Monarch Conservation Planning Tools

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U.S. Geological Survey

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Introduction

The eastern population of the monarch butterfly (*Danaus plexxipus*) has exhibited a multi-decadal population decline principally attributed to declines in oyamel fir (*Abies religiosa*) forests on their wintering grounds in Mexico (Brower and Others 2011; Vidal and Others 2014) and herbicide-related loss of their primary food source, milkweed (*Asclepias* spp.), on their breeding grounds in the eastern U.S and southern portions of Canada (Pleasants and Oberhauser 2013). The eastern population of monarchs reached their lowest observed abundance during the winter of 2013-2014, occupying approximately 2/3 of a hectare at their overwintering locations in central Mexico (Vidal and Rendón – Salinas 2014). To halt these declines and restore the population to former levels of abundance, conservation planning and implementation specifically devoted to monarchs is occurring across a wide array of federal departments, state agencies, county governments, and public-private partnerships.

USGS is assisting the Monarch Conservation Science Partnership in the development of an integrated package of scientific analyses and geospatial planning tools to guide strategic conservation for this imperiled species. Related products include the development of a continental-scale spatially explicit demographic model depicting changes in species abundance over space and time as a function of changes in vital rates (e.g., seasonal survival, fecundity, migration transitions between regions); models to inform policy leaders regarding possible population target levels and their associated levels of extinction risk; a threat analysis, evaluating existing and potential future threats; and, lastly, development of geospatial tools to assist in strategy development and planning for restoration of habitat essential to breeding monarchs.

This effort, Monarch Conservation Planning Tools, involved the creation and/or consolidation of geospatial data layers pertaining to a wide array of land use/land cover, climate, and stewardship information. Tools for helping to prioritize counties for monarch conservation, estimating the density of milkweeds across the country and for adjusting those estimates for the purposes of evaluating restoration scenarios were developed. The functionality of these tools and associated data are described here.

Toolbox Installation

To use the Monarch Conservation Planning Tools, there are some preliminary steps that need to be followed for them to function correctly on the computer. Software requirements are:

1. ArcMap 10.3 (Environmental Systems Research Institute) or more recent
2. A Spatial Analyst License
3. Python 2.4 or more recent (Automatically installed with ArcMap)
4. Pywin32 (Python for Windows extension)

Pywin32 allows Python to communicate with COM servers such as ArcMap, Microsoft Excel, Microsoft Word, etc. Python scripting in ArcMap cannot work without this extension. This extension can be downloaded at:

http://sourceforge.net/projects/pywin32/files/pywin32/

Once these software requirements are met, the user needs to:

1. Extract the compressed file "monarch_cons_plan_tools.zip" to a project directory on the computer's hard drive (Figure 1). Compressed data extraction software is freely available from http://www.7-zip.org/ . There are four sub-directories that are created. The directory *gis_data* contains the county summary shapefiles used in the tools, the directory *layer_definition_files* contains ArcMap symbology layers used to shade the outputs from the tools, the directory *scripts* contains the python scripts that are called by the tools, and the directory *tabular_data* contains spreadsheets containing important information used to develop the tools and data.
2. Open ArcMap 10.3 and activate ArcToolbox if not already activated (Geoprocessing -> ArcToolbox).
3. Right-click inside the ArcToolbox panel and select Add Toolbox… (Figure 2)
4. Open the extracted folder *monarch_cons_plan_tools* and click on the Monarch Conservation Planning Tools.tbx toolbox icon and select Open (Figure 3).
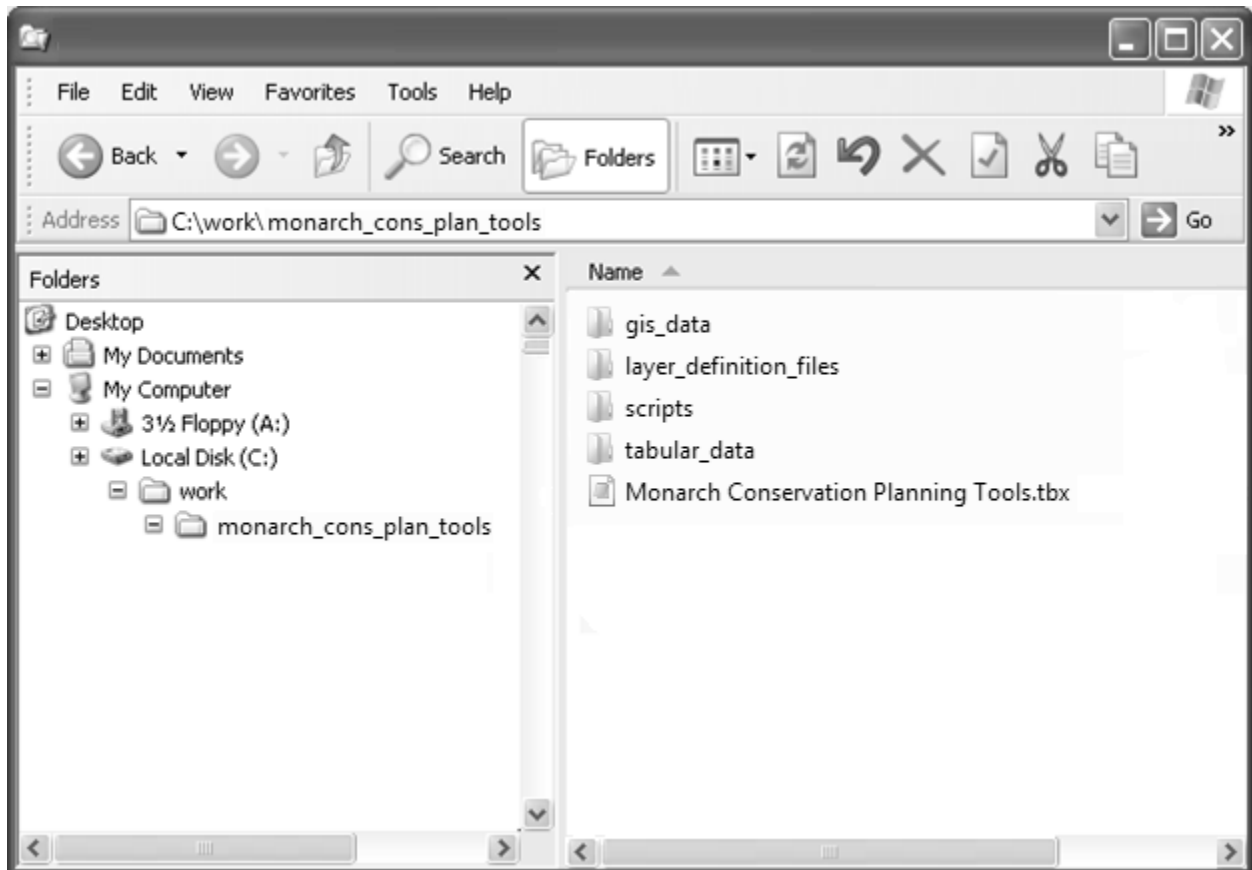
Figure 1. Windows Explorer view of extracted files
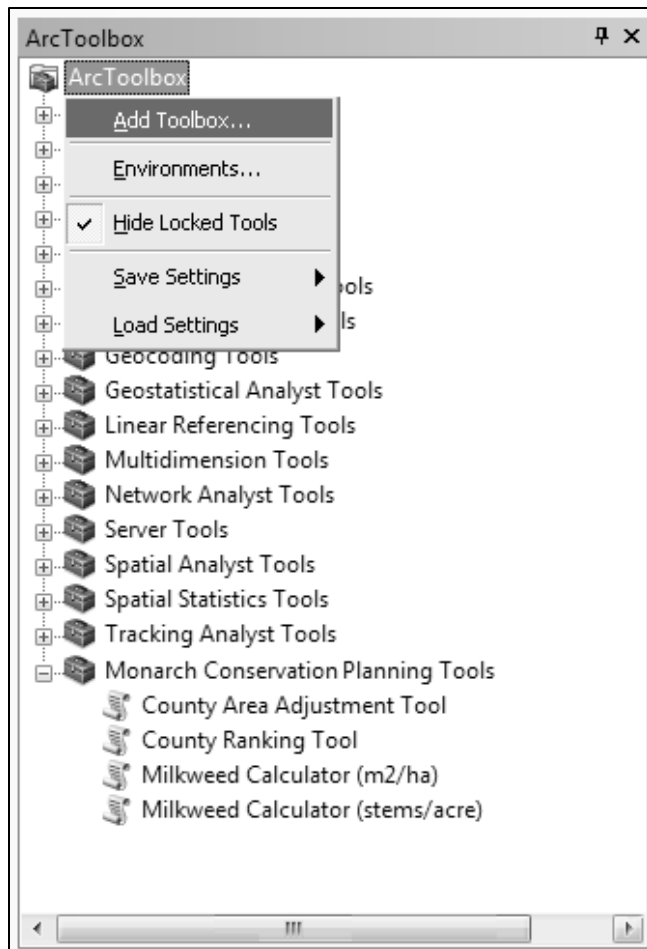
Figure 2. ArcToolbox view of Monarch Conservation Planning Tools
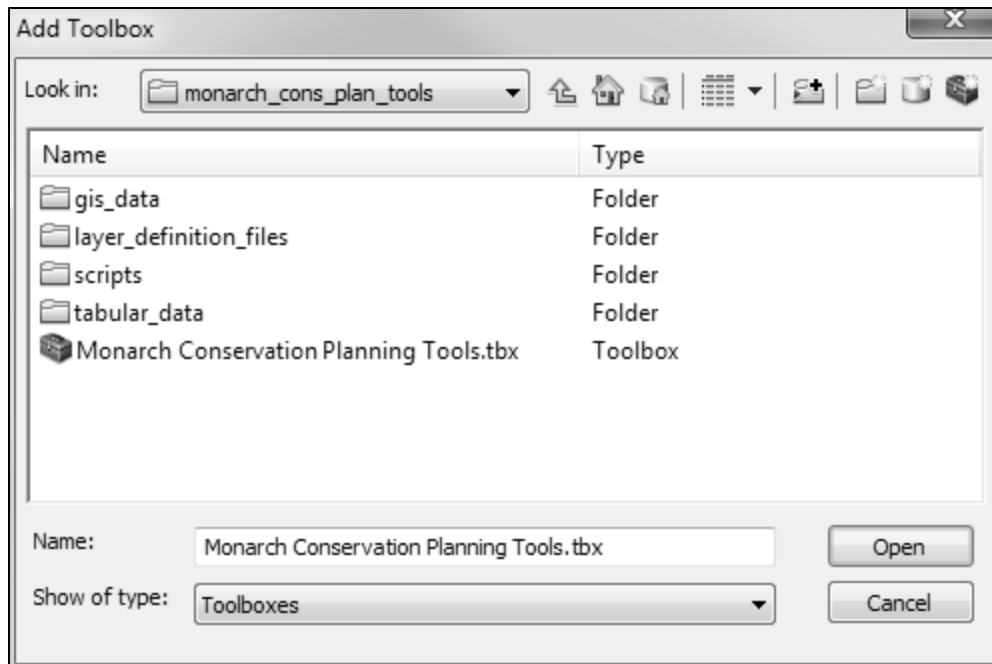
Figure 3. Windows dialog for selecting Monarch Conservation Planning Tools toolbox

Tool Development and Operation Instructions

Several spatial tools were developed to assist researchers, conservation planners, and resource managers with tasks important for monarch butterfly conservation and planning. These tools were developed using the python scripting library with ESRI ArcGIS software version 10.3. The following sections describe each tool's functionality and provide instructions on their use.

County Ranking Tool

The County Ranking Tool was developed to allow the ability to prioritize counties within the conterminous United States according to multiple input field criteria important for monarch butterfly conservation. A spatial data layer (shapefile) representing U.S. counties was assembled and attributed with the information for each input criteria. A list of potential input criteria is located in Appendix 4. Some of these criteria represent positive attributes for monarch butterfly conservation while others quantify potential threats.

To initiate the tool, click the script icon entitled "County Ranking Tool" within the "Monarch Conservation Planning Tools" toolbox (Figure 2). A dialog window will open with several input parameters to fill (Figure 4). First, select a county summary shapefile from the *gis_data* directory (monarch_data_county_summaries_090915.shp). If a subset of the counties are selected, only the selected counties will be included in the analysis. Next, designate the unique county ID from the dropdown menu (select "GEOID"). Specify a directory to create the outputs generated by the tool, an output shapefile name, and a symbology file (.lyr) to use to shade the output (rend_0_100_by_5.lyr). The user can specify whether or not to calculate statistics for the input fields designated. If this box is checked, the resulting attribute table will be amended with summary statistics (mean, max, min,

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standard deviation, sum and range) for each input field; this will increase the processing time of the tool. Next, the user can specify up to 11 different input field criteria to use to rank the counties.

Before the tool can be executed, a scratch workspace must be designated using the "Environments…" button. The scratch workspace is used to generate intermediate "scratch" datasets while the tool is running. It is suggested that the user select a workspace (folder) for this parameter and not use a geodatabase (.gdb) as is sometimes suggested in the ArcGIS literature. There have been issues with the model not operating when a geodatabase or an invalid workspace was selected. The user should also use input files on their local hard drive and set the output directory as a folder on the local hard drive.

