

Spatial Analysis 6.

Spatial decision support

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Abstract

This module aims to deepen this knowledge, to integrate the lessons learned, and to provide experiences in the field of spatial decision support. The module is giving an overview of the techniques of stakeholder's involvement and the process of spatial decision support. We will go through the decision support process of a waste disposal site selection in a GIS environment. The module briefly describes the use of the ArcGIS ModelBuilder, which can be applied in the case study.

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Table of Contents

6. Spatial decision support	1
1. 6.1 Introduction	1
2. 6.2 Basic Concepts	1
2.1. 6.2.1 Brainstorming	1
2.2. 6.2.2 The nominal group technique	2
2.3. 6.2.3 Mind mapping	2
2.4. 6.2.4 Decision model	3
2.5. 6.2.5 ArcGIS ModelBuilder	4
3. 6.3 Site selection case study	6
4. 6.4 Decision support by GIS	7
5. 6.5 Summary	14

Chapter 6. Spatial decision support

1. 6.1 Introduction

In the previous modules, our goal was to introduce step by step, how to get the information from the data. You have learned the basics spatial thinking and the basics of GIS analysis; you are in the possession of knowledge in spatial information services. This module aims to deepen this knowledge, to integrate the lessons learned, and to provide experiences in the field of spatial decision support.

The module is giving an overview of the techniques of stakeholder's involvement and the process of spatial decision support. We will go through the decision support process of a waste disposal site selection in a GIS environment. The module briefly describes the use of the ArcGIS ModelBuilder, which can be applied in the case study.

After learning of the module you will be able to:

- determine the preparation of decision model,
- explain the methods of the involvement of the stakeholders,
- introduce the automation of the analysis process in ArcGIS environment,
- explain the automation of analyses processes and the practical implementation of it,
- orientation to the practical implementation of spatial decisions support.

2. 6.2 Basic Concepts

The design is usually an iterative process. in which we should use input (ideas, needs and expectations) from the environment, a broad involvement of stakeholders in the decision-making process.

2.1. 6.2.1 Brainstorming

The theme is linked to the brainstorming. Brainstorming is a group creativity technique designed to generate a large number of ideas for the solution of a problem. In 1953 the method was propagated by Alex Osborn. Osborn proposed that groups could double their creative output with brainstorming. Brainstorming has become a popular group technique. Although traditional brainstorming does not double the productivity of groups, it may still provide benefits, such as boosting morale, enhancing work enjoyment, and improving team work.

Numerous attempts have been made to improve brainstorming or use more effective variations of the basic technique. From these attempts to improve brainstorming, electronic brainstorming stands out. Mainly through ensuring anonymity and parallel input, electronic brainstorming enforces the ground rules of effective brainstorming and thereby eliminates most of the deleterious or inhibitive effects of group work. The positive effects of electronic brainstorming become more evident with group size.

Before a brainstorming session, it is critical to define the problem. The problem must be clear, not too big, and captured in a specific question such as "What service for GIS is not available now, but needed?".

There are four basic rules in brainstorming¹. These are intended to reduce social inhibitions among group members, stimulate idea generation, and increase overall creativity of the group.

1. Focus on quantity: This rule is a means of enhancing divergent production, aiming to facilitate problem solving through the maxim quantity breeds quality. The assumption is that the greater the number of ideas generated, the greater the chance of producing a radical and effective solution.

¹ <http://en.wikipedia.org/wiki/Brainstorming>

2. Withhold criticism: In brainstorming, criticism of ideas generated should be put 'on hold'. Instead, participants should focus on extending or adding to ideas, reserving criticism for a later 'critical stage' of the process. By suspending judgment, participants will feel free to generate unusual ideas.
3. Welcome unusual ideas: To get a good and long list of ideas, unusual ideas are welcomed. They can be generated by looking from new perspectives and suspending assumptions. These new ways of thinking may provide better solutions.
4. Combine and improve ideas: Good ideas may be combined to form a single better good idea, as suggested by the slogan "1+1=3". It is believed to stimulate the building of ideas by a process of association.

The facilitator leads the brainstorming session and ensures that ground rules are followed. The steps in a typical session are:

1. A warm-up session, to expose novice participants to the criticism-free environment.
2. The facilitator presents the problem and gives a further explanation if needed. The facilitator asks the brainstorming group for their ideas.
3. All participants present their ideas, and the idea collector records them, and shows on a clearly visible way.
4. To ensure clarity, participants may elaborate on their ideas.
5. When time is up, the facilitator organizes the ideas based on the topic goal and encourages discussion. Ideas are categorized. Duplicate ideas and obviously infeasible solutions are removed.
6. The whole list is reviewed to ensure that everyone understands the ideas.

