Prioritizing Land with GIS for Environmental Quality Incentives Program (EQIP) Funding
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APPENDIX: GIS Application
This exercise will guide you through the use of a Spatial Multiple Criteria Decision Analysis (SMCDA) model developed in ModelBuilder. The multi-component tool will then be used to select and rank applications for EQIP programs based on your selection criteria. Additional data is provided for expanding and modifying the input data and selection criteria so students can build their own model with unique selection rankings.

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1. Setting up files and directories

To begin the exercise, create a new folder labeled “SMCDA_EQIP” in the “GIS4Cons” folder in C: on the computer, and copy the data in the “ToolData” folder (CD:\SMCDA_EQIP\ToolData) and the “AppSelect” Toolbox in (CD:\SMCDA_EQIP) to this folder. The ToolData folder contains additional folders Project_Input, Project_Outputs and Scratch. The 2005 Indiana Environmental Quality Incentives Program resource concerns hierarchy and weights are included as shape files in the Project_Input folder as described in Table 11.1. The decision matrix (Figure 11.1 from the chapter) is maintained in ModelBuilder, supplemented with each application’s spatial location. This data set also includes other required information such as project cost. The “AppSelect” toolbox is in the main directory and contains the selection tools for this exercise.

Table 11.1. Indiana Resource concern files and 25 sample EQIP applications saved in C:\Chapter11\ToolData\Project_INPUT folder and used as model inputs. See hierarchy in Figure 1 in the chapter.

<table>
<thead>
<tr>
<th>National Priority</th>
<th>Indiana Resource Concern</th>
<th>Points</th>
<th>File Name</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td>Surface Water</td>
<td>10</td>
<td>surwater.shp</td>
<td>Statewide</td>
</tr>
<tr>
<td></td>
<td>Ground Water</td>
<td>10</td>
<td>grdwater.shp</td>
<td>Primarily southern IN</td>
</tr>
<tr>
<td></td>
<td>Lakes</td>
<td>10</td>
<td>lks.shp</td>
<td>Small, scattered throughout</td>
</tr>
<tr>
<td>Air Quality</td>
<td>Air Quality</td>
<td>15</td>
<td>air.shp</td>
<td>Urban areas</td>
</tr>
<tr>
<td>Soil Erosion</td>
<td>Soil Condition</td>
<td></td>
<td>soil.shp</td>
<td>Scattered, mid-state</td>
</tr>
</tbody>
</table>

### Sample Applications

<table>
<thead>
<tr>
<th>Species at Risk</th>
<th>6.25</th>
<th>Shapefile</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Aquatic Habitat</td>
<td></td>
<td>aq_hab.shp</td>
<td>Lakes, streams, rivers, adjacent areas</td>
</tr>
<tr>
<td>Critical Woodland Habitat</td>
<td></td>
<td>wood_hab.shp</td>
<td>Forests, primarily southern IN</td>
</tr>
<tr>
<td>Critical Grassland Habitat</td>
<td></td>
<td>grs_hab.shp</td>
<td>Scattered throughout</td>
</tr>
<tr>
<td>Critical Wetland Habitat</td>
<td></td>
<td>wet_hab.shp</td>
<td>Scattered near aquatic</td>
</tr>
</tbody>
</table>

2. Setting up the GIS

Open a blank map in ArcGIS, and set the home directory as C:\GIS4Cons\SMCDA_EQIP or other directory where the exercise data files and toolbox are saved. Expand the ToolData folder, and Project_Input subfolder. The resource concern maps indicate the spatial distributions of environmental problems and resources in Indiana. The EQIP application file contains the spatial locations of sample applications and related tabular data. Add the shape files to the blank map and explore each to identify areas of environmental problems and resources in Indiana (Figure 11.1). Individual maps are also presented in Figure 11.2 in the chapter.

![Figure 11.1. Resource concern maps for Indiana.](image)

3. Model development in ModelBuilder

ModelBuilder is a rich, flexible, powerful tool that allows us to make a working version of our SMCDA model. The ModelBuilder flow scheme is outlined in figure 11.2 under three main categories: input, process, and output. The input element stores initial data and supplementary information, the process element fulfills the computing needs of the user, and the output element organizes and concludes the analysis.