For each input field criteria, the user must specify the field name from the shapefile, a weight, and whether or not lower values are preferred. The combined weights for all selected input field criteria must equal 100 and no input field criteria can be used more than once. Allotting a larger weight to a specific input field criteria will give that criteria more influence in the final ranking. The user may check the "lower value preferred" check box if they would like to devalue those counties with high values for certain input criteria (e.g., pesticide application rates).

When all of these input parameters are set, press the "OK" button to run the tool.
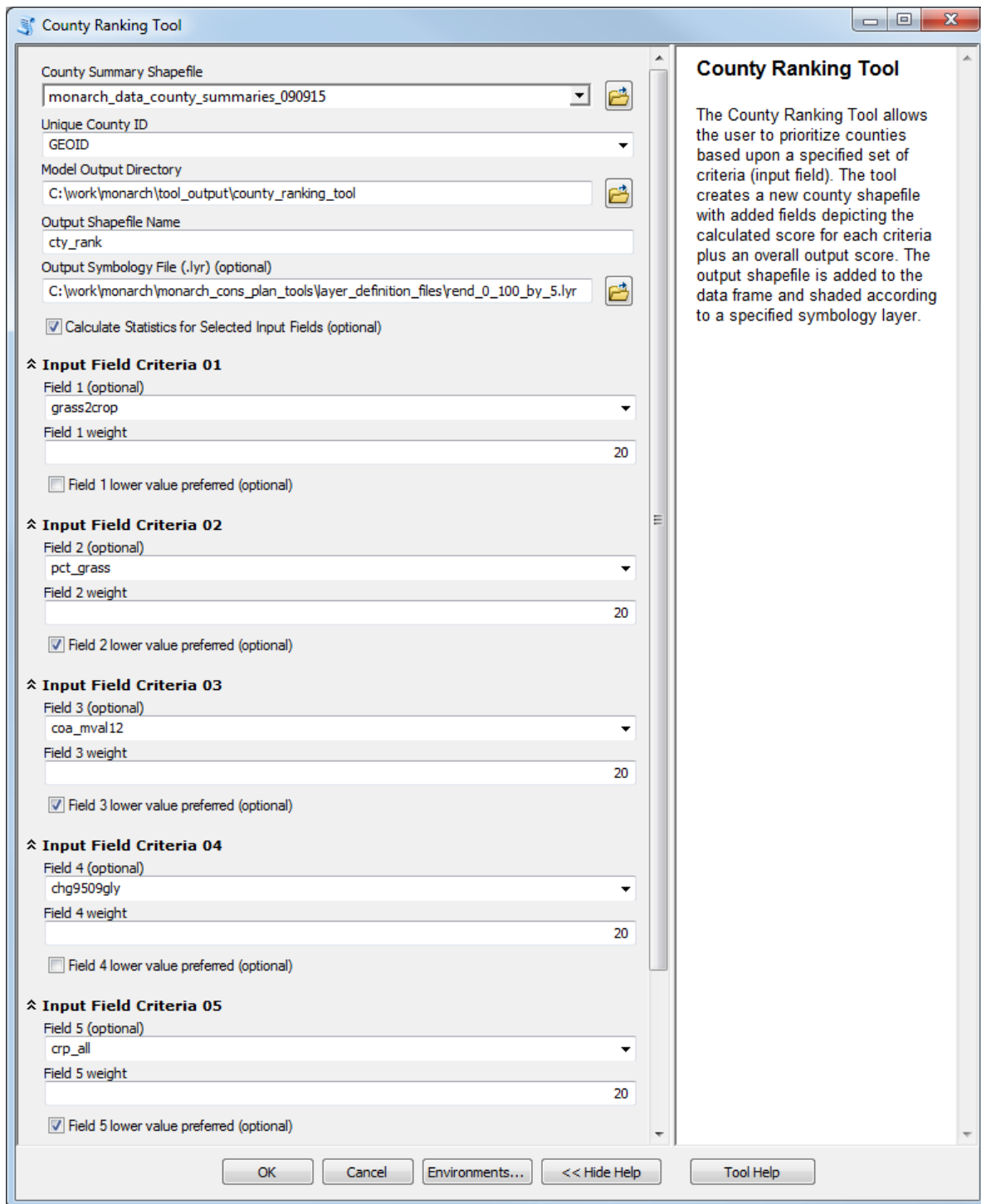
Figure 4. County Ranking Tool input dialog window

Upon tool completion, a new data layer will be added within the active data frame within ArcMap (Figure 5). This new data layer (shapefile) will be named with the specified output shapefile name with a two digit unique suffix appended at the end. If an output symbology layer was specified, the shapefile will be shaded accordingly.

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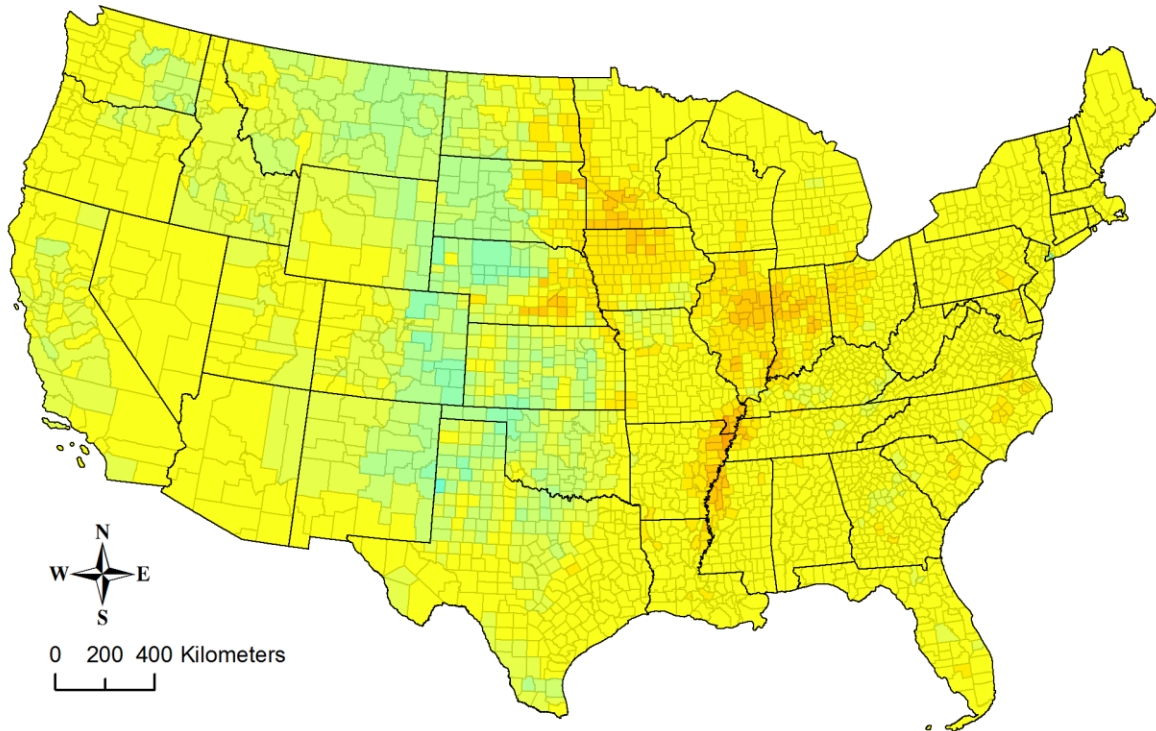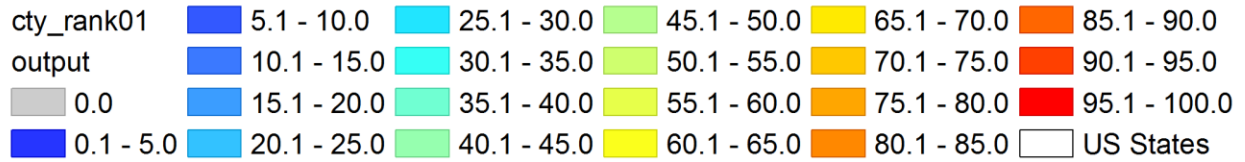
Figure 5. Sample output from County Ranking Tool

In addition to the shapefile that is generated, a log text file is also created (Figure 6). The file name for this text file is the same as the output shapefile generated by the tool but with a .txt file extension. Documented within this text file are the input field criteria selections, their associated weights, and whether or not lower values were the preferred characteristic. Summary statistics (mean, max, min, std, and range) are included for the output field generated and also for each input field criteria used, if designated.

```
cty_rank01.txt - Notepad
File   Edit   Format   View   Help
-------------------------------------------------
Date created: 2015-09-22 11:53:10.778000
-------------------------------------------------


Weight designated for Field 1 (grass2crop): 20
Weight designated for Field 2 (pct_grass): 20
 - Lower value preferred check box was checked, large values for field (pct_grass) will be given a lower score in the model.
Weight designated for Field 3 (coa_mval12): 20
 - Lower value preferred check box was checked, large values for field (coa_mval12) will be given a lower score in the mod
Weight designated for Field 4 (chg9509gly): 20
Weight designated for Field 5 (crp_all): 20
 - Lower value preferred check box was checked, large values for field (crp_all) will be given a lower score in the model.
Input county shapefile: monarch_data_county_summaries_090915
-------------------------------------------------


Developing new county shapefile: C:\work\monarch\tool_output\county_ranking_tool\cty_rank01.shp
-------------------------------------------------


Criteria for field: (grass2crop)
Added field: (grass2c_nm)
Added field: (grass2c_wt)
Added field: (grass2c_ca)
[Total Counties]: 3108
Summary statistics for field: (grass2crop)


[MEAN_grass]: 0.001
[MIN_grass2]: 0.0
[MAX_grass2]: 0.037
[STD_grass2]: 0.002
[RANGE_gras]: 0.037
-------------------------------------------------
```

```
Appended final objective model score (output) to new shapefile (cty_rank01.shp).

Summary statistics for field: (output)

[MEAN_outpu]: 61.203
[MIN_output]: 37.858
[MAX_output]: 79.871
[STD_output]: 4.764
[RANGE_outp]: 42.013


-------------------------------------------------

Completed successfully in 0:02:24.668000
```

Figure 6. Sample log text file from County Ranking Tool

The attribute table associated with the output shapefile will have several attribute fields appended to it. Figure 7 displays an example attribute record for one county. Several steps are taken in the ranking

process for each county. First, the scores for each input field criteria are normalized for each county to a consistent scale of 0 to 100. This is done using the following formula:

$$((([\text{input criteria value for individual county}] - [\text{minimum value}]) / ([\text{maximum value}] - [\text{minimum value}])) * 100)$$

The fields for the normalized scores are labeled with a "_nm" suffix.

Next, for each county, the normalized score for each separate input criteria is multiplied by the user defined weight (_wt) divided by 100. The fields holding the calculated result for this operation are labeled with a "_ca" suffix. To create the overall "output" score, each of the individual calculated scores "_ca" are summed.

GEOID	19091
NAME	Humboldt
STATE_NAME	Iowa
FIPS	19091
Area__sq_k	1,128.37
pct_grass	1.44%
pct_pastur	1.20%
pct_cultcr	87.41%
...	

Input Field Criteria

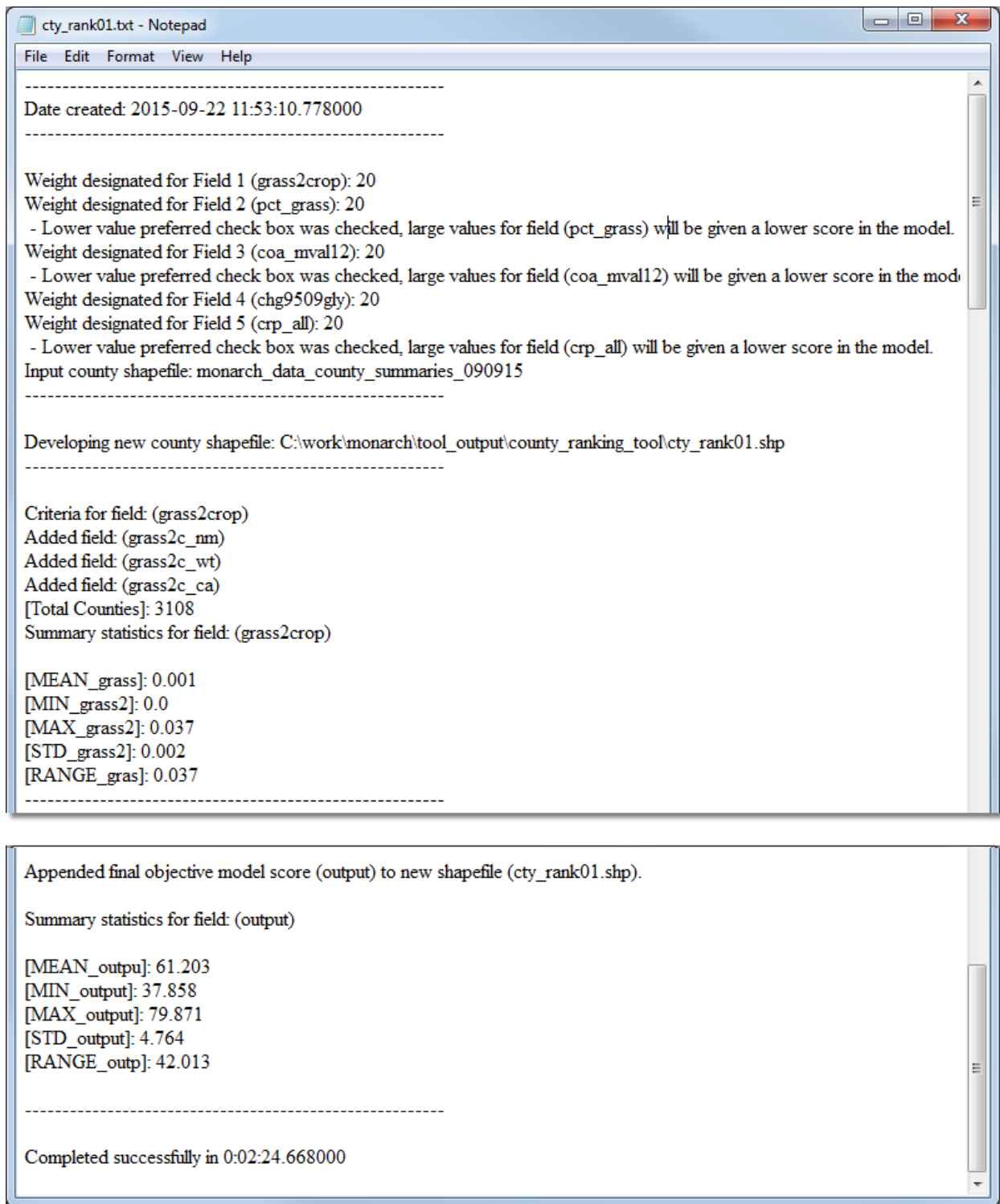|	
grass2c_nm	0.09
grass2c_wt	20
grass2c_ca	0.02
pct_gra_nm	98.52
pct_gra_wt	20
pct_gra_ca	19.70
coa_mva_nm	99.04
coa_mva_wt	20
coa_mva_ca	19.81
chg9509_nm	67.39
chg9509_wt	20
chg9509_ca	13.48
crp_all_nm	89.56
crp_all_wt	20
crp_all_ca	17.91
output	70.92

