



Urban Monarch Conservation Planning Toolsets

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*Much of this manual and the toolsets herein are based on national tools that were developed by the USGS Monarch Conservation Science Partnership. The toolsets described in this manual have been modified for use at the urban-scale and are meant to complement the national tools designed to work above the county scale.

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Background

Monarch butterfly (*Danaus plexippus*) populations east of the Rocky Mountains migrate annually to central Mexico. The overwintering population has declined more than 80% over two decades. One prevailing theory for this is the milkweed-limitation hypothesis. Increased efficiency in agricultural practices and widespread conversion of grasslands has resulted in a precipitous decline in milkweed species (*Asclepias* spp) that monarch caterpillars depend on as their obligate hosts. National scale research suggests a 5-fold increase in milkweed stems is needed to address extinction risks of the eastern monarch population. To accomplish this increase despite continued land conversion, the US Fish and Wildlife Service has recommended extensive conservation efforts across all sectors including urbanized areas. Currently, little is known about the existing density and habitat potential of milkweed in urban landscapes. We developed a field method for randomly sampling milkweed abundance across the urban gradient using “metro-transects” and field sampling in naturalized areas. We conducted our study with support from USFWS and local partners across four major metropolitan areas along the monarch migratory route: Chicago, Minneapolis-Saint Paul, Kansas City, and Austin.

Milkweed density was estimated across 16 consolidated land use categories. To better understand potential milkweed density across land use sectors, our field team also did targeted sampling of “exemplary” and “enhanced” greenspace conversion areas across land-use sectors. Two geospatial tools were developed in collaboration with USGS staff, 1) a “baseline” tool to estimate existing milkweed abundance values across municipalities and metropolitan areas, and 2) a “scenario planning” tool for estimating projected milkweed abundances and densities under various user-supplied scenarios that vary landowner participation by land use sectors. The amount of land that could be monarch habitat varied widely across metropolitan areas and across land use categories within metropolitan areas. Only a very small percentage of land available for urban monarch habitat currently contains milkweed. The potential for increasing milkweed stems and nectaring plants to provide pollinator habitat in urban landscapes is enormous and depends on engaging different audiences in each land use category. Existing and potential milkweed estimates are summarized and visualized across US Census Bureau census blocks. Our results, the geospatial tools, a manual, and a guidebook are made available to the public with a primary intended audience of municipal and regional planning agencies, major landowners, and federal, state, and not-for-profit conservation organizations interested in or working on pollinator issues.

Purpose

This manual focuses on the installation, development, and use of the urban monarch conservation planning tools, namely the *Urban Milkweed Baseline Calculator Tool*, and the *Urban Milkweed Scenario-Planning Tool*.

The intended audience for this manual is intermediate to advanced GIS users; with the aim that they be able to understand how to use the geospatial tool as well as develop a similar geospatial model using the described methods. It should be stated that the workflow and methods described below will be based on ESRI ArcGIS for Desktop and as such some toolboxes mentioned may require licensing.

Section A: Instructions for Downloading and Installing the Toolsets

This section takes the user through software requirements, installation procedures, and how to use the toolsets. Users also have the option of using their own GIS layers to enhance the utility of the tools which is integrated into this section as optional steps.

Download Options

The tools that accompany this manual have been developed for four major metropolitan areas. Users have the option of downloading customized versions of the tools developed for each of these metropolitan areas, or they can download a generic template that can be applied to other metropolitan areas.

Filename	Description
UrbanMonarch_tool_manual.pdf	This instruction manual
UrbanMonarch_Chicago_tools.zip	Customized toolset for Chicago metropolitan area
UrbanMonarch_MSP_tools.zip	Customized toolset for Minneapolis-Saint Paul metropolitan area
UrbanMonarch_KC_tools.zip	Customized toolset for Kansas City metropolitan area
UrbanMonarch_Austin_tools.zip	Customized toolset for Austin metropolitan area
UrbanMonarch_template_tools.zip	Generic template version of the toolset for other metropolitan areas

Applying the Toolset to Other Cities and Metropolitan Areas

The generic template tools for other metropolitan areas require users to either 1) use estimated milkweed density values from another city/ source, or 2) to deploy a field team that will randomly sample existing milkweed densities across the urban gradient and at sampling sites (for methods see **Section E**). While collecting data on milkweed densities it may also be helpful to document nectaring sources for other studies. There are also data requirements such as a land-use data layer (generally available through regional planning agencies) and some necessary pre-analysis steps (see **Section B** below).

Requirements

The Urban Monarch Conservation Planning Toolsets require the use of ArcGIS software. All of the toolsets (including the generic template) include an ArcGIS Toolbox. The “customized tools” available for some metropolitan areas (see *downloads* above) already include the GIS data and embedded milkweed density values needed to run the tools. The specific software requirements include:

- ArcGIS Desktop version 10.3+ (ESRI)
- ArcGIS Spatial Analyst extension (licensed separately)
- Python 2.4 or more recent (automatically installed with ArcGIS)
- Pywin32 (Python for Windows extension if not already installed)

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 for free at:

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

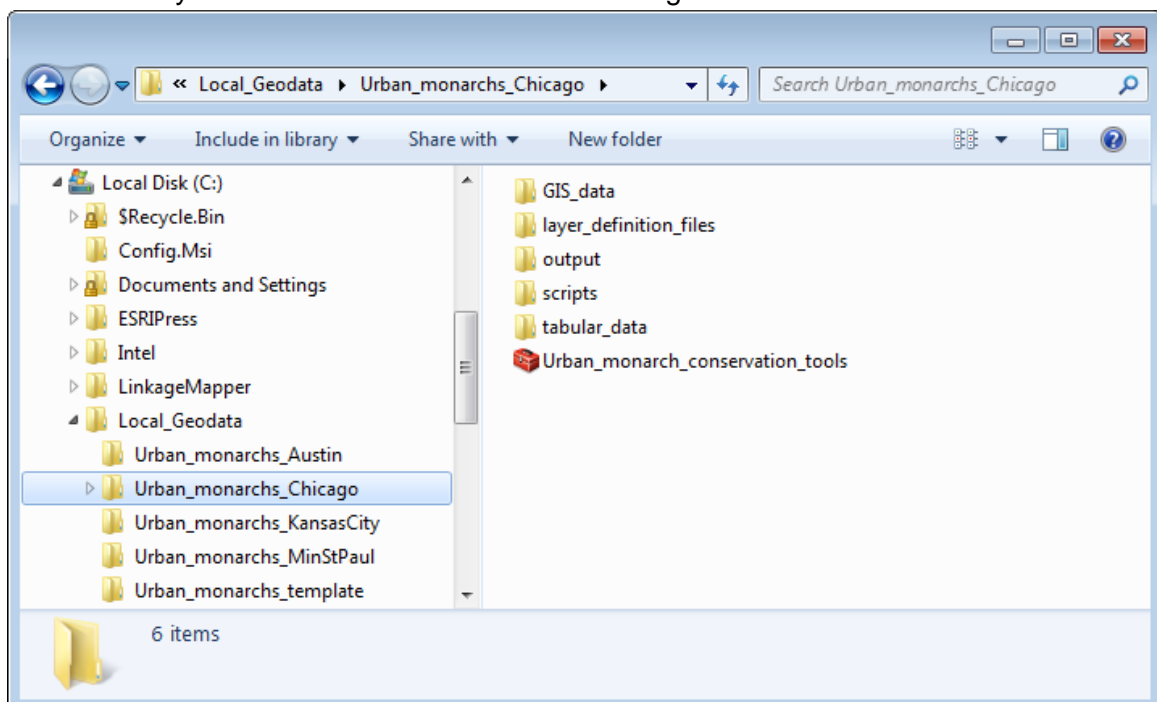
Installation

Once these software requirements are met, the user can download and install the toolbox. Administrative access to your computer is not necessary since we are just setting up the directory structure and accessing the tools and data without any software installations.

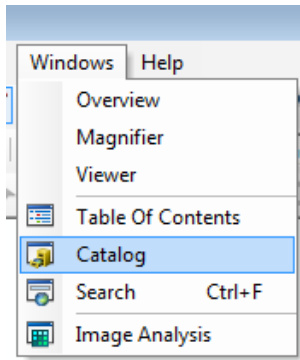
A1. **Download and extract** one or more of the compressed toolkit files (e.g. *UrbanMonarch_Chicago_tools.zip*) to a local directory on your computer. In this example, we use **C:\Local_Geodata** (see A2 below). There are four sub-directories that are created...

<i>Folder</i>	<i>Content</i>
<i>gis_data</i>	Contains the census block summary shapefiles used in the tools and ancillary data
<i>layer_definition_files</i>	Contains ArcMap symbology layers used to shade the outputs from the tools
<i>output</i>	Empty folder designated for model outputs
<i>scripts</i>	Contains the Python scripts that are called by the tools

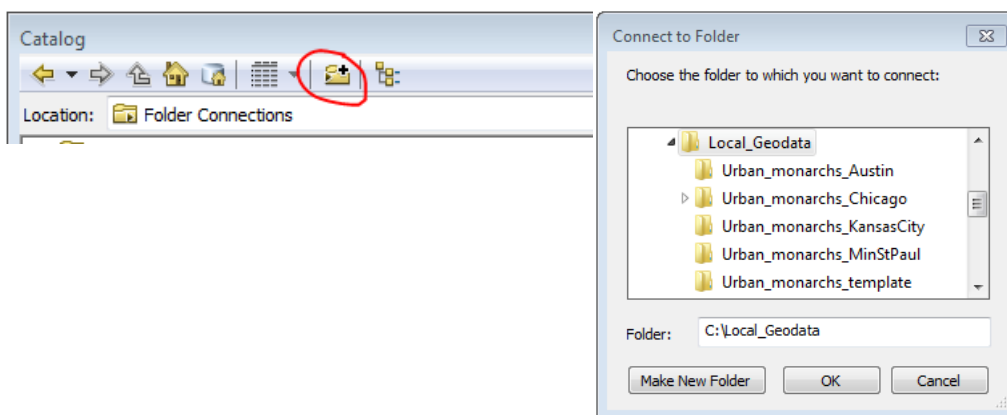
A2. Your directory structure should look similar to the figure below...



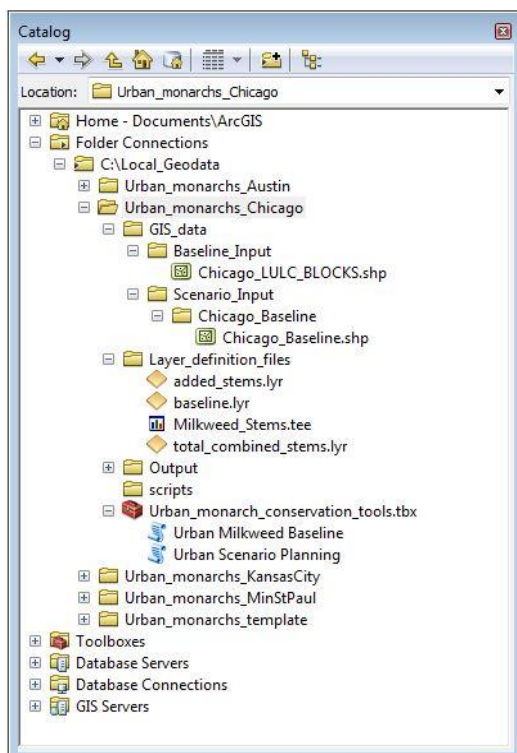
- A3. **Begin an ArcMap session** using ArcGIS for Desktop 10.3 or above with Spatial Analyst extension enabled, and open **Catalog** from the menu bar within ArcMap (as shown below)...