2.2. 6.2.2 The nominal group technique

There are many variations of brainstorming. The nominal group technique is a type of brainstorming that encourages all participants to have an equal say in the process. It is also used to generate a ranked list of ideas.

Participants are asked to write their ideas anonymously. Then the moderator collects the ideas and each is voted on by the group. The vote can be as simple as a show of hands in favor of a given idea. This process is called distillation.

After distillation, the top ranked ideas may be sent back to the group or to subgroups for further brainstorming. For example, one group may work on the color required in a product. Another group may work on the size, and so forth. Each group will come back to the whole group for ranking the listed ideas. Sometimes ideas that were previously dropped may be brought forward again once the group has re-evaluated the ideas.

It is important that the facilitator be trained in this process before attempting to facilitate this technique. The group should be primed and encouraged to embrace the process. Like all team efforts, it may take a few practice sessions to train the team in the method before tackling the important ideas.

2.3. 6.2.3 Mind mapping

The formulation of the expectations of the stakeholders' ideas should be fixed, and then they analyzed, tested. As we mentioned earlier the idea collector records the ideas on a visible way (large post-it was used before, today computer projector is much more popular). To ensure clarity, participants may elaborate on their ideas, probably needs retyping. When time is up, the facilitator organizes the ideas based on the topic goal and encourages discussion. Ideas are categorized. Duplicate ideas and obviously infeasible solutions are removed.

This process must be supported by computer techniques, instruments, if possible, be speeded up. For this purpose it is useful method to create a mind map². A mind map is a diagram used to represent words, ideas, tasks, or other items linked to and arranged around a central key word or idea. Mind maps are used to generate, visualize, structure, and classify ideas, and as an aid to studying and organizing information, solving problems, making decisions, and writing.

² http://en.wikipedia.org/wiki/Mind_map

The elements of a given mind map are arranged intuitively according to the importance of the concepts, and are classified into groupings, branches, or areas, with the goal of representing semantic or other connections between portions of information. Mind maps may also aid recall of existing memories.

By presenting ideas in a radial, graphical, non-linear manner, mind maps encourage a brainstorming approach to planning and organizational tasks. A mind map is often created around a single word or text, placed in the center, to which associated ideas, words and concepts are added. Though the branches of a mind map represent hierarchical tree structures, their radial arrangement disrupts the prioritizing of concepts typically associated with hierarchies presented with more linear visual cues. This orientation towards brainstorming encourages users to enumerate and connect concepts without a tendency to begin within a particular conceptual framework.

Mind maps have many applications in personal, family, educational, and business situations, including note taking, brainstorming (wherein ideas are inserted into the map radially around the center node, without the implicit prioritization that comes from hierarchy or sequential arrangements, and wherein grouping and organizing is reserved for later stages), summarizing, as a mnemonic technique, or to sort out a complicated idea.

Mind maps can be used for:

- problem solving,
- outline/framework design,
- anonymous collaboration,
- marriage of words and visuals,
- individual expression of creativity,
- condensing material into a concise and memorable format,
- team building or synergy creating activity,
- enhancing work morale.

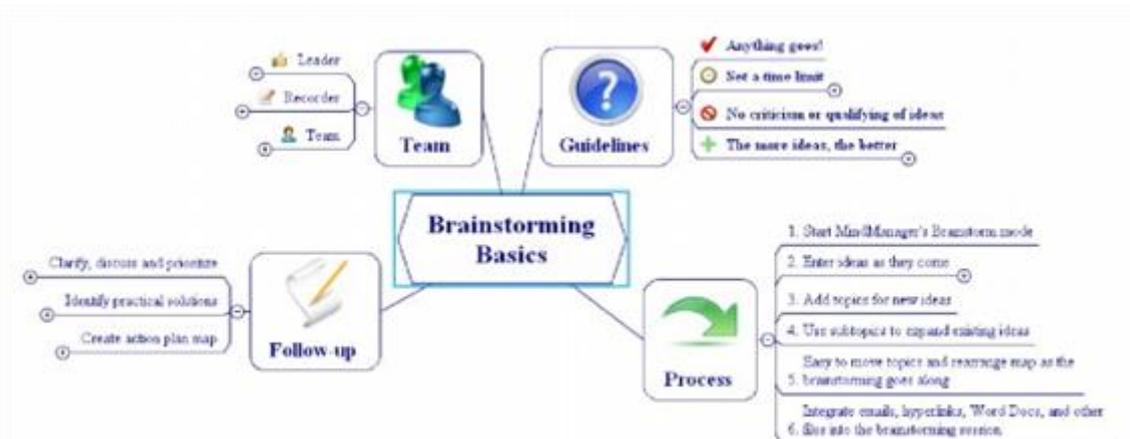


Fig.6.1. Structuring of ideas (MindManager)

Brainstorming and mind mapping are very useful tools for involvement people in spatial decision making process. The resulting mind map is a good basis for the establishment of a decision model.