Derived Input Field Criteria Outputs

_nm = normalized input score
_wt = input field criteria weight
_ca = calculated criteria score = [nm * (wt / 100)]

County Ranking Tool Output Score

Figure 7. Sample attributes (for one county) from output shapefile of County Ranking Tool

The final output (e.g., Figure 5) of the County Ranking Tool portrays the combined product of the layers and weights defined by the user. Additionally, it is possible to use the Derived Input Field Criteria Outputs (i.e., fields labeled with a "_ca" suffix) to explore the relative importance of each underlying weighted layer.

Milkweed Calculator Tools

Two separate milkweed calculator tools were developed to allow researchers, conservation planners, and managers the ability to model the anticipated number of milkweeds on the landscape. One of the tools allows the number of milkweed stems to be calculated based upon projected milkweed densities for several different habitat classes entered by the user in stems/acre. The second tool performs the same calculations using milkweed density inputs entered in the format of m^2/hectare.

The tools use a county summary shapefile (attribute table) as a base layer for analysis. A seamless milkweed habitat raster was used as the source for the summary information contained within this shapefile. This raster data set was developed as part of this project (see Appendix 1). There were a total of 42 different habitat classes created. Background information on the input data sources used to create this raster are located in Appendix 2. These classes represent all areas on the landscape which may provide potential habitat for milkweed plants. This data set was created for the lower 48 conterminous U.S. states.

Figure 8 displays a list of milkweed habitat classes developed. Some of the classes are labeled with a LOW, MEDIUM, or HIGH attribute describing their relative amenability or potential for milkweed introduction. The full list of Cropland Data Layer classes and their updated milkweed habitat classes are located in Appendix 3. Milkweed amenability scores were developed via personal communication with researchers at the Xerces Society.

1 - Corn LOW	41 - Deciduous Forest (NCLD)
2 - Corn LOW (Marginal)	42 - Evergreen Forest (NCLD)
3 - Other Crops (CDL) LOW	43 - Mixed Forest (NCLD)
4 - Other Crops (CDL) MEDIUM	52 - Shrubland (NCLD)
5 - Other Crops (CDL) HIGH	76 - Grassland (NCLD)
6 - Fallow Idle (CDL) HIGH	77 - Grassland (NCLD) PADUS Protected
7 - Fruit Xmas Trees Vines (CDL) LOW	78 - Pasture (NCLD)
8 - Fruit Xmas Trees Vines (CDL) MEDIUM	79 - Pasture (NCLD) PADUS Protected
9 - Fruit Xmas Trees Vines (CDL) HIGH	90 - Woody Wetlands (NCLD)
10 - Hay Alfalfa (CDL) LOW	95 - Herbaceous Wetlands (NCLD)
11 - Open Water (NLCD)	98 - CRP Non Wet
13 - Water (CDL)	99 - CRP Wet
14 - Soybeans LOW	100 - HSIP Transmission Line (Outside Urban Areas)
15 - Soybeans LOW (Marginal)	101 - HSIP Transmission Line (Inside Urban Areas)
21 - Developed Open Space (NCLD) Linear	110 - TIGER Primary Roads and Ramps
22 - Developed Low Intensity (NCLD) WITHIN URBAN	120 - TIGER Secondary Roads
23 - Developed Med Intensity (NCLD)	140 - TIGER Local Roads
24 - Developed High Intensity (NCLD)	174 - TIGER Private Roads
25 - Developed Open Space (NCLD) Core	180 - All TIGER Roads (Inside Urban Areas)
26 - Developed Low Intensity (NCLD) EXURBAN	200 - TIGER Rails (Outside Urban Areas)
31 - Barren (NCLD)	201 - TIGER Rails (Inside Urban Areas)

Figure 8. List of milkweed habitat classes developed for use in Milkweed Calculator Tools

Once the raster data set was developed, the area of each habitat class was summarized for each county in the conterminous United States. Both hectares and acres were calculated and are provided within the tool.

To initiate one of the milkweed calculator tools, click the script icon entitled "Milkweed Calculator (stems/acre)" or "Milkweed Calculator (m2/ha)" within the "Monarch Conservation Planning Tools" toolbox (Figure 2). Both milkweed calculator tools operate by prompting the user to assign a predicted milkweed density value for each milkweed habitat class (e.g., corn, grassland, roads, etc). The difference between these two milkweed calculator tools is that the "stems/acre" tool requires inputs to be in the form of predicted milkweed stem density (stems/acre), whereas the "m2/ha" tool requires the inputs to be in the form of predicted milkweed groundcover density (m2/ha).

Once the tool is selected, the user must identify the county summary shapefile from the *gis_data* directory. This is the shapefile with milkweed habitat class area measurements appended to the attribute table. The shapefile's area measurement attribute should be in acres for the "stems/acre" tool and in hectares for the "m2/ha" tool. If a subset of the counties are selected, only the selected counties will be included in the analysis. Next, the unique county ID field must be identified, followed by the field denoting the appropriate area field, and the directory on the computer's hard drive to store the outputs generated by the tools. In addition, a name should be specified for the output shapefile and if desired, an output symbology layer chosen. The output symbology layer applies a user-specified color scheme to the different bins of output values within the output fields. Next, the user specifies whether or not to calculate statistics for the input fields (habitat classes) designated. If this box is checked the resulting attribute table will be amended with summary statistics (mean, max, min, standard deviation, sum and range) for each input field; this will increase the processing time of the tool. The outputs for the tools can be limited to any of seven different monarch model regions developed for this project (Figure 9). This is accomplished by checking the box next to the region(s) to exclude (i.e., "Exclude Core North Central Monarch Region"). It is generally believed that milkweed density differs among land covers by region. As such, it is recommended that individual regions with region-specific estimates of milkweed density be calculated separately. Finally, the user designates the predicted milkweed density values for each of the milkweed habitat classes.
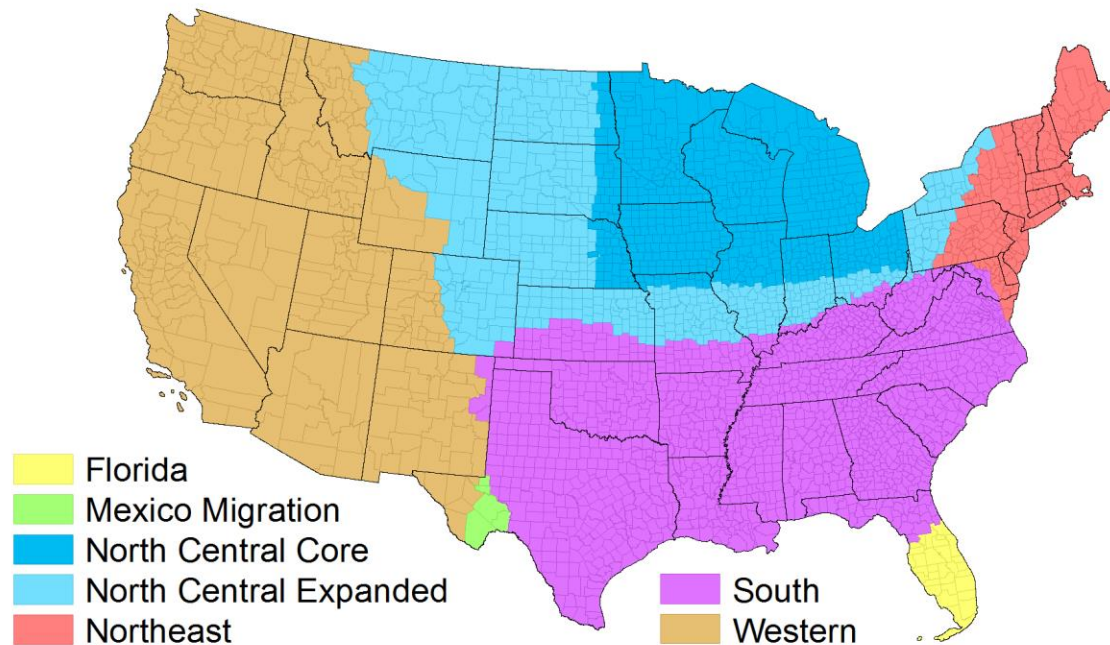
Figure 9. Monarch regions used to limit milkweed calculator tool results.

If the "m2/ha" tool is chosen, an extra parameter is required to convert from area covered in milkweed (m^2/ha) to actual stem counts (stems/ha). This parameter is entitled "Default Milkweed Stems Per Square Meter" (stems/m^2; Figure 10).

Before the tool can be executed, a scratch workspace must be designated using the "Environments…" button. The scratch workspace is used to generate intermediate "scratch" datasets while the tool is running. It is suggested that the user select a workspace (folder) for this parameter and not use a geodatabase (.gdb) as is sometimes suggested in the ArcGIS literature. There have been issues with the model not operating when a geodatabase or an invalid workspace was selected. The user should also use input files on their local hard drive and set the output directory as a folder on the local hard drive.

When all of the input parameters are set, press the "OK" button.
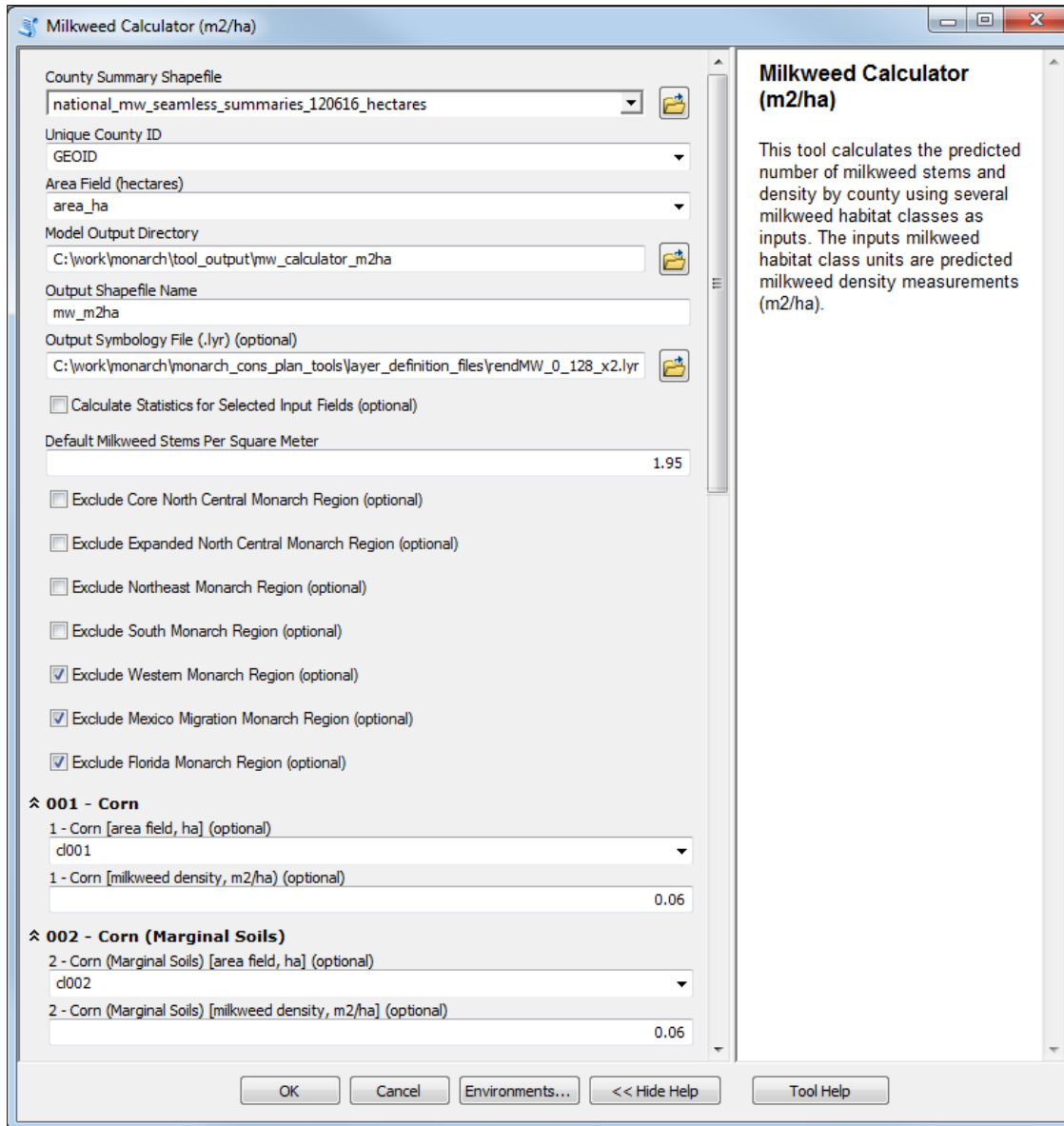
Figure 10. Input dialog for Milkweed Calculator (m2/ha) tool