- A4. In the *Catalog* window, click on the *connect to folder* icon below (left image) and navigate to the installation folder (right image) and click OK...



- A5. Select and expand the new connection within the *catalog* window. Your folder structure should look similar to the following. From here you are ready to load data and begin running the customized models for the four cities (**section B**).

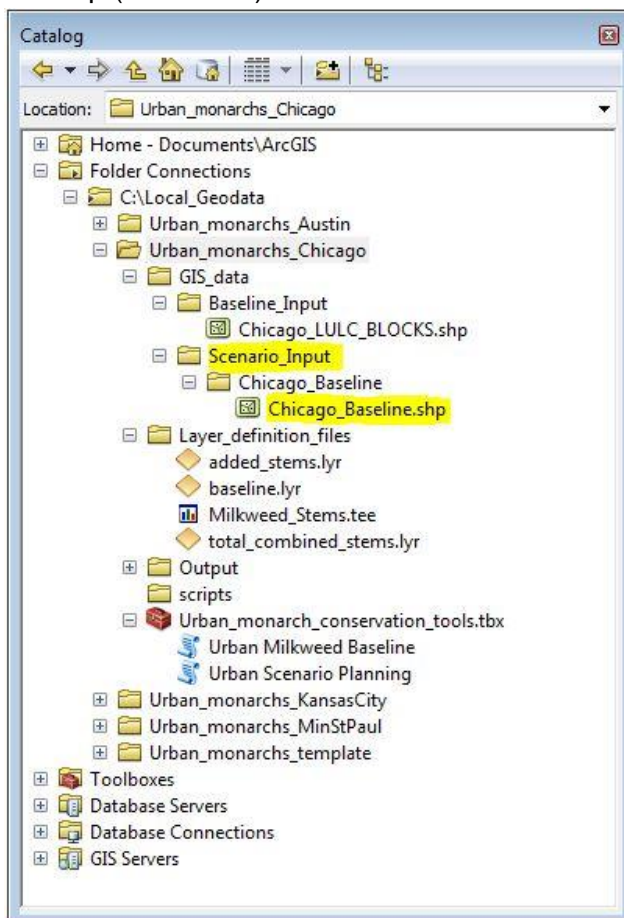


Section B: Using the Customized Toolsets

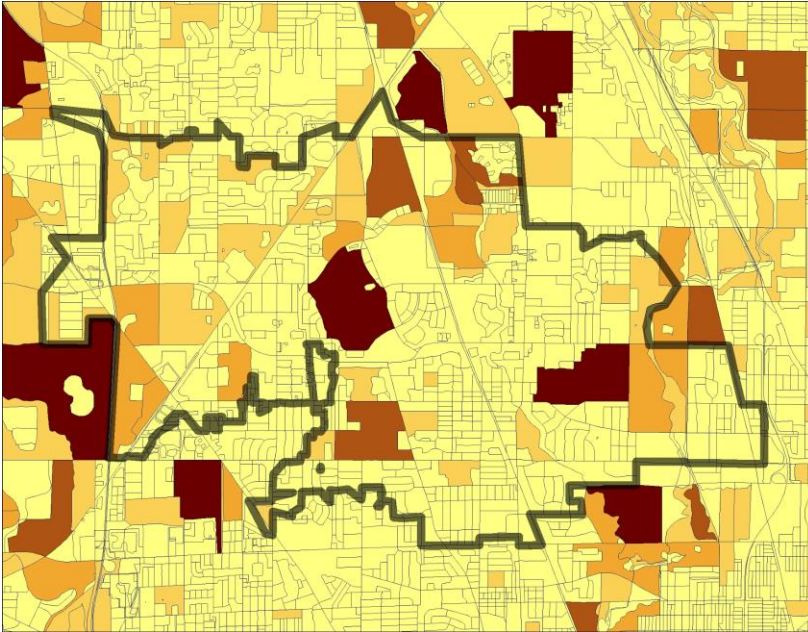
After downloading and installing one or more customized toolsets per the instructions above, you are ready to begin using the tools. There are two tools provided with the ArcGIS toolkit. The first is the **Urban Milkweed Baseline** tool which is used to estimate the amount of milkweed present across the metropolitan area summarized by census block. It also calculates the average milkweed density by census block. Casual users, will not need to run this tool since the standard baseline has already been run for you and is included with the tool. If you do not plan to deploy your own field team to estimate milkweed densities for your region, you may not need this tool. The second tool is the **Urban Scenario Planning** tool which is used to estimate the amount of milkweed stems that will be added to each census block, and the new estimated stem density after applying scenarios.

The following section walks through a tutorial demonstration of how the **Urban Scenario Planning** tool might be used in a municipality setting to help inform management decisions. In this example, we use *The Village of Glenview* in the Chicago metropolitan area as an example. If you want to follow along with this municipality or another one, add the municipalities shapefile included with the download in the *GIS_data* folder, then select the municipality of interest and export it out as a shapefile (right-click on the layer >> Data >> Export Data...)

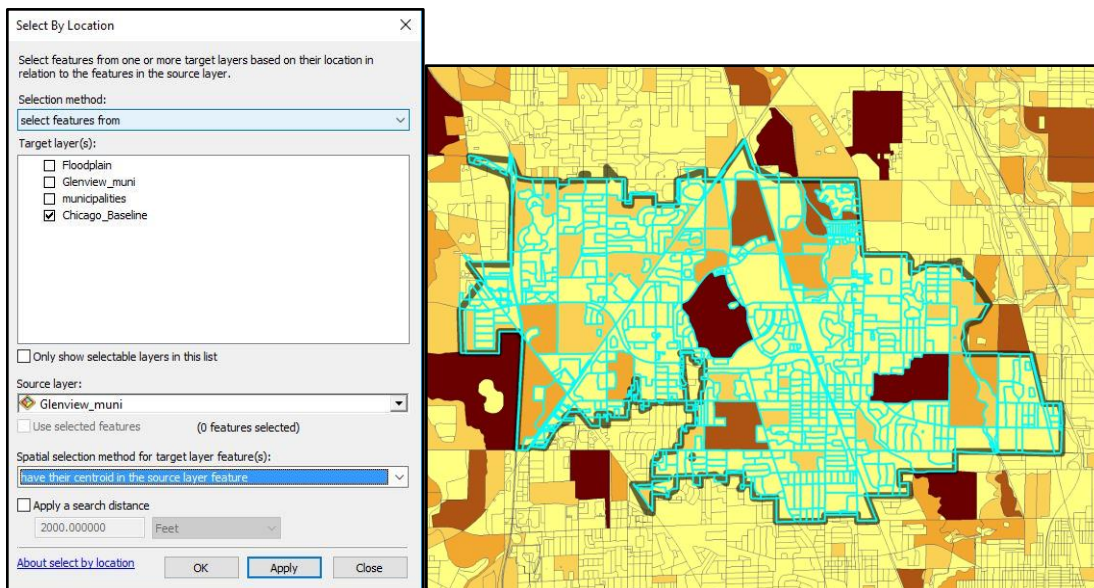
B1. Adding baseline data. In ArcMap, open **Catalog** and select the *Urban_monarchs_Chicago* data connection per the installation instructions above. Next, drag a copy of the shapefile *Chicago_Baseline.shp* from the *Scenario_Input* folder onto the Table of Contents window in ArcMap (see below).



In the following image, we added a boundary layer of Glenview (outlined in the thick gray) and added the *Chicago_Baseline.shp* layer symbolized using a color ramp based on the “*tot_stems*” field which estimates the total milkweed stems by census block. Darker areas indicates more stems of milkweed than lighter areas. Click on any census tract after selecting the information tool to see the estimated density and number of milkweed stems in the “*ave_stem*” and “*tot_stem*” fields, respectively. [Note: if you are following along using The Village of Glenview, we simplified the village boundary in the image below]

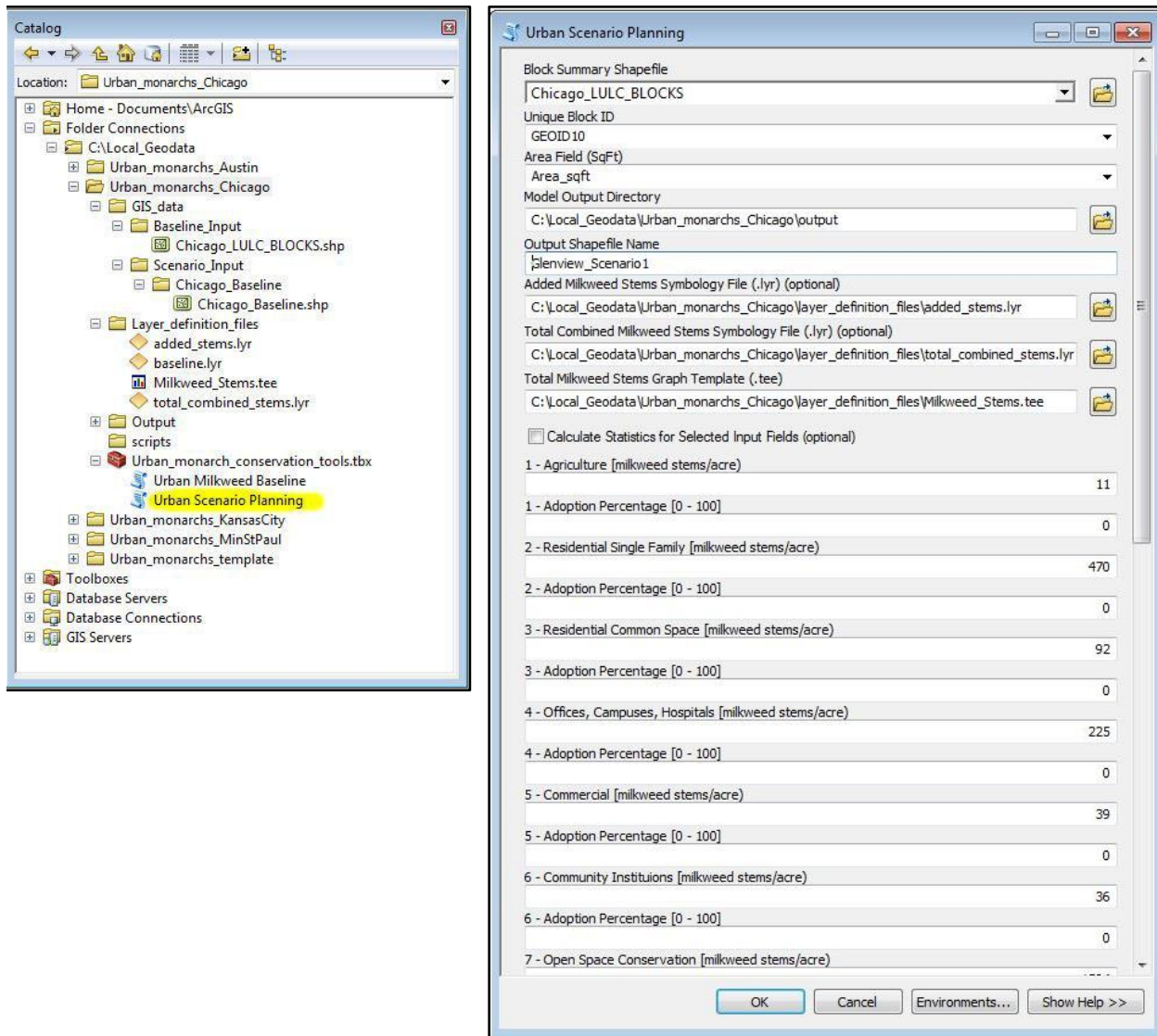


B2. Select baseline Census Blocks: We want to run the *Urban Scenario Planning* tool on the Village of Glenview. From the *Select* menu we use **Select by Location** to select all census blocks from the “Chicago_Baseline” layer that **have their centroids in the source layer feature** using the Glenview boundary layer (“*Glenview_muni*” extracted from the *chi_muni* shapefile) as the *source layer* (left image). The resulting selection is shown in the image on the right.