![ModelBuilder flow scheme](image)

In this portion, you will use an application selection tool that has been built in ModelBuilder. For more information on building a selection tool in ModelBuilder, refer to Mueller et al., Chapter 2 and Lee, Chapter 10. The basic procedures in ModelBuilder introduced in those chapters can then be applied to any other national or local priorities to develop selection criteria and build application selection tools to rank those priorities.

The complete working version of the ModelBuilder EQIP SMCDA is shown in figure 11.3. This is a complex, multi-step SMCDA that integrates all of the national priorities and state-selected resource concerns into one selection process that also incorporates expense. The input element of ModelBuilder stores the program’s criteria, weights, outcomes, and applications. The first input data set, identified in step 1 of figure 11.3, includes the resource concerns in federal conservation programs described in Table 11.1, which are used to assess importance of program objectives. In addition, the weights of these resource concerns are manually entered by the user and automatically saved with other data in the ModelBuilder application selection tool. Total points distributed among the resource concerns should sum to 100.
Figure 11.3. Overview of the 2005 Indiana Environmental Quality Incentives Program ModelBuilder diagram.

4. Exploring the SMCDA model

The complete SMCDA model is comprised of multiple steps and subtools. The model will be demonstrated by first looking at the individual steps, and then exploring the entire model. Expand the AppSelect toolbox in ArcGIS (Figure 11.4) to show the model application and intermediate models (Figure 11.4).

Figure 11.4. AppSelect Toolbox with associated selection tools.

a. Add resource concern weight field.

The **Water** national priority includes lakes, groundwater and surface water resource concerns in Indiana. To explore the selection tool, right click on the ‘Water’ ModelBuilder in the AppSelect toolbox, and select edit. This will open a window showing the ModelBuilder steps (Figure 11.5). The first step in the analysis adds a column (AddField) to each resource concern that will hold the relative weight (*_weight) of that concern. The relative weight is then added (CalculateField), and the resource concerns are then grouped (Union_water) into national priority concerns. The inputs to the model are labeled “P” (lks.shp, grdwater.shp, lakes_weight, etc.). To label a model as a parameter, right click and select “Model Parameter”. To explore any step in the ‘Water’ tool, right click and open.

![Figure 11.5. Water selection tool outlining the initial steps in the SMCDA.](image)

Once you have familiarized yourself with the steps involved in the ‘Water’ subtool, validate the tool by clicking the check mark on the toolbar, or selecting Validate in the Model window. Run the tool, and note the grey shadow that now appears after successful model run. Close the ModelBuilder window, and expand the Scratch subfolder. Add the newly created Water_union shapefile to the map, and explore its properties by opening the Attributes table. Note that an additional field has been added to the input shapefiles (e.g. ‘surut’ to ‘surwater.shp’) and contains a weighting factor.

Familiarize yourself with the initial steps in the SMCDA for each of the national priorities (‘Air’, ‘Habitat’, ‘Soil’ and ‘Water’) by opening them as above using Right Click/Edit, Validate and Run each of the subtools. Alternatively, instead of running each subtool from the ModelBuilder window, they can be run by opening them (Figure 11.5) and selecting OK. This adds the new weighted resource concern map to the map. Note the shape files used as input by each tool, the output files, and weighting factors (Figure 11.5). These weighting factors can be changed in the dialog box, but must all add to 100 for all resource concerns. Close the dialog box.
upon completion of model run.

![Figure 11.5. Initial selection tool in the SMCDA model for Water resource concern.](image)

Completion of these initial model runs (Steps 1, 2 and 3 of Figure 11.3) yields four weighted, combined files of the national priorities, air_union.shp, habitat_union.shp, soil_union.shp and water_union.shp to the Scratch subfolder.

As described previously, the resource concern maps are constraint maps. Benefits are only generated and scored if practices are applied in the environmentally sensitive areas. They are initially stored in spatial format with no identified information. Since ModelBuilder maintains both spatial and tabular information, before they are employed in estimating scores in step 2, Boolean variables are assigned as tabular information to restrain score assignment (figure 11.6). Environmentally sensitive areas are identified with “1” to ensure preserving the outcomes when resource concern is detected. Then, in step 3, the weight of each resource concern is multiplied with the Boolean variables assigned in step 2 to create weighted constraint maps (figure 11.6). This is included in the process component since it addresses one of the computing needs of the model.
b. Combining resource concerns and scoring.