Upon tool completion, a new data layer will be added within the active data frame within ArcMap (Figure 11). This data layer (shapefile) will be named with the specified output shapefile name with a two-digit unique suffix appended to the end. If an output symbology layer was specified the shapefile will be portrayed accordingly.
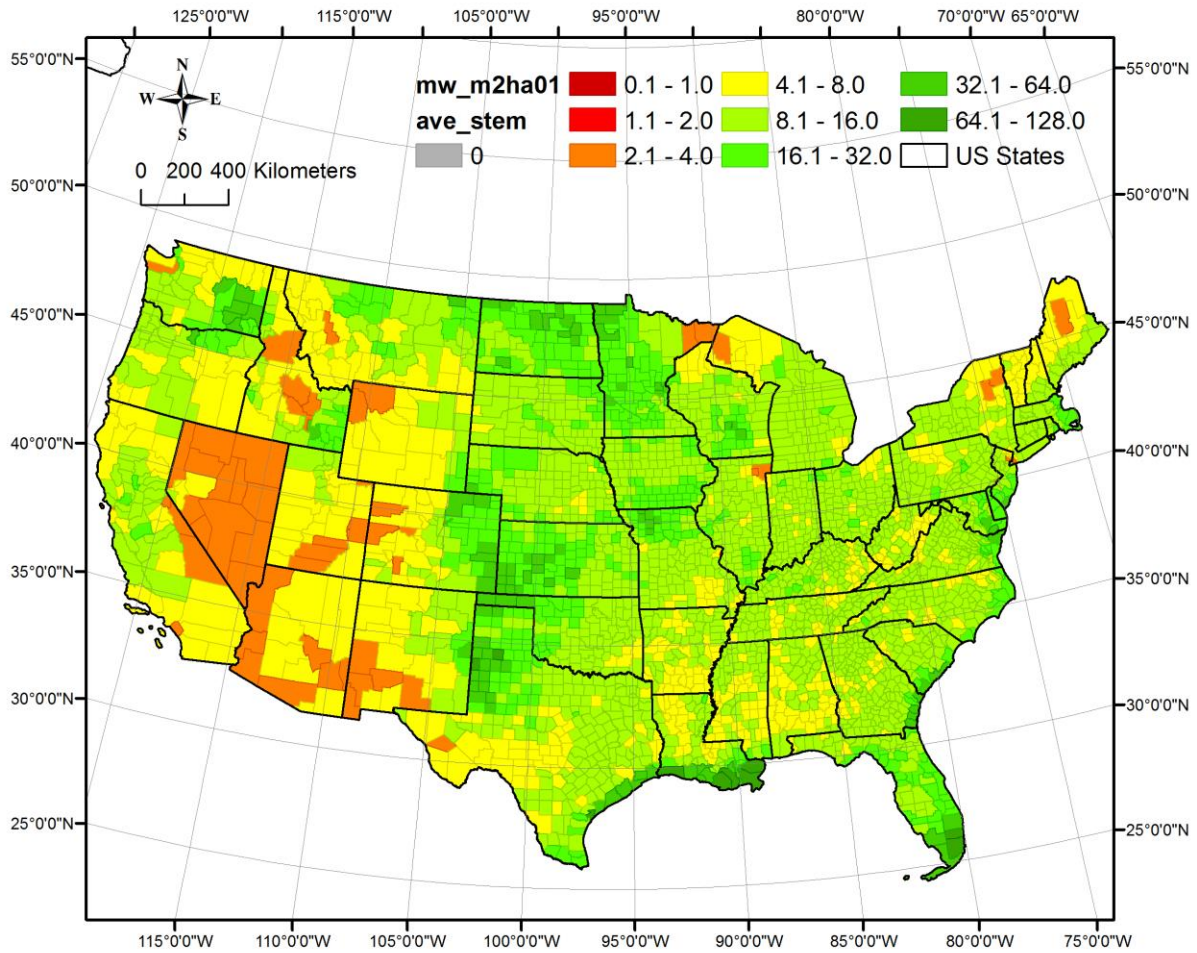
Figure 11. Sample map output from Milkweed Calculator (m2/ha) tool

In addition to the shapefile that is generated, a log text file is also created (Figure 12). The file name for this text file is the same as the output shapefile generated by the tool but with a .txt file extension. Documented within this text file are the milkweed density designated for each milkweed habitat class, summary statistics (mean, max, min, std, sum and range) for each milkweed habitat class (if that check box was checked), and summary statistics for overall milkweed density attributes.

Figure 12. Sample log text file output from Milkweed Calculator (m2/ha) tool

The attribute table associated with the output shapefile will have several fields appended to it. Figure 13 displays an example attribute record for one county for which the "m2/ha" tool was applied. Several steps are taken for the milkweed calculation process for each county. First, the area of each milkweed habitat class (ha) is multiplied by the predicted milkweed density (m^2/ha) entered by the user. The results of this calculation are stored in the field with the suffix "_ca" and the units are m^2. Next, each individual "_ca" value for each milkweed habitat class is summed to get the total milkweed density "tot_dens" for that county (m^2). Then, if applicable, the total milkweed stems "tot_stem" are calculated for that county by multiplying the total density measurement "tot_dens" by the constant value supplied

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by the user in the tools dialog window denoting the "Default Milkweed Stems Per Square Meter". To get the mean milkweed density by county, the "tot_dens" field is divided by the total hectares within that county. Also, the mean stems per hectare "ave_stem" is calculated by dividing the "tot_stem" result by the total hectares within that county.

GEOID	19091
STATE_FIPS	19
CNTY_FIPS	91
FIPS	19091
area_sqkm	1,128.37
area_ha	112,837.34
County_Nam	Humboldt
State_Name	Iowa

...

cl120	228.96
cl140	3,768.93
cl174	437.85
cl180	484.20

Milkweed Habitat Class Hectare Measurements

...

cl120_de	72.42
cl120_ca	16,581.28
cl140_de	72.42
cl140_ca	272,945.91
cl174_de	25.01
cl174_ca	10,950.63
tot_dens	580,170.81
tot_stem	1,131,333
ave_dens	5.14
ave_stem	10.03

Individual Derived Milkweed Habitat Class Outputs
_de = Habitat class input stem density (m²/ha)
_ca = Habitat class milkweed area (m²) = [hectares of habitat class in county x stem density]

Overall Derived Milkweed Habitat Outputs
tot_dens = milkweed area added for all classes (m²) = [cl120_ca + cl140_ca + ...]
tot_stem = total milkweed stems calculated for county (stems)
         = [tot_dens * constant representing milkweed stems per square meter]
ave_dens = milkweed mean density within county (m²/ha) = [tot_dens / hectares in county]
ave_stem = milkweed mean stems per hectare (stems/ha) = [tot_stem / hectares in county]

Figure 13. Sample attributes for output shapefile from Milkweed Calculator (m2/ha) tool

The "stems/acre" milkweed calculator tool works similarly. Figure 14 displays an example attribute record for one county where the "stems/acre" tool was chosen. In the milkweed calculation process for each county several steps are taken. First, the area of each milkweed habitat class (acres) is multiplied by the predicted milkweed density (stems/acre) entered by the user. The results of this calculation are stored in the field with the suffix "_ca" and the units are stems. Next, each individual "_ca" value for each milkweed habitat class is summed to get the total milkweed stems predicted "tot_stem" for that county. Then the mean stems per acre "ave_stem" is calculated by dividing the "tot_stem" result by the total acres within that county.

GEOID	19091
STATE_FIPS	19
CNTY_FIPS	91
FIPS	19091
area_sqkm	1,128.37
area_ac	278,826.72
County_Nam	Humboldt
State_Name	Iowa

...

cl120	565.77
cl140	9,313.21
cl174	1,081.95
cl180	1,196.48

Milkweed Habitat Class Acre Measurements

...

cl120_de	57.15
cl120_ca	32,333.28
cl140_de	57.15
cl140_ca	532,240.89
cl174_de	19.74
cl174_ca	21,353.35
tot_stem	1,131,338
ave_stem	4.06

Individual Derived Milkweed Habitat Class Outputs
_de = Habitat class input stem density (stems/acre)
_ca = Habitat class milkweed total stems (stems)
= [Habitat class input stem density X acres of class in county]

Overall Derived Milkweed Habitat Outputs
tot_stem = milkweed stems added for all classes (stems) = [cl120_ca + cl140_ca + ...]
ave_stem = milkweed stems per acre (stems/acre) = [tot_stem / acres in county]

Figure 14 Sample attributes for output shapefile from Milkweed Calculator (stems/acre) tool

County Area Adjustment Tool

A separate tool was developed to allow the user to make hypothetical adjustments to the area (in hectares or acres) of milkweed habitat classes for a user-defined set of selected counties. These theoretical changes in landscape composition can help to inform the user on the impact of specific conservation development activities. The user can update the total area of a milkweed habitat class within the selected counties or change the percentage of area in a particular class within those counties. For any increases in habitat class there are subsequent decreases in another habitat class selected by the user to make sure the total area for all habitat classes does not change. Outputs from the tool include added fields with adjusted milkweed habitat class area measurements and an output log text file. The updated shapefile and adjusted fields can then be used as inputs for the milkweed calculator tools.

To initiate the tool, click the script icon entitled "County Area Adjustment Tool" within the "Monarch Conservation Planning Tools" toolbox (Figure 2). Within the dialog window the user must select a county summary shapefile depicting the area (in acres or hectares) of milkweed habitat classes to edit. This shapefile must be contained within the active ArcMap data frame and not selected using the file's long path name. This restriction allows the user to only adjust area measurements of a selected subset of counties if desired. Next, select a milkweed habitat class to increase the area and also a different

milkweed habitat class to perform a decrease in area of the same value (Figure 8). The user can elect to input an absolute area increase/decrease (the units, either hectares or acres, of which should match the units of the input county summary shapefile) or a percentage increase/decrease of the current habitat class total (Figure 15).
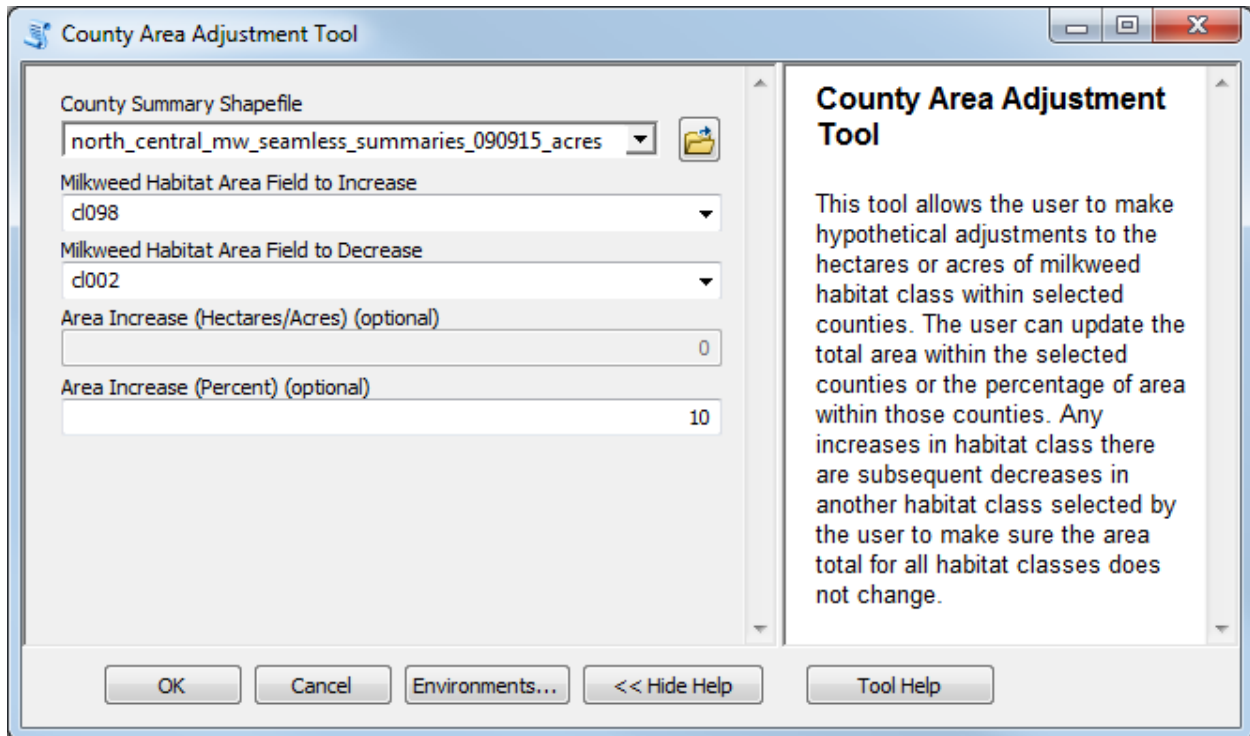
Figure 15. Input dialog window for County Area Adjustment tool