B3. We're ready to run the tool on the selected census blocks. Open **Catalog**, expand the *Urban_monarch_conservation_tools* toolbox, and double-click on the "Urban Scenario Planning" tool (left image below). In the tool dialog window (right image below), we need to select the *Block Summary Shapefile* which is the **Chicago_Baseline** layer with the selected census blocks in the image above. The tool pre-populates both the "Unique Block ID" as a unique record identifier (GEOID10), and the total Area Field (Area_SqFt) in square feet. We use the "Output" folder for storing results. The next 2 fields provide symbology for the results. Default layer files are provided in the "Layer_definition_files" folder for the estimated added stems of milkweed, and the new total combined milkweed stems. A template graph (*Milkweed_Stems.tee*) in the same folder is used for graphing the estimated total existing milkweed stems and the new total under the user scenario. The remaining fields hold 2 variables for 16 land use classes...

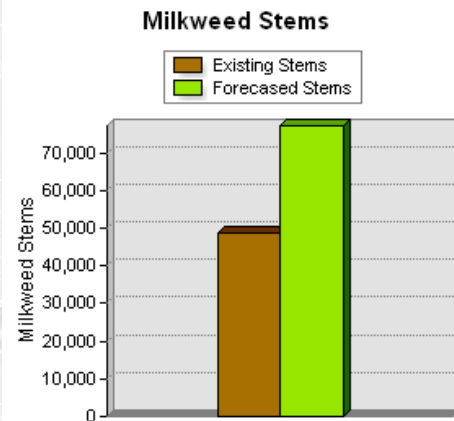
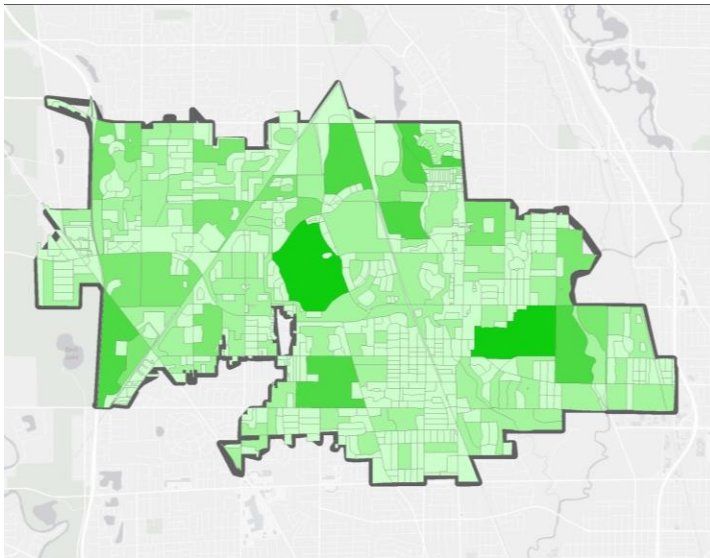
- a. The first variable, for each land use class, is pre-populated with exemplary site milkweed densities. These values are based on targeted field visits to sites with known milkweed installations.
- b. The second variable, for each land use class, called the adoption percentage largely defines the user scenario. Users set one or more *adoption percentages* to represent the percent of each land use category they anticipate will be converted into habitat similar to exemplary sites. It may be helpful to think of this in broad terms as the percent of landowners that will convert a portion of their land into pollinator friendly habitat. In this example, for simplicity sake, we set adoption percentages to 2% across all land use categories as a way of comparing across land use categories. However, in many cases, the user may find it desirable to keep the adoption rates set to zero except for one or a few land use categories. By doing this repeatedly, it is possible to compare various scenarios over the same geographic area.



B4. Scenario Results from 2% Adoption Across all Land Uses: Output from the Scenario Planning Tool is saved to the “model output directory” specified in the tool interface. By default, the tool will also add new symbolized map layers if layer file were selected in step “B3” above. Note that these layer files help to symbolized the data layers, but the default scale will not be tailored to new data layer. To resolve this, follow these steps...

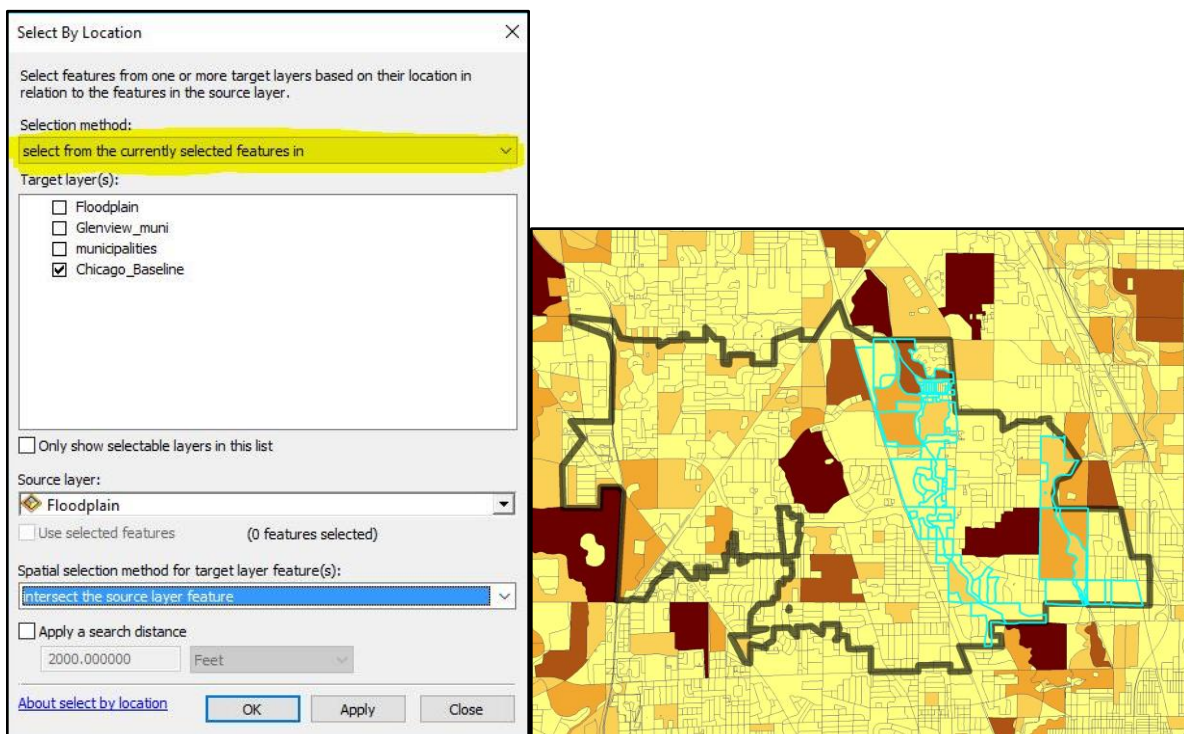
{Right-click on the layer} >> Properties... >> Symbology [tab]

In the dialog window above, change the number of classes (natural breaks/ Jenks) to any number of breaks. This causes ArcView to update the scale. Click on OK and your map will be updated with the correct values. In the results shown below, approximately 30,000 stems of milkweed were added with a 2% adoption rate across all land use categories.



B5. Leveraging Additional GIS data Layers: Next we explore how this tool can be used with other data layers. Suppose we wanted to target areas in the 100 year floodplain within Glenview since pollinator friendly habitat could be established while addressing stormwater and green infrastructure issues at the same time. To do this we first **repeat the identical census block selection process in step B2**.

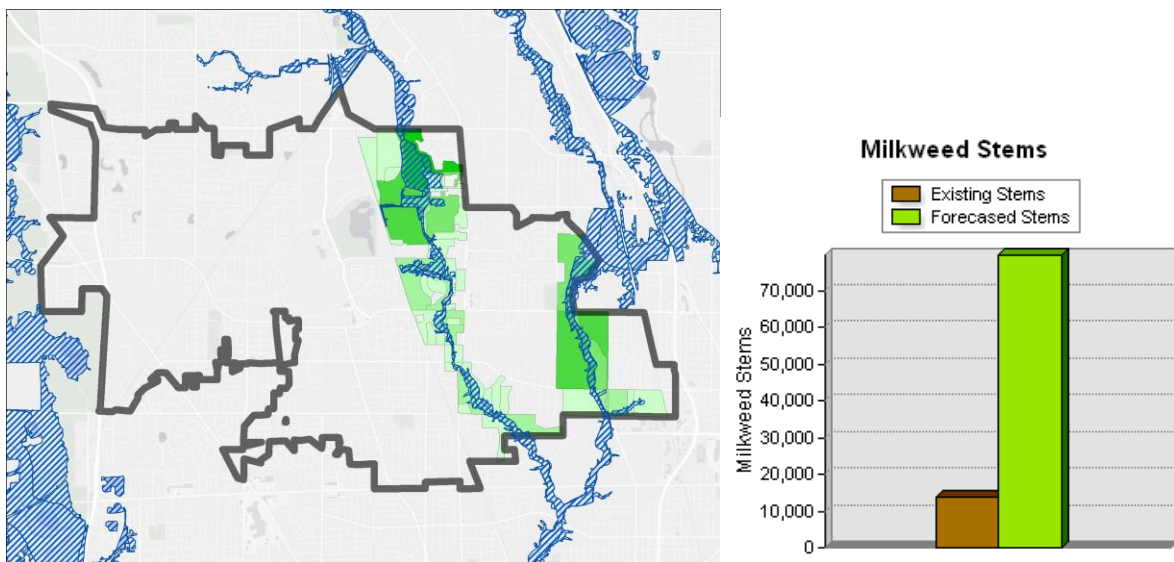
B6. Next, with all census blocks in Glenview selected, we want to select a subset of these that intersect the 100-year floodplain (available via [FEMA Flood Map Service](#)). After we **add the 100 year floodplain layer to the map**, we repeat the selection step in B2 (again) but this time using a different *selection method* called “**select from the currently selected features in**” *Chicago_Baseline* and we set the *Source Layer* to the **floodplain** layer, and the spatial selection method to **intersect the source layer feature** (left figure below). The resulting selection is shown in the right image below.