In the next step, these four priorities are then combined into one weighted file of resource concerns. Open the ‘Union Concerns’ model using edit. Validate and Run the model. This will generate a file of 279 entries, representing the combined resource concerns and locations.

Open the ‘Dissolve Resource Concerns’ model, explore using Edit. Run the model. This will generate a file of 37 weighted polygons (open Attribute table to explore). Add the new map Concern Dissolve to the display.

The process component in ModelBuilder secures all necessary computations to calculate the application score and generate the concentrated resource concern map. Next (figure 11.7), we broadened the process by preparing a weighted resource concerns map of the 2005 Indiana EQIP selection process.
Figure 11.7. 2005 Indiana Environmental Quality Incentives Program ModelBuilder diagram weighted resource concerns map preparation.

c. Creating final weighted applications with state benefits.

Next, edit the ‘Score/DecisionRule’ tool in ModelBuilder. Note the two subtools ‘Calculate Score’ and ‘Decision Rule’. Open these tools from the ‘Score/DecisionRule’ window to explore their actions.

The resource concern maps created above are intersected with sample EQIP application parcels (figure 11.8). These outcome scores are weighted based on the Boolean variable information stored with concern maps (figure 11.9). The application score is obtained by linearly summing up those weighted outcomes. These scores also indicate the environmental benefits that applications provide.

Figure 11.8. 2005 Indiana Environmental Quality Incentives Program ModelBuilder diagram applications are intersected with resource concerns map.

Figure 11.9. 2005 Indiana Environmental Quality Incentives Program ModelBuilder diagram outcome scores are multiplied with Boolean variables and scores are calculated.

Run the model ‘Score/DecisionRule’. This adds the state benefits to the 25 hypothetical...
applications and creates a new shapefile ‘eqip_final2.shp’ containing the EQIP applications, now with weightings and benefits. Open the attribute table of ‘eqip_final2.shp’ to explore these values.

Open the Layer Properties of the ‘eqip_final2.shp model to replot the data. For example, plot “scorefinal” value using Graduated Symbols and 10 classes (Figure 11.10). Application sites with greater benefits to the national priorities will be represented as larger circles.

Figure 11.10. Final scores of EQIP applications.

d. Running the complete model.

Now that you are familiar with the components of the SMCDA model, you can run the integrated model. Edit the ‘SMCDA_Model’ and verify that it is composed of all individual components explored above. Validate and Run the model from the edit window or by opening it. Close the window and dialog box, and note that four new shape files have been added to the Scratch subfolder. These files correspond to those created in a) above. Two new files have been added to the Project_Outputs subfolder as well, representing b) and c) above.

Now that you have the complete model, and understand the components that enter into the calculations, you can modify the computation by adding new resource concerns, modifying resource concerns and how they contribute to the national priorities, and changing the relative weights of concerns. Be sure to delete intermediate files in the Scratch folder between model runs.

5. Testing the SMCDA model

Double click on the ‘SMCDA_Model’ application selection link to open the tool dialog box (Figure 11.11). The input weights can be entered for each resource concern. In 2005, soil condition and wind erosion objectives (soil_condition_weight and wind_erosion_weight) are mutually exclusive concerns. Therefore, these two concerns are overlaid and share the same
weighting points. In the model dialog box, the same weighing points should be entered for these two concerns and counted only once in total point calculation. A help screen on the dialog box warns the user to verify that the weights sum to 100. Objective weights can be changed directly in the input box, or by accessing the calculator on the right side of each box. The last input data set includes program applications and their outcome scores against each criterion.

![ModelBuilder application selection tool dialog box for the SMCDA_Model](image)

**Figure 11.11.** The ModelBuilder application selection tool dialog box for the SMCDA_Model.

Output files from a model run are automatically saved in the project output folder: (Chapter11\ToolData\Project_Output). Model outputs include “eqip_final2.shp” which contains the practice scores, the application scores, that is the multiplication of practice scores with resource concern Boolean variables, state benefits scores, total benefit scores, benefit cost ratios and total scores; “Concern_Union.shp” which contains weighted Boolean scores by each resource concern; and “Concern_Dissolve.shp” which contains aggregated and summed weights of resource concerns that indicates the environmentally targeting areas.