If a percent increase is entered this increase is applied uniformly to each county selected. If an absolute hectare/acre increase is entered, this number is first converted to a percent increase so as to be able to apply the increase uniformly to each county selected. For example, if the user wants to increase milkweed habitat class "CRP non-wet" by 20,000 hectares on selected counties by decreasing "marginal corn" by 20,000 hectares, the tool calculates the amount of "CRP non-wet" on the landscape currently and then calculates the necessary percent increase to add 20,000 hectares. This percent increase (and identical decrease to "marginal corn") is applied to each county individually. If there is not enough of the milkweed habitat class in a particular county for which the user has requested to have the hectares decreased from, the tool will default to the maximum available area. As another example, a request is made to convert 200 hectares of "marginal corn" to "CRP non-wet" but currently there is only 125 hectares of "marginal corn" in the county. The tool will default to only converting the maximum amount available (125 hectares) in the shapefile's attribute table. Therefore, the absolute area or percent increase selected by the user is a "potential" increase, the "actual" increase applied to all selected counties may be lower.

When all of the input parameters are set, press the "OK" button.

The attribute table associated with the shapefile will have two attribute fields appended to it. Figure 16 displays an example attribute record for one county. One field will be added related to the increased milkweed habitat class. It will be named the same as the original field selected for increase with a two digit numeral added to the end. This numeral auto-increments to a larger number based upon the presence of any existing fields with the same base name (e.g., cl098). Another field will be added related to the decreased milkweed habitat class and this field will also have the auto-incremented numeral appended to the end.

These appended fields can then be used as input in the milkweed calculators. For instance, instead of selecting "cl002" in the milkweed calculator, the user would now select "cl002_01" as the input for "marginal corn".

GEOID	19091
STATE_FIPS	19
CNTY_FIPS	91
FIPS	19091
area_sqkm	1,128.37
area_ac	278,826.72
County_Nam	Humboldt
State_Name	Iowa
cl001	136,087.42
cl002	164.13

...

cl098	1,154.23
cl099	5,866.99
cl100	1,399.31
cl101	31.58
cl110	2.67
cl120	565.77
cl140	9,313.21
cl174	1,081.95
cl180	1,196.48
cl200	654.06
cl201	50.71

Milkweed Habitat Class Acre Measurements

cl098_01	1,269.65
cl002_01	48.70

Adjusted Milkweed Habitat Class Acre Measurements

$cl098\_01 = cl098 + (cl098 * 0.1)$
$cl002\_01 = cl002 - (cl098 * 0.1)$

Figure 16. Sample attributes from county summary shapefile updated using County Adjustment tool

In addition to the shapefile that is generated, a log text file is also created (Figure 17). This text file is named the same as the input shapefile but with an additional string of text at the end denoting the increase field added and then the decrease field added (e.g., north_central_mw_seamless_summaries_090915_acres__cl098_01-cl002_01.txt). Documented within this text file are the increase and decrease fields selected, the input county summary shapefile, the potential area increase selected, the total number of counties selected, and a list of counties which did not have enough area to perform the desired increase with the amount actually converted (if applicable). At the end of the log are summary statistics depicting the total area increased and

decreased, the adjusted total area of each increase and decrease habitat class, and the actual percent change in total area within the selected counties.

Figure 17. Sample log text file output from County Area Adjustment tool

Summary

The tools described here provide researchers, conservation planners, and resource managers with the ability to explore scenarios for milkweed amendment and to highlight regional- or national-scale

conservation priorities. These are initial but essential steps in the conservation design process. Coupled with properly elicited stakeholder goals, these tools can provide users with the means for depicting a path toward restoring monarch butterflies to former levels of abundance.

One potential limitation of these tools is their coarse spatial depiction of milkweed density. Currently, densities of milkweed are cover-specific, but not spatially variable within a habitat class. Milkweed density likely varies within cover types due to species-specific responses to environmental conditions, landscape context, and management history at a particular location. If information regarding heterogeneity in milkweed density were available (it currently is not), future iterations of these tools could more realistically map spatial patterns in milkweed abundance and more accurately estimate the outcomes of various restoration strategies. In the absence of these data, users should keep this important constraint in mind as they use these tools.

One strength of these tools is that they are written as an ArcGIS toolbox. There are uncertainties associated with the data used to inform these tools, for instance, but because these tools are written for ArcGIS, adding new information to the toolset is straightforward. Thus, if monitoring data were widely available, the initial estimates of milkweed stem density could be updated to reflect successes and failures in implementing conservation practices, helping to track progress toward goals.

The flexibility of these tools also allows users to apply them to tasks beyond how they are currently being used. For instance, with small modification to the input parameters, the Milkweed Adjustment tool could be used to assess not just availability of milkweed but also nectar-bearing plants. Further, the County Area Adjustment tool could be combined with monitoring or land trend information to depict land cover changes occurring over time, irrespective of monarch conservation concerns.

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Appendix 1. Seamless Milkweed Habitat Raster Development

The first step in the development of the seamless milkweed habitat raster for the conterminous lower 48 United States was to separate open/developed areas (value 121) from the 2015 Cropland Data Layer (CDL) into two categories, linear and core. This was accomplished by first shrinking all open/developed areas by 1 cell (30 meters) and then subsequently expanding them back out by 1 cell. This process extracts the larger core open/developed areas from the base CDL layer and the remaining open/developed areas that do not meet this criteria are the smaller, more linear areas. The core open/developed areas were given a new value of 25 and the linear areas were given a value of 21 in the revised CDL.

Next, a process was developed to identify core urban areas within the landscape. This was done by shrinking all developed areas (CDL values 121 (open/developed), 122 (low intensity developed), 123 (medium intensity developed), and 124 (high intensity developed)) by 2 cells (60 meters) and then subsequently expanding them back out by 2 cells. This process identifies the larger core developed (urban) areas from the base CDL layer. These areas were used to further reclassify roads, rails, transmission lines, and low intensity developed areas by their proximity to derived urban areas.

The CDL does not have separate classes for grassland and pasture although this is an important distinction when classifying the landscape according to milkweed densities. The National Land Cover Dataset (NLCD) does, however, have separate classes for grassland and pasture. A process was developed to extract pasture areas from the 2011 NLCD and replace the overlapping areas within the CDL classified as grassland/pasture, alfalfa, or other hay/non-alfalfa with a new value denoting it as pasture/hay. These pasture/hay areas were then further subdivided using the 2012 Protected Areas Database (PADUS) to define those areas that are under conservation protection (value 79; Pasture/Hay (PADUS Protected)) and those not currently under conservation protection (value 78; Pasture/Hay). The grassland/pasture areas from the CDL that did not overlap the areas classified as pasture/hay in the NLCD were then subdivided using the PADUS into two classes, those areas that are under conservation protection (value 77; Grassland (PADUS Protected)) and those not currently under conservation protection (value 76; Grassland).

2014 Conservation Reserve Program (CRP) data was received from the Farm Service Agency and the individual field-level polygonal data were reclassified according to whether or not they contain quality milkweed habitat. If they do, they were further reclassified according to distinguish if they are considered to be "wet" or "non-wet". These polygons were then converted to a raster data set of the same resolution as the CDL. Next, areas in the revised CDL where these milkweed-amenable CRP polygons occur were reclassified to value 98 (CRP non-wet) or value 99 (CRP wet) if they did not overlap areas in the revised CDL delineating open water, low, medium, and high intensity developed, deciduous, evergreen, and mixed forests, and woody wetlands since these classes were determined to have limited amenability to milkweed (via personal communication with researchers at the Xerces Society).

Next, using the urban area boundary created previously, low intensity developed areas outside of this boundary were reclassified to value 26 (Exurban).

Corn and soybean fields within the revised CDL were then further divided according to their Crop Productivity Index. The 2012 National Commodity Crop Productivity Index distributed by SSURGO was used as the source for this metric. Index scores of less than 40 were selected to represent those areas where the soil is considered to be "marginal" for crop production.   The value 40 was selected since the resulting area represented approximately fifteen percent of the landscape. Corn and soybean areas in the revised CDL that also overlapped marginal soils were reclassified as value 2 (corn – marginal) and value 15 (soybean – marginal), and areas that did not overlap marginal soils were reclassified as value 1 (corn - high productivity) and value 14 (soybean - high productivity).

Linear features representing transmission lines, roads, and rails were converted from vector to raster data sets using a 30-meter cell size. 2013 Homeland Security Infrastructure Program transmission lines were included in the seamless raster if they were classified as "in-service". Then, using the urban area boundary, raster cells overlapping transmission lines outside of this boundary were reclassified to value 100 and those within the boundary were reclassified to value 101. Similarly, raster cells overlapping cells designating 2015 TIGER rail lines outside of this boundary were reclassified to value 200 and those within the boundary were reclassified to value 201. 2015 TIGER roads outside of the urban area were lumped into several different categories and reclassified; primary roads and ramps (110), secondary roads (120), local roads (140), and private roads (174). All raster cells overlapping roads, regardless of type, within the urban area boundary were reclassified as value 180. Figure 18 displays a portion of the seamless milkweed habitat raster zoomed into an area without field-level CRP data or HSIP transmission lines displayed due to their inherent sensitivity.

Finally, acres and hectares of each seamless milkweed habitat raster class were summarized for each county using the 2015 TIGER county shapefile as a source. These summary data were used as input in the milkweed calculator tools.

Legend

- 1 - Corn (CDL)
- 2 - Corn (Marginal Soils) (CDL/NCCPI)
- 3 - Other Crops (Low MW amenability) (CDL)
- 4 - Other Crops (Medium MW amenability) (CDL)
- 5 - Other Crops (High MW amenability) (CDL)
- 6 - Fallow Idle (CDL)
- 7 - Fruit Xmas Trees Vines (Low MW amenability) (CDL)
- 8 - Fruit Xmas Trees Vines (Medium MW amenability) (CDL)
- 9 - Fruit Xmas Trees Vines (High MW amenability) (CDL)
- 10 - Hay Alfalfa (CDL)
- 11 - Open Water (NLCD)
- 13 - Water (CDL)
- 14 - Soybeans (CDL)
- 15 - Soybeans (Marginal Soils) (CDL/NCCPI)
- 21 - Developed Open Space (NLCD) Linear
- 22 - Developed Low Intensity (NCLD) Within Urban
- 23 - Developed Medium Intensity (NCLD)
- 24 - Developed High Intensity (NCLD)
- 25 - Developed Open Space (NLCD) Core
- 26 - Developed Low Intensity (NCLD) Exurban
- 31 - Barren (NLCD)
- 41 - Deciduous Forest (NLCD)
- 42 - Evergreen Forest (NLCD)
- 43 - Mixed Forest (NLCD)
- 52 - Shrubland (NLCD)
- 76 - Grassland (NLCD)
- 77 - Grassland (PADUS Protected)
- 78 - Pasture/Hay (NLCD)
- 79 - Pasture/Hay (PADUS Protected)
- 90 - Woody Wetlands (NLCD)
- 95 - Herbaceous Wetlands (NLCD)
- 98 - CRP Non-wet (USDA-FSA)
- 99 - CRP Wet (USDA-FSA)
- 100 - Transmission Lines (Outside Urban Areas) (HSIP)
- 101 - Transmission Lines (Inside Urban Areas) (HSIP)
- 110 - Primary Roads and Ramps (TIGER)
- 120 - Secondary Roads (TIGER)
- 140 - Local Roads (TIGER)
- 174 - Private Roads (TIGER)
- 180 - All Roads (Inside Urban Area) (TIGER)
- 200 - Rails (Outside Urban Area) (TIGER)
- 201 - Rails (Inside Urban Area) (TIGER)

This area specifically chosen due to the lack of CRP or HSIP transmission lines due to their inherent sensitivity!

Figure 18. Close-up view of seamless milkweed habitat raster.