B7. Now we can run the **Scenario Planning tool again (Step B3)**, but this time we will target only a few land use categories, and we will be more aggressive with the estimated conversion values. The following table shows the adoption percentages used in this demonstration...

Land Use Class	Adoption Percentage
7 - Open Space Conservation	40%
8 - Open Space Non-Conservation	20%
14 - Vacant Land	40%

B8. **Scenario Results for Targeted Adoption in Floodplain Areas:** In targeting a much smaller area of just the floodplain but with much more aggressive adoption percentages, we see a dramatic increase in the amount of milkweed stems added (about 65,000 new stems on top of a baseline of about 15,000 stems).



B9. In **Section C** below, we walk through how new baseline datasets can be created using the Milkweed Baseline calculator tool if milkweed densities are edited or known (usually from randomized field data collection).

Section C: Establishing a new Baseline

This section walks through how to use the Baseline tool, which is very similar to the Urban Scenario Planning Tool (above). In some situations, it may be advantageous to create a new baseline in place of using the metropolitan baseline distributed with each customized set of tools. It is also important to note, that the baseline milkweed density values used in the distributed tools are generalized by land use categories across the entire metropolitan area. These values are listed in **Appendix 1**. While these values are helpful for establishing a baseline at the metropolitan scale, it is clear from anecdotal evidence that these values can vary greatly from one neighborhood to the next, and from one natural area to another. For this reason, some municipalities or counties may find it advantageous to gather milkweed density values particular to their own area. This can be accomplished by deploying a field team where efforts can be concentrated across a much smaller geography resulting in a more precise estimate of existing stem densities, and for the purpose of the scenario planning tool, local examples of exemplary and enhanced sites can be targeted for sampling as well. For a discussion about how milkweed densities can be collected in the field across all land use categories, and at targeted sites, see *“Enhancing the Tools with Fieldwork”* (**Section E**).

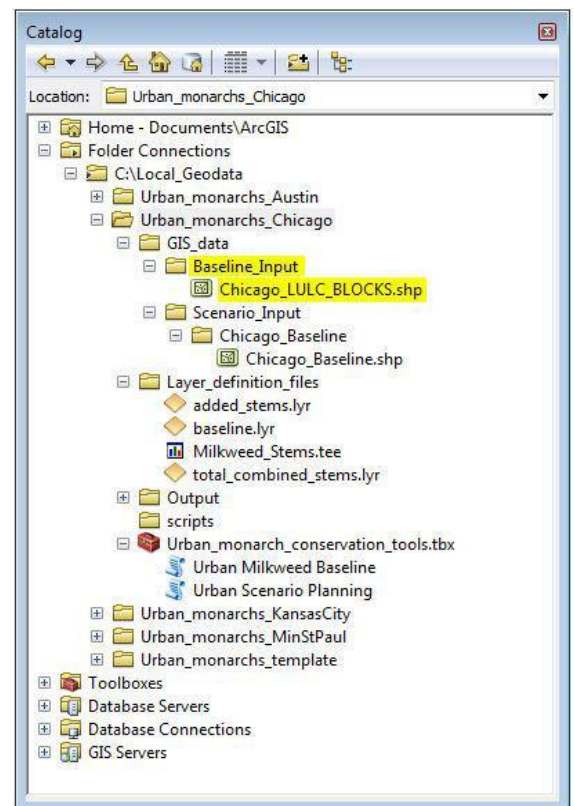
Users that are applying the template tools for other metropolitan areas (**Section D**), will be starting without a baseline model output and milkweed density values. These users will need to either: 1) estimate milkweed density values from other cities and sources, or 2) deploy one or more field teams across the metropolitan area to estimate milkweed densities across consolidated land use categories (**Section E**). In the example that follows, we continue using the data and tools from the “UrbanMonarch_Chicago_tools.zip” download.

C1. Preparing to run the Baseline Tool. Prior to running this tool, you need to download and install the tools, **Section A** (above).

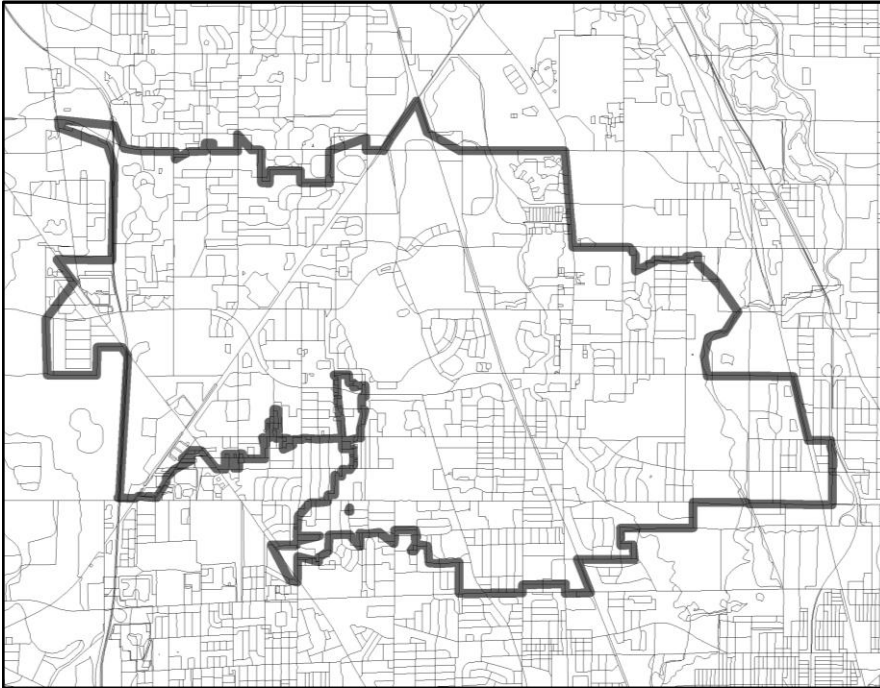
C2. Next, we need to add pre-processed¹ census block data to ArcMap. This layer is distributed with the customized tools, or alternatively, if using the generic template, this layer can be developed for other metropolitan areas by following the steps outlined in **Section D**.

¹[Includes area calculations in the attribute table with the amount of “grass/shrub” by land use category summarized for all census blocks.]

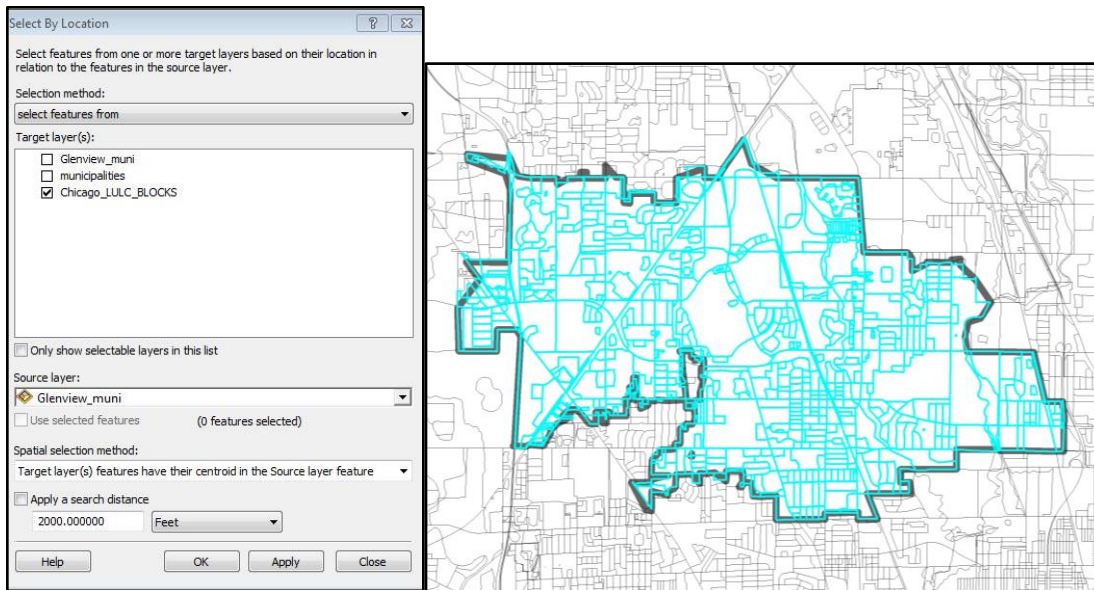
- a. In ArcMap, open **Catalog** and select the *Urban_monarchs_Chicago* data connection per the installation instructions in **Section A**. Next, drag a copy of the shapefile *Chicago_LULC_BLOCKS.shp* from the *Baseline_Input* folder onto the Table of Contents window in ArcMap (see right).



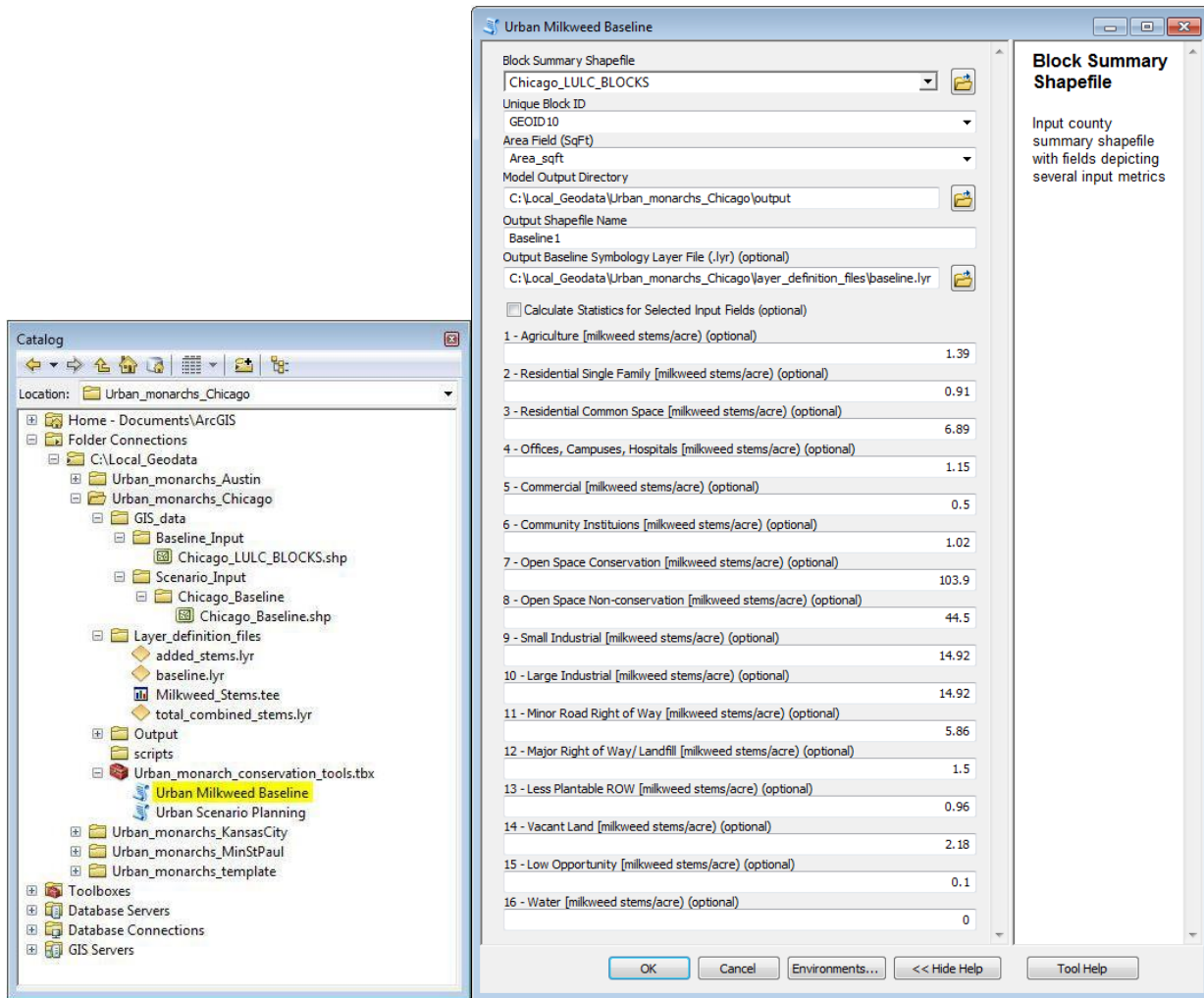
C3. In the following example, we will generate a new baseline for The Village of Glenview by running the tool on only the census blocks that intersect with Glenview. If you instead want to run a baseline for your entire dataset, than no selection process is needed and you can skip this step and the next one. In the image below, we added a boundary layer of Glenview (outlined in the thick gray). Click on any census tract after selecting the information tool . With the correct layer selected, you should see 16 input fields {LU01_GS, LU02_GS,...} that will be used to run the tool. The value in these fields indicates the amount of “grass/shrub” (in square feet) by land use category in each census tract. For a complete list of all of these fields, their definitions, and data types see **Appendix 2**. [Note: if you are following along using The Village of Glenview, we simplified the village boundary in the image below]



