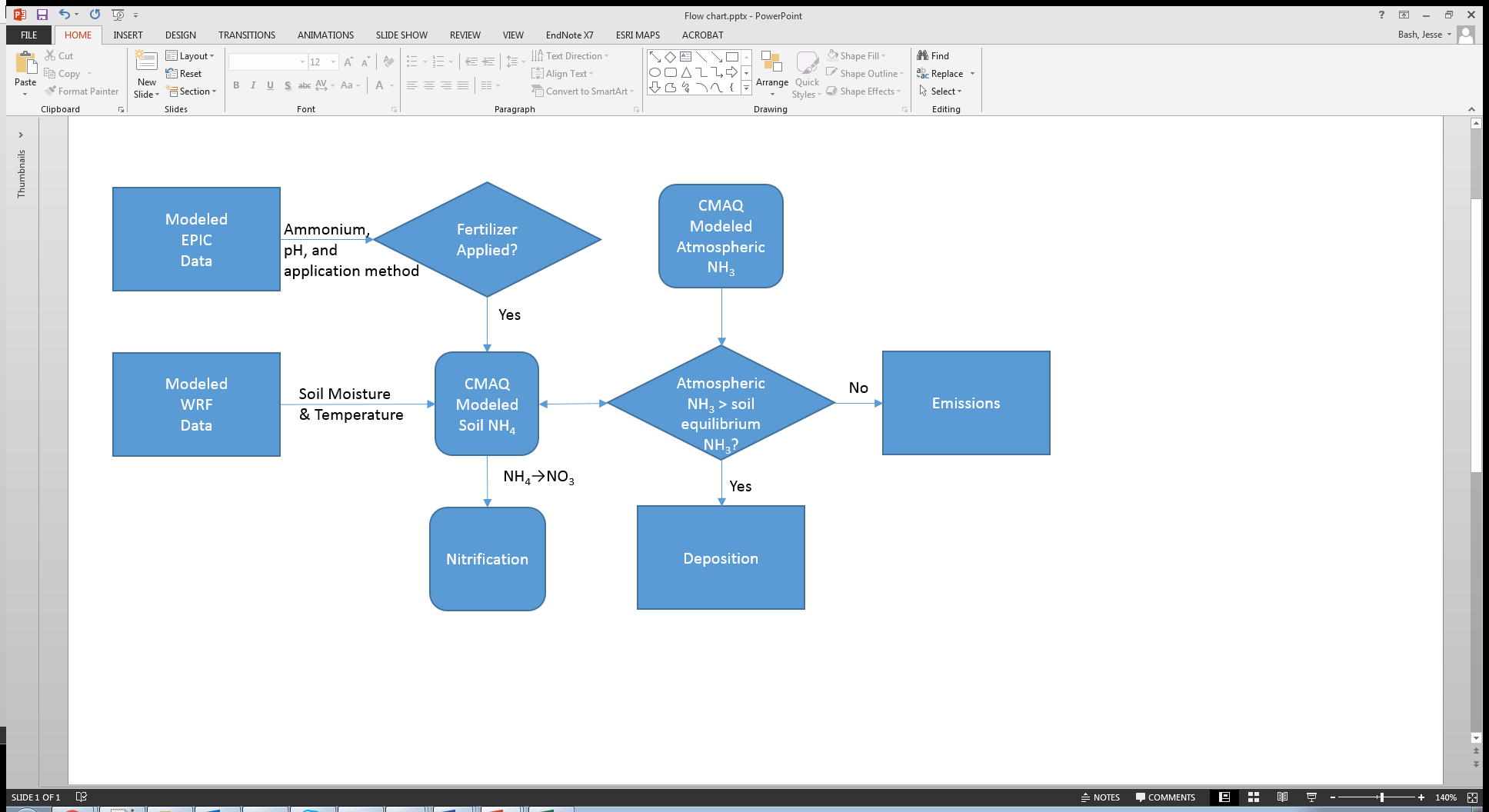
County-level fertilizer emissions (NH3) for 2014 are computed as:

(2011 Fertilizer Emissions/2011 Total N Fertilizer) \* 2014 Total N Fertilizer

***e. Sample Calculations***

With this modeling system, it would be difficult to perform a sample calculation; this is not something that could be demonstrated in a spreadsheet. These emissions are computed via the full chemical transport model, as illustrated in Figure 3.