Appendix 2. Data Sources

Cropland Data Layer – 2014/2015

Source

United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Research and Development Division (RDD), Geospatial Information Branch (GIB), Spatial Analysis Research Section (SARS)

Abstract

The USDA, NASS Cropland Data Layer (CDL) is a raster, geo-referenced, crop-specific land cover data layer. The CDL has a ground resolution of 30 meters. The CDL is produced using satellite imagery from the Landsat 8 OLI/TIRS sensor and the Disaster Monitoring Constellation (DMC) DEIMOS-1 and UK2 sensors collected during the current growing season. Agricultural training and validation data are derived from the Farm Service Agency (FSA) Common Land Unit (CLU) Program. The most current version of the NLCD is used as non-agricultural training and validation data. The purpose of the Cropland Data Layer Program is to use satellite imagery to (1) provide acreage estimates to the Agricultural Statistics Board for the state's major commodities and (2) produce digital, crop-specific, categorized geo-referenced output products.

National Land Cover Dataset - 2011

Source

US Geological Survey (USGS)

Abstract

The National Land Cover Database products are created through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies (www.mrlc.gov), consisting of the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), the U.S. Forest Service (USFS), the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), the Bureau of Land Management (BLM) and the USDA Natural Resources Conservation Service (NRCS). The success of NLCD over nearly two decades is credited to the continuing collaborative spirit of the agencies that make up the MRLC. NLCD 2011 is the most up-to-date iteration of the National Land Cover Database, the definitive Landsat-based, 30-meter resolution land cover database for the Nation. The data in NLCD 2011 are completely integrated with NLCD 2001 (2011 Edition) and NLCD 2006 (2011 Edition). Questions about the NLCD 2011 land cover product can be directed to the NLCD 2011 land cover mapping team at the USGS/EROS, Sioux Falls, SD (605) 594-6151 or mrlc@usgs.gov.

Transmission Lines - 2013

Source

The Homeland Security Infrastructure Program Gold database is assembled by the National Geospatial-Intelligence Agency (NGA) in partnership with the Homeland Infrastructure Foundation-Level Data (HIFLD) Working Group for use by Homeland Defense (HD), Homeland Security (HLS), National Preparedness – Prevention, Protection, Mitigation, Response and Recovery (NP-PPMR&R) communities.

Abstract

The Transmission Lines feature class is a GIS file depicting market significant electric power transmission lines in North America. Included lines generally have a capacity of greater than 69 kilovolts. Features in this feature class often represent multiple circuits. Some features have been created in order to link major features from the Electric Power Generation Plants feature class to the electrical grid through the associated feature from the Substations feature class. The Transmission Lines feature class contains existing and proposed features. Features that are currently operational can be isolated by examining the PROPOSED field for an "In Service" attribute.

Roads – 2014/2015

Source

U.S. Department of Commerce, U.S. Census Bureau, Geography Division

Abstract

The TIGER/Line shapefiles and related database files (.dbf) are an extract of selected geographic and cartographic information from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB). The MTDB represents a seamless national file with no overlaps or gaps between parts, however, each TIGER/Line shapefile is designed to stand alone as an independent data set, or they can be combined to cover the entire nation.

The All Roads Shapefile includes all features within the MTDB Super Class "Road/Path Features" distinguished where the MAF/TIGER Feature Classification Code (MTFCC) for the feature in MTDB that begins with "S". This includes all primary, secondary, local neighborhood, and rural roads, city streets, vehicular trails (4wd), ramps, service drives, alleys, parking lot roads, private roads for service vehicles (logging, oil fields, ranches, etc.), bike paths or trails, bridle/horse paths, walkways/pedestrian trails, and stairways.

Rails - 2014/2015

Source

U.S. Department of Commerce, U.S. Census Bureau, Geography Division

Abstract

The TIGER/Line shapefiles and related database files (.dbf) are an extract of selected geographic and cartographic information from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB). The MTDB represents a seamless national file with no overlaps or gaps between parts, however, each TIGER/Line shapefile is designed to stand alone as an independent data set, or they can be combined to cover the entire nation.

The Rails Shapefile includes all features within the MTDB Super Class "Rail Features" distinguished where the MAF/TIGER Feature Classification Code (MTFCC) for the feature in MTDB that begin with "R". This includes main lines such as spur lines, rail yards, mass transit rail lines such as carlines, streetcar track, monorail or other mass transit rail and special purpose rail lines such as cog rail lines, incline rail lines and trams.

Protected Areas Database of the United States - 2012

Source

US Geological Survey (USGS) - Gap Analysis Program (GAP)

Abstract

The Protected Areas Database of the United States (PAD-US) is a geodatabase, managed by USGS GAP, that illustrates and describes public land ownership, management and other conservation lands, including voluntarily provided privately protected areas. The geodatabase contains four feature classes such as, Marine Protected Areas (MPA) and Easements that each contains uniquely associated attributes. These two feature classes are combined with the PAD-US Fee feature class to provide a full inventory of protected areas in a common schema (i.e. Combined file).

Conservation Reserve Program - 2014

Source

US Department of Agriculture (USDA) - Farm Service Agency (FSA) Aerial Photography Field Office

Abstract

The common land unit (CLU) dataset consists of digitized farm tract and field boundaries and associated attribute data. The USDA Farm Service Agency (FSA) defines farm fields as agricultural land that is delineated by natural and man-made boundaries such as road ways, tree lines, waterways, fence lines, etc. Field boundaries are visible features that can be identified and delineated on aerial photography and digital imagery. Farm tracts are defined by FSA as sets of contiguous fields under single ownership. Common land units are used to administer USDA farm commodity support and conservation programs in a GIS environment.

Gridded SSURGO (gSSURGO) National Commodity Crop Productivity Index (NCCPI) Version 2 - 2012

Abstract

This dataset is called the National Value Added Look Up (valu) Table database. The valu1 table resides in the valu database and is comprised of 57 pre-summarized or "ready to map" attributes derived from the official SSURGO database. These attribute data are pre-summarized to the map unit level using best-practice generalization methods intended to meet the needs of most users. The generalization methods include map unit component weighted averages and percent of the map unit meeting a given criteria. These themes were prepared to better meet the mapping needs of users of soil survey information and can be used with both SSURGO and gridded SSURGO (gSSURGO) datasets. Below is a partial list of the data found in the valu1 table. National Commodity Crop Productivity Index (NCCPI) Version 2 - weighted average index for major components (Dobos, Sinclair, and Robotham, 2012)

Counties - 2014/2015

Abstract

The TIGER/Line shapefiles and related database files (.dbf) are an extract of selected geographic and cartographic information from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB). The MTDB represents a seamless national file with no overlaps or gaps between parts, however, each TIGER/Line shapefile is designed to stand alone as an independent data set, or they can be combined to cover the entire nation.

The primary legal divisions of most states are termed counties. In Louisiana, these divisions are known as parishes. In Alaska, which has no counties, the equivalent entities are the organized boroughs, city and boroughs, municipalities, and for the unorganized area, census areas. The latter are delineated cooperatively for statistical purposes by the State of Alaska and the Census Bureau. In four states (Maryland, Missouri, Nevada, and Virginia), there are one or more incorporated places that are independent of any county organization and thus constitute primary divisions of their states. These incorporated places are known as independent cities and are treated as equivalent entities for purposes of data presentation. The entire area of the United States, Puerto Rico, and the Island Areas is covered by counties or equivalent entities.

Estimated Annual Agricultural Pesticide Use for Counties of the Conterminous United States, 1992–2009

Source

U.S. Geological Survey

Abstract

These data were estimated annual agricultural pesticide use for the four most commonly used neonictinoid pesticides for counties of the conterminous United States from 1992 through 2009, following the methods described in Thelin and Stone (2013). As described in Thelin and Stone (2013), U.S. Department of Agriculture county-level data for harvested-crop acreage were used in conjunction with proprietary Crop Reporting District (CRD)-level pesticide-use data to estimate county-level pesticide use. Estimated pesticide use (EPest) values were calculated with both the EPest-high and EPest-low methods. The estimates of annual agricultural pesticide use were provided in tab-delimited files and organized by compound, year, state Federal Information Processing Standard (FIPS) code, county FIPS code, and kg (amount in kilograms).

Thelin, G.P., and Stone, W.W., 2013, Estimation of annual agricultural pesticide use for counties of the conterminous United States, 1992–2009: U.S. Geological Survey Scientific Investigations Report 2013-5009, 54 p.

Census of Agriculture – 2002-2012

Source

United States Department of Agriculture, National Agricultural Statistics Service

Abstract

The Census of Agriculture is the leading source of facts and figures about American agriculture. Conducted every five years, the Census provides a detailed picture of U.S. farms and ranches and the people who operate them. It is the only source of uniform, comprehensive agricultural data for every state and county in the United States. Participation by every farmer and rancher, regardless of the size or type of operation, is vitally important. By responding to the Census, producers are helping themselves, their communities and all of U.S. agriculture.

The 2012 Census of Agriculture collected information concerning all areas of farming and ranching operations, including production expenses, market value of products, and operator characteristics. This information is used by everyone who provides services to farmers and rural communities - including federal, state and local governments, agribusinesses, and many others. Census data is used to make

decisions about many things that directly impact farmers, including: community planning, store/company locations, availability of operational loans and other funding, location and staffing of service centers, farm programs and policies.

Biota of North America Program, North American Plant Atlas – 2015

Source

Biota of North America Program

Kartesz, J.T., The Biota of North America Program (BONAP). 2015. North American Plant Atlas. (http://bonap.net/napa). Chapel Hill, N.C. [maps generated from Kartesz, J.T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)].

Abstract

The North American Plant Atlas represents the first comprehensive attempt to provide state- and county-level distribution maps of all vascular plant taxa found within the study area. It also provides multiple unique maps depicting unique soil and substrate types, climates and temperature zones, along with vegetation maps for the continent.

Monarch regions

Source

Diffendorfer, J. E., L. Ries, J. B. Loomis, K. Oberhauser, L. Lopez-Hoffman, B. Semmens, B. Butterfield, D. Semmens, K. Bagstad, J. Goldstein, R. Wiederholt, J. Dubovsky, B. Mattsson, and W. E. Thogmartin. 2014. National valuation of monarch butterflies indicates an untapped potential for incentive-based conservation. Conservation Letters 7:253-262.

See USGS press release at http://goo.gl/rXh3bj

Abstract

Monarch regions were developed and used in the study defined as; West breeding, East summer, East spring, Florida, California overwintering and Mexico overwintering.

Asclepias and monarch distribution models under moderate and severe climate change scenarios

Source

Lemoine, N. P. 2015. Climate change may alter breeding ground distributions of eastern migratory monarchs (*Danaus plexippus*) via range expansion of Asclepias host plants. PLoS ONE 10(2): e0118614. doi:10.1371/journal.pone.0118614

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0118614

Abstract

Given that monarchs largely depend on the genus *Asclepias* as larval host plants, the effects of climate change on monarch northward migrations will most likely be mediated by climate change effects on *Asclepias*. Lemoine used MaxEnt species distribution modeling to assess potential changes in *Asclepias* and monarch distributions under moderate and severe climate change scenarios. Model predictions suggest *Asclepias*, and consequently monarchs, should undergo expanded northern range limits in summer months while encountering reduced habitat suitability throughout the northern migration.

Core monarch breeding boundary identified by isotope analysis

Source

Wassenaar, L. I., and K. A. Hobson. 1998. Natal origins of migratory monarch butterflies at wintering colonies in Mexico: New isotopic evidence. Proceedings of the National Academy of Sciences, USA 95:15436-15439. http://www.pnas.org/content/95/26/15436.full

Abstract

Each year, millions of monarch butterflies from eastern North America migrate to overwinter in 10–13 discrete colonies located in the Oyamel forests of central Mexico. For decades, efforts to track monarch migration have relied on observations and tag-recapture methods. Stable hydrogen (δD) and carbon ($\delta 13C$) isotope ratios of wintering monarchs were used to evaluate natal origins on the summer breeding range. Stable-hydrogen and carbon isotopic values of 597 wintering monarchs from 13 wintering roost sites were compared with isotopic patterns measured in individuals at natal sites across their breeding range over a single migration cycle. Wassenaar and Hobson determined that all monarch wintering colonies were composed of individuals originating mainly from the Midwest, United States, thereby providing evidence for a panmictic model of wintering colony composition. The figure in this paper depicting the primary breeding area for monarch butterflies in North America was digitized for use as a coarse filter in prioritization scenarios.