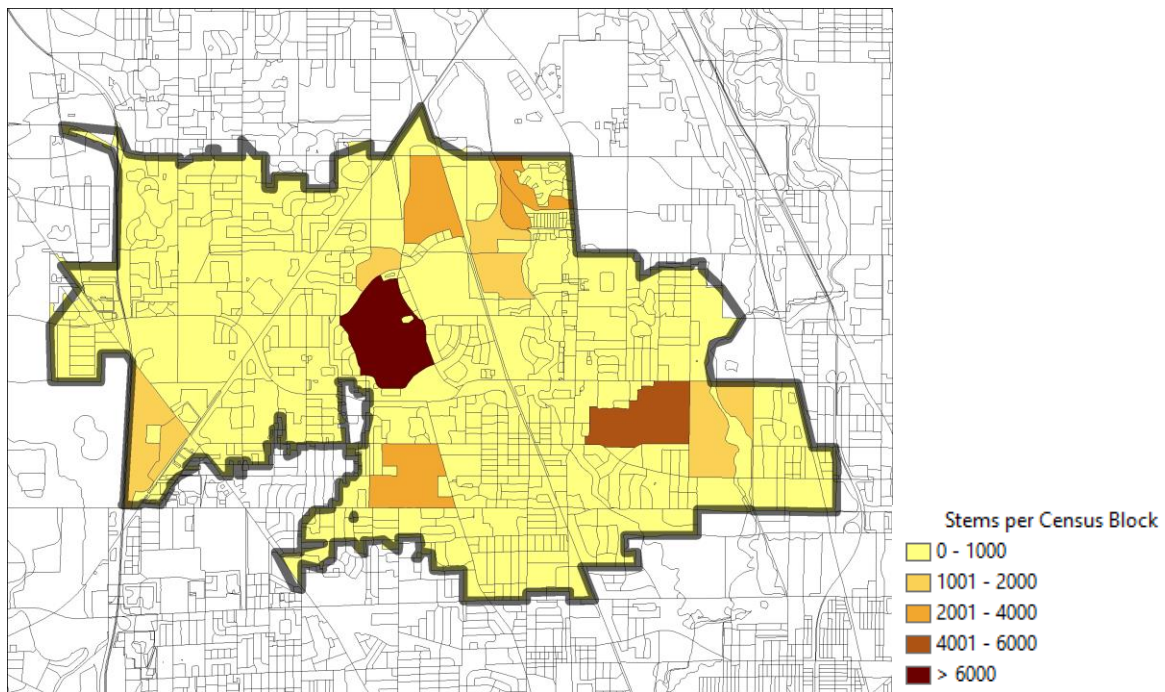
C4. **Select Census Blocks:** We want to run the *Baseline* tool on the Village of Glenview. From the *Select* menu we use **Select by Location** to select all census blocks from the **Chicago_LULC_BLOCKS** layer that **have their centroids in the source layer feature** using the Glenview boundary layer (**Glenview_muni**) as the *source layer* (left image below). The resulting selection is shown in the image on the right.



C5. We're ready to run the tool on the selected census blocks. Open **Catalog**, expand the *Urban_monarch_conservation_tools* toolbox, and double-click on the "Urban Milkweed Baseline" tool (left image below). In the tool dialog window (right image below), we need to select the *Block Summary Shapefile* which is the **Chicago_LULC_BLOCKS** layer with the selected census blocks in the image above. The tool pre-populates both the "Unique Block ID" as a unique record identifier (GEOID10), and the total Area Field (Area_SqFt) in square feet. The *Model Output Directory* is the location where the results will be stored. In the example below we use the "Output" folder, but you may want to store the results in the "Scenario_Input" folder if you plan on running the Scenario Planning tool afterwards. After providing a name for the output baseline, you can select an "output baseline symbology layer. A default "Baseline" layer file (baseline.lyr) is provided in the "Layer_definition_files" folder for the estimated baseline stems of milkweed. Checking the "calculate statistics" checkbox generates an additional tabular output file with summary statistics. The remaining numbered fields hold the estimated milkweed density values for the 16 land use classes. If you are running this tool from one of the customized toolsets, these fields will be prepopulated with the density values in **Appendix 1**. Users of the template toolset will need to supply add their own values based on local fieldwork (**Section E**) or by adopting density values from a similar geography for an approximation. Click on OK to run the tool.



C6. Output from the *Urban Milkweed Baseline* tool. This output could now be used as the input for the *Scenario Planning* tool (**Section B**).



Section D: Using the Template for Additional Metropolitan Areas

The following section describes how the template toolset can be applied to other metropolitan areas. This section take you through the process of how to prepare GIS data for use in the template tool. Users have a couple of options in preparing data for the template toolsets depending on if high-resolution¹ land cover data is available. The first option, is to estimate abundance based on plantable space within land use categories, and the second option is to estimate milkweed abundance more simply on a land use basis only. We expect that the first option will yield more precise estimates, but it requires high-resolution land cover data.

Data Requirements

1. Land Use
2. High Resolution Land Cover (optional)
3. Milkweed Density
4. Census Blocks

The required data listed above such as Land-Use data are generally available through regional planning agencies and county assessors offices, a good resources to check to see if your geography has land use data is the Wikipedia page for *Metropolitan Planning Organizations*, which includes links to all planning agencies in the United States. Optionally, high-resolution land cover data can be used to enhance the model, however, these data can be difficult to obtain and are not be available in some areas. US census blocks are used as the analysis units and summarized output layers from the tools. These are available for the entire United States on the US Census Bureau website (www.census.gov).

If you have high-resolution land cover you will need to complete **steps 1-4**, if you have land use data and no high-resolution land cover you will only need to complete **steps 2 & 4** in order to have a working model.

Step 1: Estimating Plantable Space

ESRI Tool/Extension: Reclassify (Spatial Analyst)

Each land cover dataset will usually have a number of classes that digitally represent what is on the ground. For example the Chicago high resolution land cover had 7 land cover classes. They included, tree canopy, grass/shrub, developed, bare soil and roads. In order to get plantable space you will first need to isolate the plantable space class in the high resolution land cover dataset.

To do this we will need to use the Reclassify Tool in the spatial analyst toolbox. Adding the raster to the input field, usually automatically populates the reclassification window, however if it does not, you can change the field you need to reclass by using the drop down in the “Reclass field” window and select the correct field to reclass. Once you have the reclassification field correctly populated you can now begin to change the old values to the new reclassification.

Since we only want to isolate the grass/shrub class we will need to change all the old values to ‘NoData’ except the grass/shrub class which we will change to ‘1’. Choose the path where the new raster will be stored and give the new raster a file name. You should also be sure to select “Change missing values to NoData” radial button. The result of this will give you a binary raster

that has grass/shrub classified as a '1' and all the other classes as 'NoData'. This raster will be used to reclassify the grass/shrub by land use.

Step 2: Land Use - Crosswalking

Land use datasets typically have more classes than are needed for our purposes, and it is because of this that we need to consolidate the land use classes into sixteen distinct categories. The generic template can only accommodate up to sixteen land use classes, you may still be able to prep the data with less than 16 classes but not more than 16 classes.

Initially the Chicago land use data had 60 classes, which were crosswalked into 16 classes based on expert opinions. We realize that many organizations will not have access to these experts, so it is suggested that the user consolidate the land use classes based on the parent or common categories of the land use data.

Original Land Use Class	New Land Use Class	New Land Use Class
Single Family Detached	Residential	1
Single Family Attached	Residential	1
Multifamily	Residential	1
Mobile Home Parks/Trailer Parks	Residential	1

For example the land use data in Chicago had individual classes for; Single-Family Detached, Single-Family Attached, Mobile Home Parks / Trailer Parks, Multi-family and Residential Common Open Space. Instead of using all these classes, it is recommended to consolidate them into a single common or parent class called Residential. You will also need to add a column to the attribute table, this field will be used for giving the consolidated land use classes a new unique class value. The same process should then be applied to the remaining classes.

Common Land Use Classes

- Agricultural
- Residential
- Commercial
- Institutional
- Industrial
- Transportation
- Utilities
- Open Space
- Vacant Lots

Step 3: Land Cover by Land Use

ESRI Tool/Extension: Extract by Mask (Spatial Analyst)

At this point in the manual you should have a binary raster of grass/shrub, which will be used as our plantable space, and/or a land use feature class that has been reclassified with no more than 16 classes. If you do not have high resolution land cover in your geography you may move on to step 4.

What we are doing in this step is taking the binary plantable space raster and assigning the land use classes to the grass/shrub land cover class. It should be noted that there are a number of ways to do this next step, but this was the most stable when processing the large land use and land cover datasets.

Taking the reclassified land use shapefile, convert the file to a raster layer by using the “Feature to Raster” geoprocessing tool found in the conversion tool box. The input will be your land use shapefile, the ‘field’ drop down should correspond to the field in the shapefile attribute table with the 16 consolidated land use classes and the output cell size should match the same cell size as the land cover dataset. Once that process has completed, may take a while depending on the computer’s processing speed, we can classify the plantable space raster by land use.

To do this we will need to use the “Extract by Mask” geoprocessing tool found in the Spatial Analyst toolbox. The input raster will be the recently created land use raster with the 16 consolidated classes and the input for the mask data will be the binary grass/shrub land cover raster.