- The model creates five intermediate files which are saved in “C:\CHAPTER11\ToolData\Scratch” folder.
- The example project folder (CHAPTER11\Project_Example\EQIP_final_distributions.mxd) contains the outputs from a Indiana 2005 EQIP Application Selection run: eqip_final.shp and concern_dissolved.shp calculated using 2005 Indiana EQIP weights.

The sample output of a model run and ArcMap project is included in “Project_Example.”

6. Modifying or Creating a New ModelBuilder Application Selection Tool
   The existing Indiana ModelBuilder Application Selection Tool has considerable flexibility that can be used to conduct sensitivity analyses or modify the existing EQIP program.
   - Sensitivity Analysis – Modification of the weights of resource concerns: From the dialog box, the weight of each resource concern could be changed to determine if certain resource concerns significantly change the ranking and selection of applications for funding in Indiana’s EQIP program.
   - Sensitivity Analysis – Replacement of existing resource concern maps with more detailed maps: Are binary resource concern maps sufficient? Will more detailed resource concern maps significantly change the ranking and selection of applications for funding? These questions can be answered by replacing the existing maps with more detailed maps and running ModelBuilder again for the Indiana EQIP program.
   - Sensitivity Analysis – Replacement of qualitative practice scores with quantitative scores: A major criticism of EQIP has been the use of expert opinion and a limited number of categories (0 to 4). More categories could be added and the Application Selection Tool rerun to determine if ranking and selection of applications changed significantly for the Indiana 2005 EQIP program. If quantitative impacts such as tons of soil saved are available for conservation practices, the qualitative rankings could be replaced. Again, a sensitivity analysis could be conducted to determine if the quantitative variables improved program performance. For both of these analyses, you would need to update the tabular data of EQIP applications.
   - Update modifications: If the program does not change from year to year, but the basic data does, updating is relatively straightforward. New applications could be added or some applications could be deleted from EQIP application file. The local scores, costs and practice scores in the tabular table of EQIP application data layer could be replaced easily. For example, costs can be updated by replacing the existing “TotalCost” field with the new data.

   The ModelBuilder Application Selection Tool is extremely flexible and can be modified to fit EQIP programs in other states or new conservation programs. The key concept here is that the tool provides the basic framework and code that the user can then expand, modify or contract to build a new state tool. Once it is built, all of the above sensitivity analyses can be conducted.
   - Modify the existing Indiana EQIP tool for use by other states: States have the flexibility to keep the same resource concern definitions but just modify spatial designation of the maps; or they can introduce new resource concerns or delete some of them. Additionally, if they desire, they can introduce new decision rules by editing the tool.
   - Modify the existing Indiana EQIP tool to use in a new conservation program: The resource concern description could be different for new conservation programs. The tool could be edited, by keeping the main structure the same, to fit the requirements of the new programs.

Model Execution Concerns
   - Model failure can occur if the model has been executed and existing files are not removed. The files in the Scratch folder (C:\CHAPTER11 \ToolData\Scratch) and Output...
folder (C:\CHAPTER11\ToolData\Project_Outputs) should be deleted. Also, the weighted Boolean variables created for each resource concern should be removed. In order to avoid this problem, you may also select the “overwrite the outputs of geoprocessing operations” check box from Geoprocessing options. This controls whether tools automatically overwrite any existing output when run. When it is checked, you receive a warning before tool execution that the output exists, but the tool executes and overwrites the output dataset. With this option off, existing outputs are not overwritten, and the tool displays an error, preventing you from executing the tool.

- For installation of the data and project in a hard drive, the entire directory “ToolData” (\CHAPTER11\ToolData) and the Toolbox (\CHAPTER11) should be copied to the hard drive directory before the model is run. Errors can result if the model output is pointed to the incorrect directory. If files are not generated as expected, check intermediate model steps (Edit) to be sure files are saved correctly.
- The model execution from the CD or remote site is limited as output must be written to a writable drive. Files must be copied to the computer for running the model.