Tagged monarch capture frequencies

Source

Chip Taylor, Monarch Watch

Abstract

Monarch frequencies, larger number denotes lower frequency of capture during migration (Min. 800 - Max. 12)

Appendix 3. List of Cropland Data Layer classes and updated milkweed habitat classes including potential milkweed amenability

CDL Code	CDL Description	MW Habitat Code	MW Habitat Description	Milkweed Amenability
1	Corn	1	Corn LOW	Low
237	Dbl Crop Barley/Corn	1	Corn LOW	Low
226	Dbl Crop Oats/Corn	1	Corn LOW	Low
225	Dbl Crop WinWht/Corn	1	Corn LOW	Low
207	Asparagus	3	Other Crops (CDL) LOW	Low
214	Broccoli	3	Other Crops (CDL) LOW	Low
243	Cabbage	3	Other Crops (CDL) LOW	Low
38	Camelina	3	Other Crops (CDL) LOW	Low
206	Carrots	3	Other Crops (CDL) LOW	Low
244	Cauliflower	3	Other Crops (CDL) LOW	Low
245	Celery	3	Other Crops (CDL) LOW	Low
51	Chick Peas	3	Other Crops (CDL) LOW	Low
2	Cotton	3	Other Crops (CDL) LOW	Low
235	Dbl Crop Barley/Sorghum	3	Other Crops (CDL) LOW	Low
234	Dbl Crop Durum Wht/Sorghum	3	Other Crops (CDL) LOW	Low
233	Dbl Crop Lettuce/Barley	3	Other Crops (CDL) LOW	Low
232	Dbl Crop Lettuce/Cotton	3	Other Crops (CDL) LOW	Low
230	Dbl Crop Lettuce/Durum Wht	3	Other Crops (CDL) LOW	Low
239	Dbl Crop Soybeans/Cotton	3	Other Crops (CDL) LOW	Low
240	Dbl Crop Soybeans/Oats	3	Other Crops (CDL) LOW	Low
238	Dbl Crop WinWht/Cotton	3	Other Crops (CDL) LOW	Low
236	Dbl Crop WinWht/Sorghum	3	Other Crops (CDL) LOW	Low
208	Garlic	3	Other Crops (CDL) LOW	Low
219	Greens	3	Other Crops (CDL) LOW	Low
56	Hops	3	Other Crops (CDL) LOW	Low
52	Lentils	3	Other Crops (CDL) LOW	Low
227	Lettuce	3	Other Crops (CDL) LOW	Low
29	Millet	3	Other Crops (CDL) LOW	Low
14	Mint	3	Other Crops (CDL) LOW	Low
44	Other Crops	3	Other Crops (CDL) LOW	Low
10	Peanuts	3	Other Crops (CDL) LOW	Low
53	Peas	3	Other Crops (CDL) LOW	Low
43	Potatoes	3	Other Crops (CDL) LOW	Low
246	Radishes	3	Other Crops (CDL) LOW	Low

3	Rice	3	Other Crops (CDL) LOW	Low
59	Sod/Grass Seed	3	Other Crops (CDL) LOW	Low
4	Sorghum	3	Other Crops (CDL) LOW	Low
41	Sugarbeets	3	Other Crops (CDL) LOW	Low
45	Sugarcane	3	Other Crops (CDL) LOW	Low
46	Sweet Potatoes	3	Other Crops (CDL) LOW	Low
60	Switchgrass	3	Other Crops (CDL) LOW	Low
11	Tobacco	3	Other Crops (CDL) LOW	Low
205	Triticale	3	Other Crops (CDL) LOW	Low
247	Turnips	3	Other Crops (CDL) LOW	Low
224	Vetch	3	Other Crops (CDL) LOW	Low
21	Barley	4	Other Crops (CDL) MEDIUM	Medium
39	Buckwheat	4	Other Crops (CDL) MEDIUM	Medium
31	Canola	4	Other Crops (CDL) MEDIUM	Medium
42	Dry Beans	4	Other Crops (CDL) MEDIUM	Medium
22	Durum Wheat	4	Other Crops (CDL) MEDIUM	Medium
32	Flaxseed	4	Other Crops (CDL) MEDIUM	Medium
35	Mustard	4	Other Crops (CDL) MEDIUM	Medium
28	Oats	4	Other Crops (CDL) MEDIUM	Medium
49	Onions	4	Other Crops (CDL) MEDIUM	Medium
25	Other Small Grains	4	Other Crops (CDL) MEDIUM	Medium
13	Pop or Orn Corn	4	Other Crops (CDL) MEDIUM	Medium
34	Rape Seed	4	Other Crops (CDL) MEDIUM	Medium
27	Rye	4	Other Crops (CDL) MEDIUM	Medium
33	Safflower	4	Other Crops (CDL) MEDIUM	Medium
30	Speltz	4	Other Crops (CDL) MEDIUM	Medium
23	Spring Wheat	4	Other Crops (CDL) MEDIUM	Medium
221	Strawberries	4	Other Crops (CDL) MEDIUM	Medium
6	Sunflower	4	Other Crops (CDL) MEDIUM	Medium
12	Sweet Corn	4	Other Crops (CDL) MEDIUM	Medium
24	Winter Wheat	4	Other Crops (CDL) MEDIUM	Medium
242	Blueberries	5	Other Crops (CDL) HIGH	High
55	Caneberries	5	Other Crops (CDL) HIGH	High
209	Cantaloupes	5	Other Crops (CDL) HIGH	High
58	Clover/Wildflowers	5	Other Crops (CDL) HIGH	High
250	Cranberries	5	Other Crops (CDL) HIGH	High
50	Cucumbers	5	Other Crops (CDL) HIGH	High
231	Dbl Crop Lettuce/Cantaloupe	5	Other Crops (CDL) HIGH	High
248	Eggplants	5	Other Crops (CDL) HIGH	High
249	Gourds	5	Other Crops (CDL) HIGH	High
57	Herbs	5	Other Crops (CDL) HIGH	High

213	Honeydew Melons	5	Other Crops (CDL) HIGH	High
47	Misc Vegs & Fruits	5	Other Crops (CDL) HIGH	High
216	Peppers	5	Other Crops (CDL) HIGH	High
229	Pumpkins	5	Other Crops (CDL) HIGH	High
222	Squash	5	Other Crops (CDL) HIGH	High
54	Tomatoes	5	Other Crops (CDL) HIGH	High
48	Watermelons	5	Other Crops (CDL) HIGH	High
61	Fallow/Idle Cropland	6	Fallow Idle (CDL) HIGH	High
72	Citrus	7	Fruit Xmas Trees Vines (CDL) LOW	Low
218	Nectarines	7	Fruit Xmas Trees Vines (CDL) LOW	Low
211	Olives	7	Fruit Xmas Trees Vines (CDL) LOW	Low
212	Oranges	7	Fruit Xmas Trees Vines (CDL) LOW	Low
74	Pecans	7	Fruit Xmas Trees Vines (CDL) LOW	Low
204	Pistachios	7	Fruit Xmas Trees Vines (CDL) LOW	Low
217	Pomegranates	7	Fruit Xmas Trees Vines (CDL) LOW	Low
76	Walnuts	7	Fruit Xmas Trees Vines (CDL) LOW	Low
70	Christmas Trees	8	Fruit Xmas Trees Vines (CDL) MEDIUM	Medium
69	Grapes	8	Fruit Xmas Trees Vines (CDL) MEDIUM	Medium
71	Other Tree Crops	8	Fruit Xmas Trees Vines (CDL) MEDIUM	Medium
75	Almonds	9	Fruit Xmas Trees Vines (CDL) HIGH	High
68	Apples	9	Fruit Xmas Trees Vines (CDL) HIGH	High
223	Apricots	9	Fruit Xmas Trees Vines (CDL) HIGH	High
66	Cherries	9	Fruit Xmas Trees Vines (CDL) HIGH	High
67	Peaches	9	Fruit Xmas Trees Vines (CDL) HIGH	High
77	Pears	9	Fruit Xmas Trees Vines (CDL) HIGH	High
220	Plums	9	Fruit Xmas Trees Vines (CDL) HIGH	High
210	Prunes	9	Fruit Xmas Trees Vines (CDL) HIGH	High
36	Alfalfa	10	Hay Alfalfa (CDL) LOW	Low
37	Other Hay/Non Alfalfa	10	Hay Alfalfa (CDL) LOW	Low
111	Open Water	11	Open Water (NLCD)	Excluded
112	Perennial Ice/Snow	12	Perennial Ice Snow (NCLD)	Excluded
92	Aquaculture	13	Water (CDL)	Excluded
83	Water	13	Water (CDL)	Excluded
254	Dbl Crop Barley/Soybeans	14	Soybeans LOW	Low
241	Dbl Crop Corn/Soybeans	14	Soybeans LOW	Low
26	Dbl Crop WinWht/Soybeans	14	Soybeans LOW	Low
5	Soybeans	14	Soybeans LOW	Low
82	Developed	20	Developed (CDL)	Medium
121	Developed/Open Space	21	Developed Open Space (NCLD)	High

122	Developed/Low Intensity	22	Developed Low Intensity (NCLD)	High
123	Developed/Med Intensity	23	Developed Med Intensity (NCLD)	High
124	Developed/High Intensity	24	Developed High Intensity (NCLD)	High
65	Barren	30	Barren (CDL)	Medium
131	Barren	31	Barren (NCLD)	Medium
63	Forest	40	Forest (CDL)	Low
141	Deciduous Forest	41	Deciduous Forest (NCLD)	Low
142	Evergreen Forest	42	Evergreen Forest (NCLD)	Low
143	Mixed Forest	43	Mixed Forest (NCLD)	Low
64	Shrubland	50	Shrubland (CDL)	High
152	Shrubland	52	Shrubland (NCLD)	High
176	Grassland/Pasture	76	Grassland Pasture (NCLD)	Medium
190	Woody Wetlands	90	Woody Wetlands (NCLD)	Low
87	Wetlands	91	Wetlands (CDL)	Medium
195	Herbaceous Wetlands	95	Herbaceous Wetlands (NCLD)	Medium
81	Clouds/No Data	NoData	NoData	Excluded
88	Nonag/Undefined	NoData	NoData	Excluded

Appendix 4. List of potential input field criteria used within the County Ranking Tool

FIELD	DESCRIPTION
GEOID	Unique county identifier (TIGER)
NAME	County Name
STATE_NAME	State Name
STATE_FIPS	State FIPS code
CNTY_FIPS	County FIPS code
FIPS	State and County FIPS Codes
Area (sq km)	Area of county in square kilometers
pct_nodata	NLCD 2011 - Percentage of county classified as No Data
pct_opwat	NLCD 2011 - Percentage of county classified as Open Water
pct_ice_sn	NLCD 2011 - Percentage of county classified as Perennial Ice Snow
pct_dev_op	NLCD 2011 - Percentage of county classified as Developed Open Space
pct_dev_li	NLCD 2011 - Percentage of county classified as Developed Low Intensity
pct_dev_mi	NLCD 2011 - Percentage of county classified as Developed Medium Intensity
pct_dev_hi	NLCD 2011 - Percentage of county classified as Developed High Intensity
pct_barren	NLCD 2011 - Percentage of county classified as Barren Land
pct_de_for	NLCD 2011 - Percentage of county classified as Deciduous Forest
pct_ev_for	NLCD 2011 - Percentage of county classified as Evergreen Forest
pct_mi_for	NLCD 2011 - Percentage of county classified as Mixed Forest
pct_shrub	NLCD 2011 - Percentage of county classified as Shrub Scrub
pct_grass	NLCD 2011 - Percentage of county classified as Grassland Herbaceous
pct_pastur	NLCD 2011 - Percentage of county classified as Pasture Hay
pct_cultcr	NLCD 2011 - Percentage of county classified as Cultivated Crops
pct_woodyw	NLCD 2011 - Percentage of county classified as Woody Wetlands
pct_e_herb	NLCD 2011 - Percentage of county classified as Emergent Herbaceous Wetlands
pad_nodata	NLCD 2011 - Percentage of county classified as No Data within protected areas as defined in Protected Areas Database
pad_opwat	NLCD 2011 - Percentage of county classified as Open Water within protected areas as defined in Protected Areas Database
pad_ice_sn	NLCD 2011 - Percentage of county classified as Perennial Ice Snow within protected areas as defined in Protected Areas Database
pad_dev_op	NLCD 2011 - Percentage of county classified as Developed Open Space within protected areas as defined in Protected Areas Database
pad_dev_li	NLCD 2011 - Percentage of county classified as Developed Low Intensity within protected areas as defined in Protected Areas Database
pad_dev_mi	NLCD 2011 - Percentage of county classified as Developed Medium Intensity within protected areas as defined in Protected Areas Database
pad_dev_hi	NLCD 2011 - Percentage of county classified as Developed High Intensity within protected areas as defined in Protected Areas Database

pad_barren	NLCD 2011 - Percentage of county classified as Barren Land within protected areas as defined in Protected Areas Database
pad_de_for	NLCD 2011 - Percentage of county classified as Deciduous Forest within protected areas as defined in Protected Areas Database
pad_ev_for	NLCD 2011 - Percentage of county classified as Evergreen Forest within protected areas as defined in Protected Areas Database
pad_mi_for	NLCD 2011 - Percentage of county classified as Mixed Forest within protected areas as defined in Protected Areas Database
pad_shrub	NLCD 2011 - Percentage of county classified as Shrub Scrub within protected areas as defined in Protected Areas Database
pad_grass	NLCD 2011 - Percentage of county classified as Grassland Herbaceous within protected areas as defined in Protected Areas Database
pad_pastur	NLCD 2011 - Percentage of county classified as Pasture Hay within protected areas as defined in Protected Areas Database
pad_cultcr	NLCD 2011 - Percentage of county classified as Cultivated Crops within protected areas as defined in Protected Areas Database
pad_woodyw	NLCD 2011 - Percentage of county classified as Woody Wetlands within protected areas as defined in Protected Areas Database
pad_e_herb	NLCD 2011 - Percentage of county classified as Emergent Herbaceous Wetlands within protected areas as defined in Protected Areas Database
pwr_inslen	HSIP Gold 2013 - Transmission line density for each county - In-Service Transmission Length (km)
pwr_prolen	HSIP Gold 2013 - Transmission line density for each county - Proposed Transmission Length (km)
pwr_insden	HSIP Gold 2013 - Transmission line density for each county - In-Service Length Per Area (km/sq km)
pwr_proden	HSIP Gold 2013 - Transmission line density for each county - Proposed Length Per Area (km/sq km)
grass2crop	NLCD 2001-2011 percentage change - grassland herbaceous to cultivated crops
grass2dev	NLCD 2001-2011 percentage change - grassland herbaceous to developed (classes 21, 22, 23, 24)
pct_edge	NLCD 2011 cultivated crop edge/core - pct of county classified as cultivated crops within 30 meters of another class (crop edge)
pct_core	NLCD 2011 cultivated crop edge/core - pct of county classified as cultivated crops not within 30 meters of another class (crop core)
pct_edge2	NLCD 2011 cultivated crop edge/core - pct of cultivated crop total area within county classified as cultivated crops within 30 meters of another class (crop edge)
pct_core2	NLCD 2011 cultivated crop edge/core - pct of cultivated crop total area within county classified as cultivated crops not within 30 meters of another class (crop core)
rail_len	TIGER 2014 - Railroad Length (km) by county
rail_den	TIGER 2014 - Railroad Length Per Area (km/sq km) by county
crp_chg	Percentage of county that changed in CRP enrollment from 9/30/2007 to 10/31/2013 - USDA FSA
pct_corn02	Census of Agriculture 2002 - Percent of county corn for grain
pct_soyb02	Census of Agriculture 2002 - Percent of county soybeans for beans
pct_whea02	Census of Agriculture 2002 - Percent of county wheat for grain