This new raster should now have the land use value where ever there was grass/shrub value, which is the plantable space by land use.

Step 4: Census Blocks with plantable space by Land Use

ESRI Tool/Extension: Tabulate Area (Spatial Analyst)

- Make sure to use a projection with foot as the linear unit
- Do not delete the GEOID10 field
- Rename column headers (see appendix 2)
- Add area field, calculated in square feet for each census block

In the census block’s attribute table delete all columns except the GEOID field. This field is the unique identifier for the census block and contains additional information as well. If you want to aggregate to census tracts instead of blocks, having the GEOID field will enable you to do this as the it also contains the track ID which you can dissolve on if desired to. Additionally it also contains the county and state codes as well, again giving the GIS user the ability to aggregate based on different scales needed.

In order to get the total plantable space by land use in each of the census blocks, we will need to use the “Tabulate Area” tool in the Spatial Analyst tools. This tool will give us the total plantable space by land use for each of the census blocks. The input feature zone data will be the census blocks. Since each census block is a ‘zone’, under the drop down for the ‘Zone Field’ should be the GEOID field. We will be using this field to join up too so make sure to not delete this field out of the attribute table. The feature class data field will be plantable space by land use raster and the class field drop down should be the field with the consolidated land use classes. The processing cell size field can be left alone.

If you are working without high resolution land cover, you will need to use the reclassified Land Use shapefile as the input for the feature class file with the reclassified land use values as the class field.

The output of this tool will be a table that contains the plantable space by land use for each of the census blocks. Each row in the table is a census block and each column in the table is the area of the consolidated land use class. The final step will be joining the output table to the census shapefile attribute table. This will be the shapefile you will use to run both the baseline and future scenario planning tool.

In order for the tool to run the user will need to rename some of the field names in the output table. LU01_GS, LU02_GS...LU16_GS. These field names should correspond to your cross walked land use classes. If you do not have the same exact names for the field column the tool will not run. Again you can use less than the 16 land use classes but the tool is not able to process more than 16 classes. You should also be aware of the projection that your data frame is in when running the zonal stats tool. The tool converts square feet to acres when reporting the density values so you will need to use a data projection that has feet as the linear unit (e.g. state plane).

For more information about how the census block attribute table should look refer to **Appendix 2** to see what the required field are. Additionally if you want to change the default milkweed density values in the template tool please refer to the end of **Section C**.

Section E: Enhancing the Toolsets with Fieldwork

This section is for people who are either: 1) using the generic template, 2) want to improve the accuracy of tools by applying improved field estimates of milkweed densities, or 3) want to improve scenario modeling estimates. Our recommended approach for each is the same for *open space conservation*, and *open space recreation* land use categories (see “**natural areas sampling**” below), but will differ for sampling other land-use categories depending on the scale of the project area you want to sample (e.g. town, municipality, county, metro-region). At the metropolitan scale, we use “**metro-transect sampling**” for sampling across all land-use categories other than open space conservation and recreation (see below). The same or a similar approach can be used at the county-scale, such as a random selections of townships, census tracts or census blocks. At the town/ municipal-scale, a randomized selection of census blocks, or block-groups may be used, or comprehensive mapping may be reasonable. Field data “**sampling for scenario planning**” is the same at all scales (see below).

For users working in one of the four sampled metropolitan areas, be aware that since milkweed densities were averaged over the entire metropolitan landscape, they do not account well for localized variance, or the “social momentum” observed in some neighborhoods where native gardens and conservation practices are more prevalent. For this reason and other localized differences, it is advisable to conduct field work to obtain localized milkweed densities in your municipality or sub-area.

Fieldwork was conducted over the summer of 2016 in the four metropolitan pilot cities (Chicago, Minneapolis-St. Paul, Kansas City, and Austin). The purpose was to estimate the amount of existing milkweed in these metropolitan areas, and to estimate the amount of milkweed present in “exemplary” or “enhanced sites” for scenario planning. This sampling strategy is explained below. Small teams, typically 2-3 people in each municipality were deployed across randomized transect lines that spanned across the entire metropolitan area. Sampling across these transects were done using metro-transects, natural areas, and exemplary sites. Each are described below.

In order to understand the capacity cities have for increasing the amount of monarch butterfly habitat available for breeding and migrating adult butterflies, a “baseline” of milkweed densities must be established. For establishing the baseline, data is collected in two ways: 1) sampling random locations across the landscape, and 2) sampling larger natural areas where a more rigorous approach is necessary. These areas are treated differently for a few reasons: 1) we expect natural areas to have some of the highest densities of milkweed and we wanted to get a more accurate estimate by visiting more sites than we would hit randomly on the metro-transect lines, 2) sampling across larger natural areas will generally require field equipment and more time, 3) permission of the owner and often permits are required. Sampling across other land use categories can be done by relying on what is publicly visible from roads, sidewalks, and publically accessible areas. Areas that are not visible to the field team are marked as inaccessible.

Natural Areas Sampling

Sampling from natural areas establishes an average milkweed density that can be applied across all natural areas on a land use basis for *open space conservation* and *open space recreation* land use classes. Not only are natural areas important for monarchs, but they are also places where residents learn about native plants and native landscaping. The percent habitat in natural areas is determined by calculating the area of digitized milkweed habitat in proportion to the total plantable space on the entire site. Milkweed density is the total estimated stem count over the same area. When possible, a distinction should be made between natural areas in municipal parks with a primarily recreational mandate and natural areas with a primarily conservation mandate. The full sampling protocol for measuring milkweed density in natural areas can be found in *Protocols for Monitoring Urban Landscapes (Appendix 3)*.

Metro-Transect Sampling

A baseline for milkweed density is calculated using randomized sampling across the metropolitan area from the more densely populated areas to less populated areas. Sampling points are located approximately every 4-5 miles across “metro-transect” lines that span across the entire metropolitan area (**figure 1**). By visiting these sampling areas, data on habitat and milkweed can be collected across all consolidated land-use types. Typically these field visits take anywhere from 30 minutes to a maximum of 2 hours for each sampling area. This approach gathers the data that will be needed to determine milkweed densities and the proportion of greenspace typically allocated as gardens and habitat. Ultimately, these numbers are used to populate the model used for the monarch conservation planning tools. Differences may exist along the transect lines between some land-use categories in more populated areas compared with less populated areas. Clusters of intersecting US census blocks are used as the analysis zones for sampling. The figure below illustrates an example of metro-transect lines in the Chicago metropolitan area and data that was collecting by the field team in an urban and a rural area. Note the hashed out areas in the rural area, this indicates that this area was not surveyed by the field team and was removed from the analysis when calculating milkweed stem density.

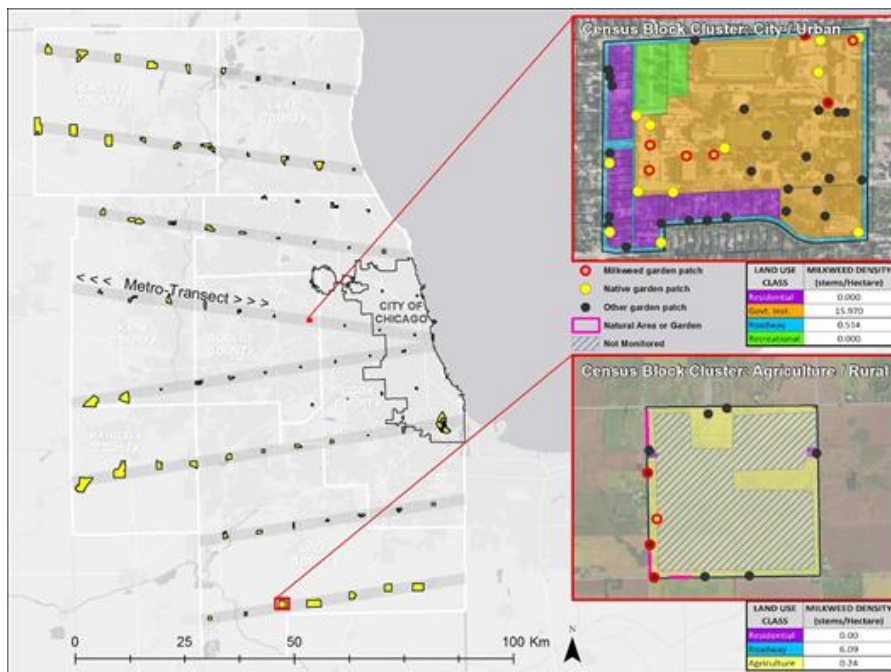


Figure 1. To establish a basis for milkweed and monarch butterfly habitat, “Metro-transect” lines are established across the city where field sampling occurs. These transect lines establish random sampling areas. Field data is compared with land-use categories to estimate the density of milkweed and monarch habitat across land-use categories for extrapolating to other areas across the region.

Metro-transect lines are a way of sampling randomly across land use classes along transect lines drawn across entire metropolitan areas. These lines are established in a GIS by following a few simple steps. First, download and display population density data. Display the data using standard deviations for population density. Second, bisect the highest density areas using one or more “skeleton” centerlines through the densest city center area(s). Third, decide how many transect lines your field team will have time to sample. Fourth, create linear “radial” lines that use the skeleton lines as their point of origin. So they pass from high population areas to low. After the radial lines are drawn, the first sampling point along the transect line is randomized at a distance of 0-4 miles from the point of origin. Next, segment or “dice” the transect lines every 5 miles from the point of origin.

Setting up the transect lines in this way accomplishes two goals: 1) it intentionally biases the amount of sampling in urban versus rural areas since we anticipate greater heterogeneity in populated areas compared to less populated areas.

Electronic Data Collection

In order to collect the data an ESRI Collector App was developed to facilitate field data collection.

Before sending out field team, sampling points are located every 4-5 miles across “metro-transect” lines that span across the entire metropolitan area. The census tract that the point falls in, is then selected in the GIS and all land use classes in that selected area are sampled to best of the field teams ability.

Typically these field visits take anywhere from 15 minutes to a maximum of 2 hours for each sampling area. This approach gathers the data that will be needed to determine milkweed densities and the proportion of greenspace typically allocated as gardens and habitat. Ultimately, these numbers are used to populate the baseline milkweed estimate, used for the monarch conservation planning tools.

Differences may exist along the transect lines between some land-use categories in more populated areas compared with less populated areas. US census blocks can be used to partition the metropolitan area into zones corresponding to high, medium and low population densities used for more advanced modeling techniques.

Enhanced Sites (Future Scenario Planning)

Enhanced sites are sites that have converted a proportion of land to native habitat. These example sites have higher milkweed densities when compared to the baseline milkweed densities and are used for in the future scenario planning tool.

There are a number of ways to identify these enhanced sites, one of those resources being the social survey and the respondents who have identified as having a site that they actively work on. The social survey allows willing respondents to give a geographic location of a site that they actively manage or have managed in the past along with an estimated amount of both milkweed and native plants.

Knowing these key players in monarch conservation can give social scientists insights into what drives these people as well as biological information about native plants and milkweed densities on these sites. These enhanced site densities values will then be used in the scenario planning tool as a way to inform users of the tool what impact these enhanced site densities can contribute under differing conversion scenarios.