**Figure 3.** Simplified flow of operations in estimating NH3 emissions across the EPIC/WRF/CMAQ modeling system



***f. Comparison to 2011 Methodology***

The 2014 fertilizer estimates are based on a new “bidi” approach that couples meteorological inputs, CMAQ and the EPIC modeling system. The 2011 fertilizer estimates are based on the Carnegie Mellon (CMU) Ammonia Model v.3.6. In short, the methodologies are completely different. Documentation of the methodology for the 2011 EPA dataset as well as the county level data and maps are located in the zip file at:

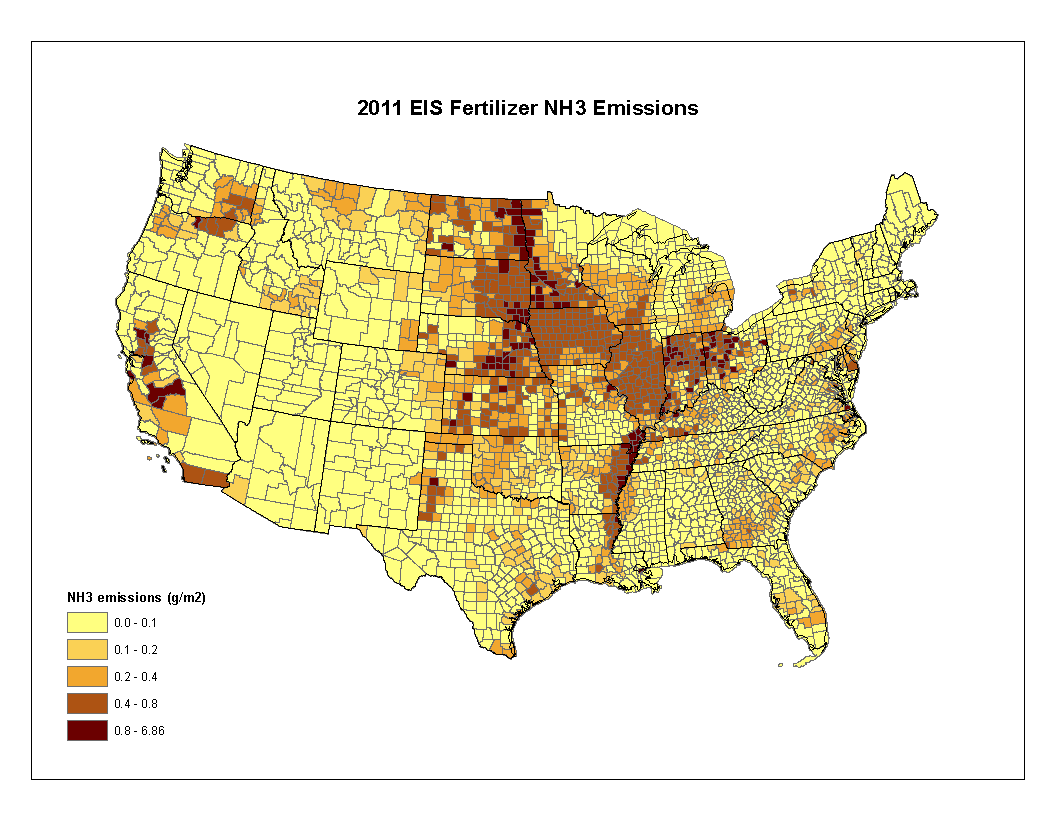
<ftp://ftp.epa.gov/EmisInventory/2011nei/doc/>[ag\_fertilizer\_application\_2011.zip](ftp://ftp.epa.gov/EmisInventory/2011nei/doc/ag_fertilizer_application_2011.zip)

For 2014 a comparison of the 2011 EPA data, 2014 EPA data, and 2011 NEI selection (EIS) as well as maps for those datasets are located in the zip file “*2014\_Fertilizer\_Application\_v1.0\_22apr2016.zip*” available at:

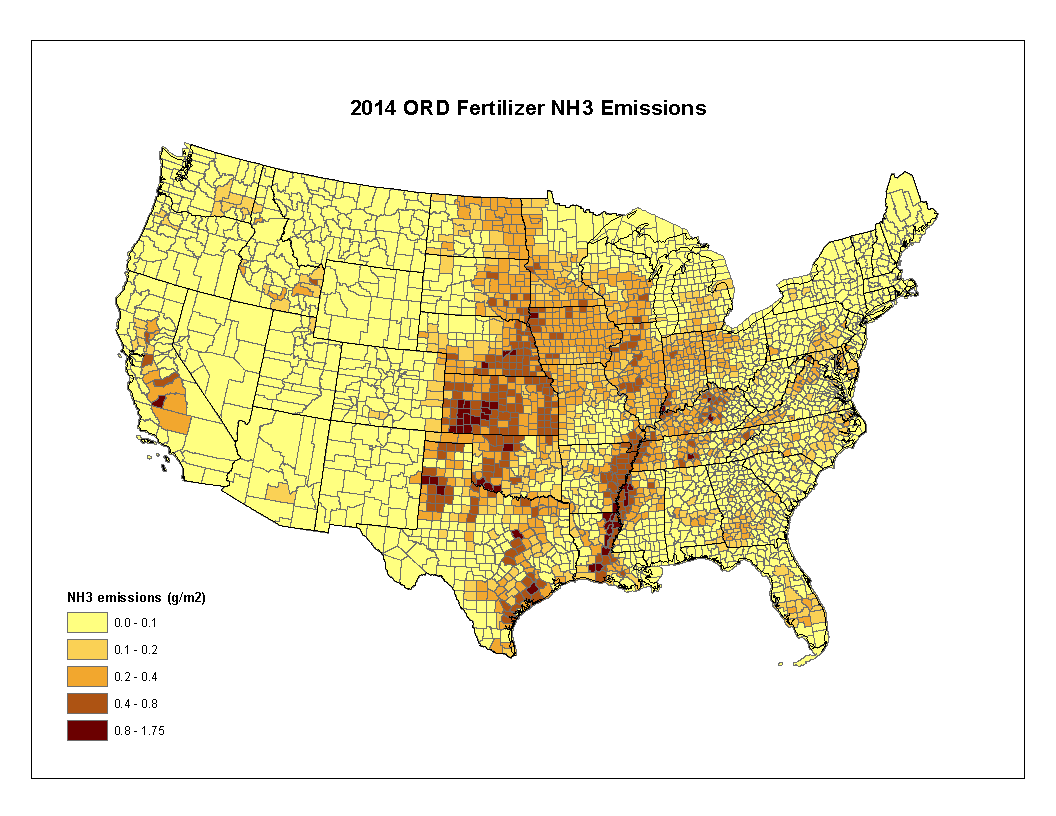
<ftp://ftp.epa.gov/EmisInventory/2014/doc/nonpoint/>

Emission maps for the NEI 2011v2 and these 2014 estimates are provided below in Figure 4 and Figure 5, respectively. In addition, the “*Emissions\_and\_fertilizer\_2011bidi\_vs\_2014bidi.xlsx*” Excel workbook provided in the previously-mentioned 2014 zip file, includes the comparison of these 2014 county-level emissions (column N) to 2011 (not 2011 NEI) estimates (column H) using the “bid” approach. Comparisons to the 2011 NEI at the county-level to the “bidi” approach for 2011 are also available in the workbook “*ORD2011\_NEI2011\_EIS2011\_Fertilizer\_NH3\_bycounty\_compare\_wREADME.xlsx*”.

**Figure 4.** NEI 2011v2 fertilizer emissions (publicly-available)



**Figure 5.** 2014 “bidi” fertilizer emissions (draft for 2014v1 NEI)



***g. References***

1. Fertilizer Emission Scenario Tool for CMAQ (FEST-C) system, available at: <https://www.cmascenter.org/fest-c/>

2. Community Multiscale Air Quality (CMAQ v5.1) model, available at: <https://www.cmascenter.org/>

3. Environmental Policy Integrated Climate (EPIC) model, available for download at: <http://epicapex.tamu.edu/>

4. Weather Research Forecast (WRF) model, available at: <http://www.wrf-model.org/index.php>

5. Cooter, E.J., Bash, J.O., Benson V., Ran, L.-M.; Linking agricultural management and air-quality models for regional to national-scale nitrogen deposition assessments, *Biogeosciences*, 9, 4023-4035, 2012. Also available at: <http://www.biogeosciences.net/9/4023/2012/>

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