pct_corn07	Census of Agriculture 2007 - Percent of county corn for grain
pct_soyb07	Census of Agriculture 2007 - Percent of county soybeans for beans
pct_whea07	Census of Agriculture 2007 - Percent of county wheat for grain
pct_corn12	Census of Agriculture 2012 - Percent of county corn for grain
pct_soyb12	Census of Agriculture 2012 - Percent of county soybeans for beans
pct_whea12	Census of Agriculture 2012 - Percent of county wheat for grain
corn02_07	Census of Agriculture - Percent change corn for grain 2002-2007 by county
soyb02_07	Census of Agriculture - Percent change soybeans for beans 2002-2007 by county
whea02_07	Census of Agriculture - Percent change wheat for grain 2002-2007 by county
corn07_12	Census of Agriculture - Percent change corn for grain 2007-2012 by county
soyb07_12	Census of Agriculture - Percent change soybeans for beans 2007-2012 by county
whea07_12	Census of Agriculture - Percent change wheat for grain 2007-2012 by county
cdl_var	NASS Cropland data layer - Variety of crop types by county
cdl_maj	NASS Cropland data layer - Majority crop type by county
s1100_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Primary road
s1200_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Secondary road
s1400_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Local Neighborhood Road, Rural Road, City Street
s1500_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Vehicular Trail (4WD)
s1630_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Ramp
s1640_rds	Tiger 2014 roads - Percent of county composed of rasterized road class -Service Drive usually along a limited access highway
s1710_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Walkway/Pedestrian Trail
s1720_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Stairway
s1730_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Alley
s1740_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Private Road for service vehicles (logging, oil fields, ranches, etc.)
s1750_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Internal U.S. Census Bureau use
s1780_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Parking Lot Road
s1820_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Bike Path or Trail
s1830_rds	Tiger 2014 roads - Percent of county composed of rasterized road class - Bridle Path
crp_cp01	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp02	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp04D	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp04B	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp08	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp09	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp10	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp15	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp21	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county

crp_cp23BC	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp23FP	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp23NF	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp24	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp25	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp27	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp28	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp29	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp30	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp33	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp37	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp38	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp39	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp41	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_cp42	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county
crp_all	2014 - FSA - Potential pollinator/milkweed CRP practices - Percent of county - All CRP practices
pest92gly	USGS Estimated Annual Agricultural Pesticide Use, 1992 (Glyphosate) - kg/sq km
pest93gly	USGS Estimated Annual Agricultural Pesticide Use, 1993 (Glyphosate) - kg/sq km
pest94gly	USGS Estimated Annual Agricultural Pesticide Use, 1994 (Glyphosate) - kg/sq km
pest95gly	USGS Estimated Annual Agricultural Pesticide Use, 1995 (Glyphosate) - kg/sq km
pest96gly	USGS Estimated Annual Agricultural Pesticide Use, 1996 (Glyphosate) - kg/sq km
pest97gly	USGS Estimated Annual Agricultural Pesticide Use, 1997 (Glyphosate) - kg/sq km
pest98gly	USGS Estimated Annual Agricultural Pesticide Use, 1998 (Glyphosate) - kg/sq km
pest99gly	USGS Estimated Annual Agricultural Pesticide Use, 1999 (Glyphosate) - kg/sq km
pest00gly	USGS Estimated Annual Agricultural Pesticide Use, 2000 (Glyphosate) - kg/sq km
pest01gly	USGS Estimated Annual Agricultural Pesticide Use, 2001 (Glyphosate) - kg/sq km
pest02gly	USGS Estimated Annual Agricultural Pesticide Use, 2002 (Glyphosate) - kg/sq km
pest03gly	USGS Estimated Annual Agricultural Pesticide Use, 2003 (Glyphosate) - kg/sq km
pest04gly	USGS Estimated Annual Agricultural Pesticide Use, 2004 (Glyphosate) - kg/sq km
pest05gly	USGS Estimated Annual Agricultural Pesticide Use, 2005 (Glyphosate) - kg/sq km
pest06gly	USGS Estimated Annual Agricultural Pesticide Use, 2006 (Glyphosate) - kg/sq km
pest07gly	USGS Estimated Annual Agricultural Pesticide Use, 2007 (Glyphosate) - kg/sq km
pest08gly	USGS Estimated Annual Agricultural Pesticide Use, 2008 (Glyphosate) - kg/sq km
pest09gly	USGS Estimated Annual Agricultural Pesticide Use, 2009 (Glyphosate) - kg/sq km
chg9509gly	USGS Estimated Annual Agricultural Pesticide Use, Change from 1995-2009 (Glyphosate) - kg/sq km
pest94imi	USGS Estimated Annual Agricultural Pesticide Use, 1994 (Imidacloprid) - kg/sq km - Neonicotinoid
pest95imi	USGS Estimated Annual Agricultural Pesticide Use, 1995 (Imidacloprid) - kg/sq km - Neonicotinoid
pest96imi	USGS Estimated Annual Agricultural Pesticide Use, 1996 (Imidacloprid) - kg/sq km -

	Neonicotinoid
pest97imi	USGS Estimated Annual Agricultural Pesticide Use, 1997 (Imidacloprid) - kg/sq km - Neonicotinoid
pest98imi	USGS Estimated Annual Agricultural Pesticide Use, 1998 (Imidacloprid) - kg/sq km - Neonicotinoid
pest99imi	USGS Estimated Annual Agricultural Pesticide Use, 1999 (Imidacloprid) - kg/sq km - Neonicotinoid
pest00imi	USGS Estimated Annual Agricultural Pesticide Use, 2000 (Imidacloprid) - kg/sq km - Neonicotinoid
pest01imi	USGS Estimated Annual Agricultural Pesticide Use, 2001 (Imidacloprid) - kg/sq km - Neonicotinoid
pest02imi	USGS Estimated Annual Agricultural Pesticide Use, 2002 (Imidacloprid) - kg/sq km - Neonicotinoid
pest03imi	USGS Estimated Annual Agricultural Pesticide Use, 2003 (Imidacloprid) - kg/sq km - Neonicotinoid
pest04imi	USGS Estimated Annual Agricultural Pesticide Use, 2004 (Imidacloprid) - kg/sq km - Neonicotinoid
pest05imi	USGS Estimated Annual Agricultural Pesticide Use, 2005 (Imidacloprid) - kg/sq km - Neonicotinoid
pest06imi	USGS Estimated Annual Agricultural Pesticide Use, 2006 (Imidacloprid) - kg/sq km - Neonicotinoid
pest07imi	USGS Estimated Annual Agricultural Pesticide Use, 2007 (Imidacloprid) - kg/sq km - Neonicotinoid
pest08imi	USGS Estimated Annual Agricultural Pesticide Use, 2008 (Imidacloprid) - kg/sq km - Neonicotinoid
pest09imi	USGS Estimated Annual Agricultural Pesticide Use, 2009 (Imidacloprid) - kg/sq km - Neonicotinoid
chg9509imi	USGS Estimated Annual Agricultural Pesticide Use, Change from 1995-2009 (Imidacloprid) - kg/sq km - Neonicotinoid
pest04clo	USGS Estimated Annual Agricultural Pesticide Use, 2004 (Clothianidin) - kg/sq km - Neonicotinoid
pest05clo	USGS Estimated Annual Agricultural Pesticide Use, 2005 (Clothianidin) - kg/sq km - Neonicotinoid
pest06clo	USGS Estimated Annual Agricultural Pesticide Use, 2006 (Clothianidin) - kg/sq km - Neonicotinoid
pest07clo	USGS Estimated Annual Agricultural Pesticide Use, 2007 (Clothianidin) - kg/sq km - Neonicotinoid
pest08clo	USGS Estimated Annual Agricultural Pesticide Use, 2008 (Clothianidin) - kg/sq km - Neonicotinoid
pest09clo	USGS Estimated Annual Agricultural Pesticide Use, 2009 (Clothianidin) - kg/sq km - Neonicotinoid
pest05din	USGS Estimated Annual Agricultural Pesticide Use, 2005 (Dinotefuran) - kg/sq km - Neonicotinoid
pest06din	USGS Estimated Annual Agricultural Pesticide Use, 2006 (Dinotefuran) - kg/sq km - Neonicotinoid
pest07din	USGS Estimated Annual Agricultural Pesticide Use, 2007 (Dinotefuran) - kg/sq km - Neonicotinoid

pest08din	USGS Estimated Annual Agricultural Pesticide Use, 2008 (Dinotefuran) - kg/sq km - Neonicotinoid
pest09din	USGS Estimated Annual Agricultural Pesticide Use, 2009 (Dinotefuran) - kg/sq km - Neonicotinoid
pest00thi	USGS Estimated Annual Agricultural Pesticide Use, 2000 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest01thi	USGS Estimated Annual Agricultural Pesticide Use, 2001 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest02thi	USGS Estimated Annual Agricultural Pesticide Use, 2002 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest03thi	USGS Estimated Annual Agricultural Pesticide Use, 2003 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest04thi	USGS Estimated Annual Agricultural Pesticide Use, 2004 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest05thi	USGS Estimated Annual Agricultural Pesticide Use, 2005 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest06thi	USGS Estimated Annual Agricultural Pesticide Use, 2006 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest07thi	USGS Estimated Annual Agricultural Pesticide Use, 2007 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest08thi	USGS Estimated Annual Agricultural Pesticide Use, 2008 (Thiamethoxam) - kg/sq km - Neonicotinoid
pest09thi	USGS Estimated Annual Agricultural Pesticide Use, 2009 (Thiamethoxam) - kg/sq km - Neonicotinoid
coa_mval12	Census of Agriculture 2012 - Estimated market value of land and buildings \ Average per acre (dollars)
I35_100mi	Counties centroid falls within buffer around I-35 (Source: TIGER roads)
mon_5_reg	Model regions made to facilitate the economic analysis for monarchs (Semmens)
mw_reg_fnl	Monarch regions from willingness to pay analysis (Diffendorfer)
pct_harv12	Census of Agriculture 2012 - Percent of county harvested cropland
ascl_cu_cl	Mean probability of occurrence of all *Asclepias* species using Current climate model
ascl_a2_cl	Mean probability of occurrence of all *Asclepias* species using A2 climate change model
ascl_b1_cl	Mean probability of occurrence of all *Asclepias* species using B1 climate change model
dana_cu_cl	Mean probability of occurrence of *Danaus* genus using Current climate model
dana_a2_cl	Mean probability of occurrence of *Danaus* genus using A2 climate change model
dana_b1_cl	Mean probability of occurrence of *Danaus* genus using B1 climate change model
past2crop	NLCD 2001-2011 percentage change - pasture/hay to cultivated crops
past2dev	NLCD 2001-2011 percentage change - pasture/hay to developed (classes 21, 22, 23, 24)
bonapMWspp	2015 - BONAP North American Plant Atlas - species richness - Total species belonging to *Asclepias* genus (Milkweed)
bonapSWspp	2015 - BONAP North American Plant Atlas - species richness - Total species belonging to *Cynanchum* genus (Swallowworts)
nccpi_all	2012 - NRCS - SSURGO - Mean National Commodity Crop Productivity Index score - North Central, Northeast, South Monarch Regions - All Crops
nccpi_cs	2012 - NRCS - SSURGO - Mean National Commodity Crop Productivity Index score - North

	Central, Northeast, South Monarch Regions - Corn/Soybeans
nccpi_co	2012 - NRCS - SSURGO - Mean National Commodity Crop Productivity Index score - North Central, Northeast, South Monarch Regions - Cotton
nccpi_sg	2012 - NRCS - SSURGO - Mean National Commodity Crop Productivity Index score - North Central, Northeast, South Monarch Regions - Small Grains
nccpi_nul	2012 - NRCS - SSURGO - Mean National Commodity Crop Productivity Index score - North Central, Northeast, South Monarch Regions - % of county with Null NCCPI score (All Crops)
wass_hobs	Core eastern breeding population - 50%, 95%, 100%
mig_gratic	Monarch frequencies, larger number denotes lower frequency of capture during migration (Min. 800 - Max. 12)