Summary

As grasslands are converted to agriculture and agriculture becomes developed space, an all hands on deck approach will be needed for the continued conservation of the Monarch Butterfly. The tools and workflows described are the beginning steps in understanding how urban areas and small cities can contribute to Monarch Habitat

A possible limitation that users may encounter when trying to develop a tool for their own geography, is the availability of data. The foundation of the tool is based off of high-resolution land cover and Land Use data sets. The High Resolution land cover will probably be the most limiting to users, in which case it is advised that they instead use the gross area of the land use data per census blocks.

Most cities that have a population of 50,000 or more will have a land use dataset. If you are not sure if your city has these data, on Wikipedia you can search for the Metropolitan planning organization that is closest to your city. Even if your city is smaller than 50,000 it may still be included in the extent of your regional planning agency.

The milkweed density data that are used were specifically collected in the 4 pilot areas. It should be noted that these densities can vary drastically in other geographic areas. In order for the most accurate reporting of milkweed densities, baseline and future scenario planning, it is strongly encouraged that users sample milkweed densities that are specific in their area. Following the methods and using the generic tool template GIS users can quickly developed their own spatial model for their desired geography.

Appendix 1: Metropolitan Milkweed Densities on a Grass/Shrub Basis

Land Use Class	Twin Cities Milkweed Densities*	Chicago Milkweed Density	Kansas City Milkweed Densities	Austin Milkweed Densities	Average Milkweed Densities
Agriculture (1)	-	1.4	1.5	0.0	1.0
Residential Single Family and Mobile Home Parks (2)	30.0	0.9	0.0	0.6	7.9
Residential Development Common Space and Multifamily (3)	-	6.9	0.1	1.8	2.9
Office complexes, Campus, Medical Facilities and associate retention basins (4)	-	1.2	0.2	0.1	0.5
Commercial (5)	-	0.5	0.1	0.1	0.2
Community Institutions (6)	-	1.0	0.1	0.1	0.4
Open Space Conservation (7)	-	103.9	2.1	127.0	77.7
Open Space Non-conservation (8)	-	44.5	1.5	107.3	51.1
Small Industrial (9)	-	14.9	3.0	0.1	6.0
Large Industrial (10)	-	14.9	3.0	0.1	6.0
Minor ROW (11)	-	5.9	1.2	1.6	2.9
Major ROW/Landfill (12)	-	1.5	1.8	0.2	1.2
Less Plantable ROW (13)	-	1.0	0.1	0.1	0.4
Vacant Land without intact building / undeveloped (14)	-	2.2	5.1	0.1	2.5
Low Opportunity (15)	-	0.1	0.1	0.1	0.1
Water(16)	-	0.1	0.1	0.1	0.1

*Milkweed densities for the Minneapolis-Saint Paul customized toolbox uses densities from the Chicago Metropolitan area except for *Residential Single Family and Mobile Home Parks*

Appendix 2: Census Blocks Attribute Table Required Fields

Census Block Attribute Table		
Field*	Description	Data Type
GEOID10	Unique Identifier for the Census blocks	String
LU01_GS	Area (sqft) of Land Use Class	Long
LU02_GS	Area (sqft) of Land Use Class	Long
LU03_GS	Area (sqft) of Land Use Class	Long
LU04_GS	Area (sqft) of Land Use Class	Long
LU05_GS	Area (sqft) of Land Use Class	Long
LU06_GS	Area (sqft) of Land Use Class	Long
LU07_GS	Area (sqft) of Land Use Class	Long
LU08_GS	Area (sqft) of Land Use Class	Long
LU09_GS	Area (sqft) of Land Use Class	Long
LU10_GS	Area (sqft) of Land Use Class	Long
LU11_GS	Area (sqft) of Land Use Class	Long
LU12_GS	Area (sqft) of Land Use Class	Long
LU13_GS	Area (sqft) of Land Use Class	Long
LU14_GS	Area (sqft) of Land Use Class	Long
LU15_GS	Area (sqft) of Land Use Class	Long
LU16_GS	Area (sqft) of Land Use Class	Long
Area_sqft	Area calculated in Square Feet	Double

*These are required fields for the census block shapefile in order to get the geospatial tool to run properly.

Appendix 3 : Protocols for Monitoring Urban Landscapes*

*Methods developed by Kyle Kasten, Laura Lukens, and Karen Oberhauser (University of Minnesota)

Methods for Monitoring Urban Open Spaces

Methods for Pre-screening Sites

Sites should be pre-screened using ArcMAP 10, Google Earth, or some other satellite imaging program in order to determine whether the plot meets the criteria for a site visit. Pre-screening criteria includes:

- Sites must be located in the Twin Cities Metro
- Site must appear "green" (i.e. not paved over)
 - Size larger than 0.25 acres (after resizing to exclude roads or other development if originally included in shapefile)

Methods for Preliminary Site Quality Assessments

During this assessment, the site is quickly evaluated to determine whether the site will be intensively monitored. During this visit, record information about milkweed, nectar plants, and percentage mowed according to the instructions below. Selection criteria includes:

- One or more milkweed plants present within site boundaries
- Size is still larger than 0.25 acres after mapping boundaries with GPS
- Legal accessibility (i.e. areas where there are "No Trespassing" signs will be excluded)

If the site meets the criteria to be intensively monitored, walk the boundaries with handheld GPS in order to obtain plot boundaries.

Data recording instructions

Record the site ID, size class, date, and your initials when beginning the assessment.

Estimate

the percent of the site that is covered with mowed lawn. Count the number of milkweed plants present by species within the site boundaries and list as one of the following categories: <10, 10-100, >100. Monitor the milkweed plants you encounter for monarch eggs and larvae. Record this information in the appropriate rows. Note the presence of blooming nectar plant species by recording the species acronym under the column "Forb species".

A. Plots Smaller than 0.5 ac:

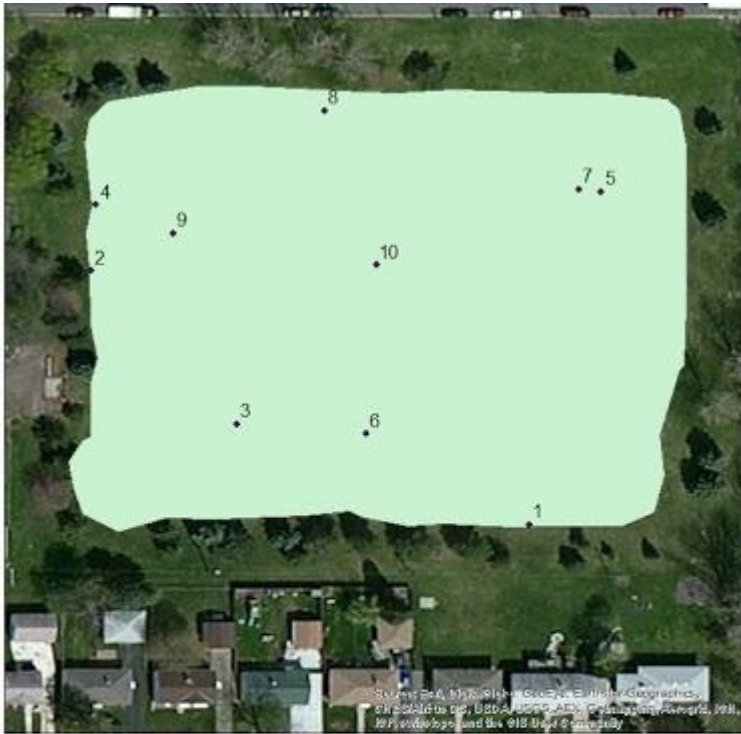
If a site is smaller than 0.5 acres, monitor blooming nectar plants, milkweed, and monarchs comprehensively, **without using subplots**. To do this, use **Datasheet 4: Meandering Walk and Small Sites**. Measure and report the area of the site and record the nectar plant species present and the number of milkweed plants and any monarch eggs or larvae. Use

Datasheet 3: Adult Monarch Observations to note any adult monarch sightings while monitoring (excluding the column for SP #).

B. Plots Larger than 0.5 ac:

Create plots maps

Before sampling, use a handheld GPS unit to obtain site boundaries. Using this outline, create a site map that contains a series of randomly generated points and the site boundaries (Figure 1). Sampling will begin at the coordinates of point 1, and proceed until 6 points have been sampled. A new set of points should be randomly generated for each sequential visit.



Site ID: 21

OBJECTID*	x_coord	y_coord
1	-93.020963	44.965464
2	-93.021875	44.966049
3	-93.021538	44.965695
4	-93.021862	44.966201
5	-93.020697	44.966232
6	-93.021238	44.965673
7	-93.02075	44.966238
8	-93.021335	44.966419
9	-93.021685	44.966135
10	-93.021216	44.966062

Figure 1. Example of map used during sampling. Maps consist of 10 randomly generated points with assigned coordinates, the plot ID, and plot boundaries (created using ArcMap 10).

Field Methods

1. Record a start time when leaving the vehicle with your gear and an end time when completing the protocol. Take a photograph of the site before monitoring, trying to capture all areas of the plot.
2. Using a GPS locate the first randomly generated point within the site.

3. Position the first stake of the subplot at point 1 (Figure 2). This will be the southwest corner of the subplot. Place the remaining three stakes 5 m apart at 90 degree angles to form the corners of the square subplot (Figure 2). Extend the paracord between the stakes to form the boundaries of the subplot. The frame should be positioned so that the rope on the left side of quadrants 1 and 3 should be aligned along a Northward bearing.

- Note: if point 1 is located near a boundary such that setting the plot would extend out of the site, rotate the plot 180 degrees. This would mean that the first stake is now the Northeast corner. Proceed to set up the remaining plot corners.
- Note: woody areas that are too dense to walk through or that prevent understory growth will not be monitored. In such cases, skip the inaccessible point, and proceed to the next randomly generated point within the site.

4. Within each quadrant of the subplot, record information about nectar plants, milkweed, and monarch eggs and larvae as detailed below.

5. Locate and walk to the second randomly generated point and repeat steps 3-4. Continue these steps until six plots have been sampled.

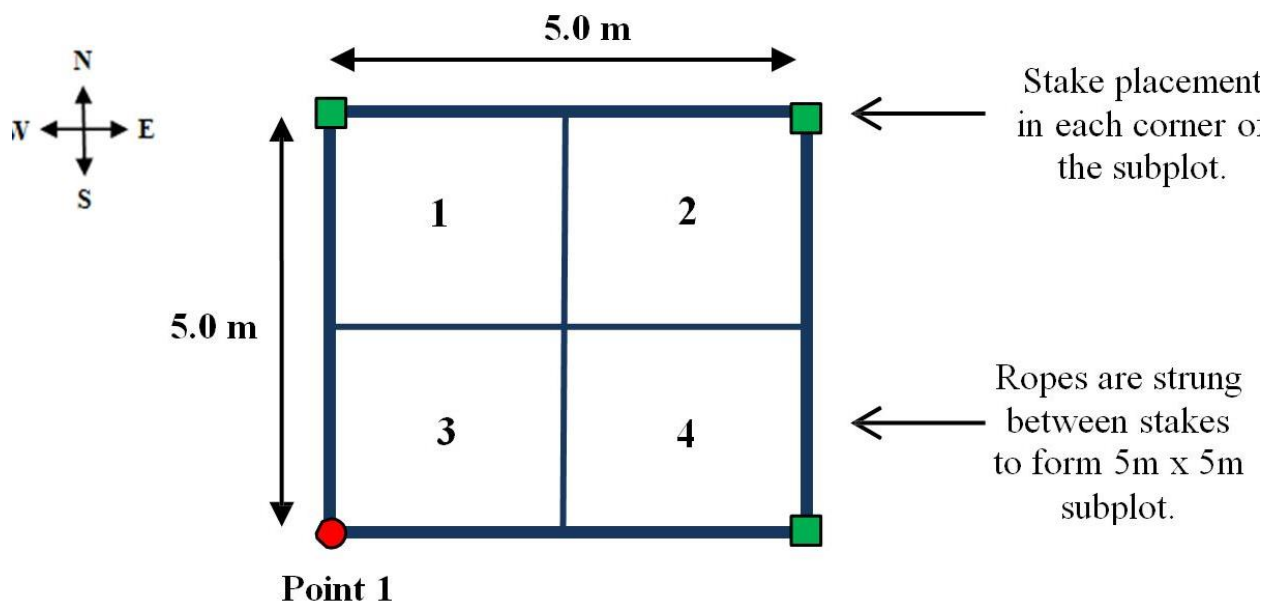


Figure 2. Sampling subplots are constructed using four metal garden stakes with lightweight paracord strung between each. The subplots measure 5.0 m by 5.0 m (25.0 m²) and are divided into 4 quadrants. When placing the plot frame, the subdivided count should always be started with the Southwest corner of the plot at random point 1 (red sphere). Each stake should be placed 5 m apart in each corner to form the square plot (green squares). The frame should be positioned so that the side of quadrants 1 and 3 should be aligned along a Northward bearing.

When to skip a subplot

If a subplot contains obviously incorrect strata or an impediment not detected by remote sensing (such as a stream or a recently tilled area), skip that subplot. Note plots skipped and

the reason why in the notes section of Datasheet 2: Nectar Plant Frequency. **Only disqualify sections of the plot under extreme and obvious situations so as not introduce bias or potentially invalidate the plot for use in the random draw.**

Use the following method when skipping a subplot. If you disqualified subplots in the plot's first 6, then continue sampling until you reach 6 qualified subplots. We suggest generating more than 6 randomly generated points in order to account for ones that are unable to be sampled.

Data Recording Instructions

Datasheet 1:

Part A: Milkweed density. For each 5.0 m x 5.0 m subplot, record the number of plants and stems of each milkweed species on Datasheet 1: Milkweed Count and Larvae. Only record information about stems rooted within the subplot, even if the plant includes stems out of the plot. If a milkweed plant is blooming, record it on Datasheet 2: Nectar Plant Frequency, and again on Datasheet 1: Milkweed Count and Larvae; you are treating the nectar and hostplant functions of milkweed separately.

Part B: Monarch egg and larva density. You will search the milkweed plants in the subplots for monarch eggs and larvae. Search each milkweed that you encounter in the 5.0 x 5.0 m subplot for monarch eggs and larvae. Record the number of eggs and larvae (identified to instar) that you see on the milkweed and the corresponding plot on Datasheet 1: Milkweed Counts and Larvae. Always record the number of milkweed plants (and stems) that you examine. The result will be an estimate of monarch density at the site, calculated as a proportion of milkweed plants with monarchs.

Datasheet 2: Nectar plant relative abundance. Starting with the quadrant 1 in the measurement frame (Figure 1), record the species acronym for plants with blooming flowers on Datasheet 2: Nectar Plant Frequency. Record blooming nectar plant species as you find them throughout the remaining quadrants. Record each species in each area it occurs, as follows: in the appropriate column for a given subplot, make a check mark for species found in that particular quadrant of the subplot. If a species was found in all quadrants of subplot 1, write a check mark for each column (1, 2, 3, and 4) underneath SP-1. Leave the space blank for quadrants where the species was not present.

Datasheets 3: Adult monarch observations. During sampling, record any adult monarch sightings on Datasheet 3: Adult Monarch Observations. If the adult monarch was within a subplot being sampled, record the subplot number. Also note the approximate distance from you, the behavior (F = flying, R = resting, O = ovipositing, M = mating, N = nectaring), the nectar plant species acronym if nectaring, and any other relevant information.

Datasheet 4: Meandering walk. If a more complete list of nectar and milkweed species is desired from a site, a meandering walk can be added and performed after sampling is completed. During the walk, record any additional blooming nectar plants or milkweed species. Search additional milkweed plants for monarch eggs and larvae.

Appendix 4 : Data sources for pilot cities

Chicago:

Land Use Inventory for Northeast Illinois - 2010

Source

Chicago Metropolitan Agency for Planning

- <https://datahub.cmap.illinois.gov/group/land-use-inventories>

Summary

The Land Use Inventory for Northeastern Illinois is produced by the Chicago Metropolitan Agency for Planning (CMAP). Identification of land use in the seven-county region of northeast Illinois serves in CMAP's development of long-range population, household and employment forecasts in support of the comprehensive planning efforts. Additionally, agency planners and analysts frequently use Inventory for local technical assistance, watershed planning, and policy analyses. Counties, municipalities, transportation agencies, universities, developers, and conservation groups also make use of these data.

High-Resolution Land Cover, NE Illinois and NW Indiana, 2010

Source

University of Vermont's Spatial Analysis Laboratory (UVM-SAL), United States Department of Agriculture - Forest Service (USDA-FS)

- <https://datahub.cmap.illinois.gov/dataset/high-resolution-land-cover-ne-illinois-and-nw-indiana-2010>

Summary

This dataset was developed as part of the Urban Tree Canopy (UTC) Assessment for the 7-County CMAP Region and the 3 NW Indiana Counties of Lake, Porter, and LaPorte. The dataset represents a 'top down' mapping perspective in which tree canopy overhanging other features is assigned to the tree canopy class. At the time of its creation this dataset represents the most detailed and accurate land cover dataset for the area.

This assessment was completed by the University of Vermont's Spatial Analysis Laboratory with funding the USDA Forest Service Northern Research Station. The methods used were developed by the University of Vermont Spatial Analysis Laboratory with funding from the USDA Forest Service. Tree canopy assessments have been conducted for numerous communities throughout the U.S. where the results have been instrumental in helping to establishing tree canopy goals.

Austin:**Land Use Inventory for Austin Texas - 2014****Source**

City of Austin Planning and Development Review Department

- ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html

Summary

The land inventory is based on several sources. Information is collected only in the City of Austin's Full, Limited Purpose, and Extra-territorial jurisdictions, and not entire counties. The polygon geography is taken from appraisal district parcel layers. A land use inventory is performed by classifying land according to a coding system that reflects the primary improvements (buildings or structures) on each parcel. Most of the land use information is attached through a GIS Union from past land use inventories. Undeveloped parcels are checked against building permit, aerials, and appraisal records, generally collected during the fall of the previous year, or when data was made available.

Remaining Pervious Cover 2013**Source**

City of Austin Enterprise Geospatial Services, Sanborn Mapping Company

- ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html

Summary

Remaining pervious features are created from heads up digitizing using 2012/2013 Orthoimagery and 2012 Lidar where Orthoimagery is not available. Orthoimagery collected by Sanborn Mapping Company for the GeoMap consortium. The source imagery used was 6-inch, natural color with an accuracy; accuracy is based on ground control and DEM data. The accuracy statement does not apply to vertical surface features, such as structures, appearing in the digital orthophotography due to inherent lean. Remaining pervious features were captured using heads up digitizing methods against the COA supplied 2012/2013 orthoimagery and 2012 Lidar collection series.

Tree Canopy - 2010**Source**

City of Austin Watershed Protection Department Policy & Planning

- ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html

Summary

Dataset created to depict approximate 2010 tree canopy cover for greater Austin, Texas area. The 2010 Tree canopy GIS layer was derived from 4 band, 1 M resolution, Color Infrared (CIR), 2010 NAIP aerial imagery, using supervised image classification techniques. The National Agriculture Imagery Program (NAIP) acquires aerial imagery during the agricultural growing seasons in the continental U.S. NAIP is administered by the USDA's Farm Service Agency (FSA) through the Aerial Photography Field Office in Salt Lake City. This "leaf-on" imagery is used as a base layer for GIS programs in FSA's County Service Centers, and is used to maintain the Common Land Unit (CLU) boundaries.

Twin Cities:**Regional Planned Land Use - Twin Cities Metropolitan Area - 2016****Source**

Twin Cities Metropolitan Council

- <https://gisdata.mn.gov/organization/us-mn-state-metc>

Summary

The Metropolitan Council routinely compiles individual land use plans and plan amendments from communities within the seven-county Twin Cities metropolitan area into a single regional data layer. A principal goal of the Regional Planned Land Use dataset is to allow users to view, analyze and display planned land use data for anywhere in the seven county metropolitan area with a consistent land use classification scheme. The Metropolitan Council uses the Regional Planned Land Use (PLU) data to help monitor growth and plan for regional services such as regional parks, transit service, and wastewater collection and treatment.

TCMA 1-Meter Land Cover Classification - 2016**Source**

Remote Sensing and Geospatial Analysis Laboratory, University of Minnesota - Version 1

- <https://gisdata.mn.gov/dataset/base-landcover-twincities>

Summary

A high-resolution (1-meter) land cover classification raster dataset was completed for three different geographic areas in Minnesota: Duluth, Rochester, and the seven-county Twin Cities Metropolitan area. This classification was created using high-resolution multispectral National Agriculture Imagery Program (NAIP) leaf-on imagery (2015), spring leaf-off imagery (2011-2014), Multispectral derived indices, LiDAR data, LiDAR derived products, and other thematic ancillary data including the updated National Wetlands Inventory, LiDAR building footprints, airport, OpenStreetMap roads and railroads centerlines. These data sets were integrated using an Object-Based Image Analysis (OBIA) approach to classify 12 land cover classes: Deciduous Tree Canopy, Coniferous Tree Canopy, Buildings, Bare Soil, other Paved surface, Extraction, Row Crop, Grass/Shrub, Lakes, Rivers, Emergent Wetland, Forest and Shrub Wetland.

Kansas City:

2013 Kansas City Regional Land Cover classification

Source

Mid-America Regional Council (MARC), Applied Ecological Services (AES)

- <http://www.marc.org/Home>

Summary

2012 Kansas City Regional Land Cover classification of Johnson, Leavenworth, Miami and Wyandotte Counties in Kansas, and Cass, Clay, Jackson, Platte, and Ray Counties in Missouri. Provide an assessment of the land cover within the Kansas City metro region to support regional and local planning efforts.

2012 Kansas City Regional Land Use

Source

Mid-America Regional Council (MARC)

- <http://www.marc.org/Home>

Summary

2012 Kansas City Regional Land Use classification of Johnson, Leavenworth, Miami and Wyandotte Counties in Kansas, and Cass, Clay, Jackson, Platte, and Ray Counties in Missouri. Provide an assessment of the land cover within the Kansas City metro region to support regional and local planning efforts