2.4. 6.2.4 Decision model

The decision model is the graphical representation of the decision-making process. This tool is mentioned in the GIS literature as cartographic model. Cartographic modeling offers a procedural approach to the integration of map layers which allows the design of analysis schema for spatial data.

Figure 6.2 shows how a simple GIS overlay procedure would be represented as a cartographic model and as an algebraic expression.

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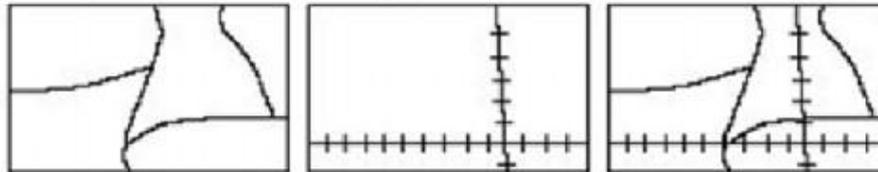


Fig.6.2. Adding together roads and railways

The procedure for the development of a Cartographic model is outlined in four stages described below (after Burrough, 1986):

1. Identify the map layers or spatial data sets which are required.
2. Use clear logic and natural language to develop the process of moving from the available data to a solution.
 1. Set up a flow chart with steps to graphically represent the above process. In the context of map algebra this flow chart represents a series of equations you must solve in order to produce the answer to your spatial query.
 2. Annotate this flow chart with the commands necessary to perform these operations within the GIS you are using.

Having regard to the fact that the „cartographic model” is used for decision support, we will use in the entire module decision model.

2.5. 6.2.5 ArcGIS ModelBuilder

ModelBuilder is an application in which you create, edit, and manage models. If you haven't done so already, you should read Creating a simple model, for it shows you, by example, the basic tasks of creating a model in ModelBuilder. You should also read An overview of model concepts and terms and the topics referenced there, since they define many of the terms used here.

The components of the ModelBuilder application are shown below.

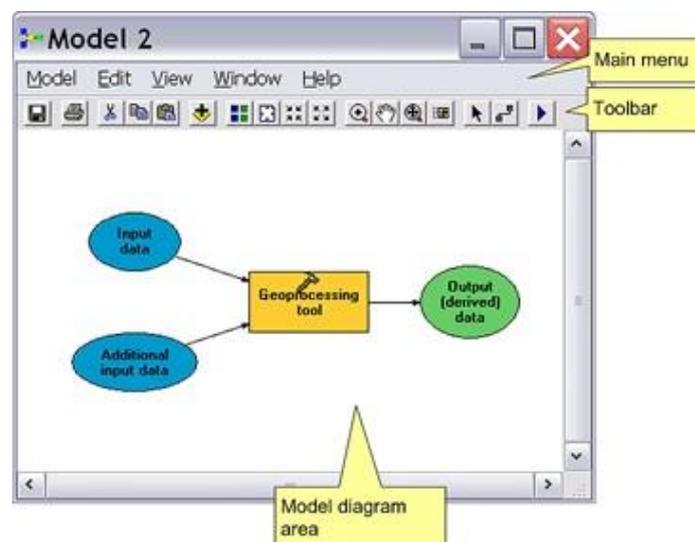


Fig.6.3. ModelBuilder main menu (Source: ESRI)

There are five pull-down menus on the Main menu.

Menu Description

Model Options for running, validating, viewing messages, saving, printing, importing, exporting, and closing the model. You can also use this menu to delete intermediate data and set properties for the model.

Edit Cut, copy, paste, delete, and select model elements.

View Contains an Auto Layout option that applies the settings specified in the Diagram Properties dialog box to your model. It also contains options for zooming in or out.

Window Contains an overview window you can use to display the entire model while you zoom in on a certain part of the model in the display window.

Help Access the ArcGIS Desktop online Help system and the About ModelBuilder box.

The toolbar has the following buttons and tools:

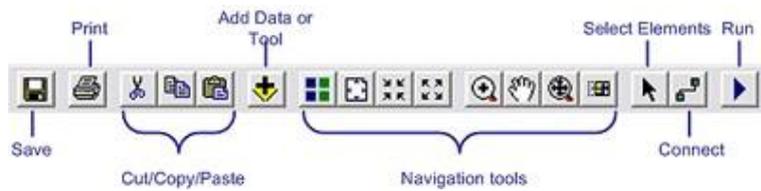


Fig.6.4. Toolbar elements

ModelBuilder can be started from the main ArcMap Main menu.



Fig.6.5. Start ModelBuilder from here

The decision model can be built using „drag&drop” way, and displayed in the window as a flowchart. If you click on the icon of the GIS operation, it will display its Wizard.

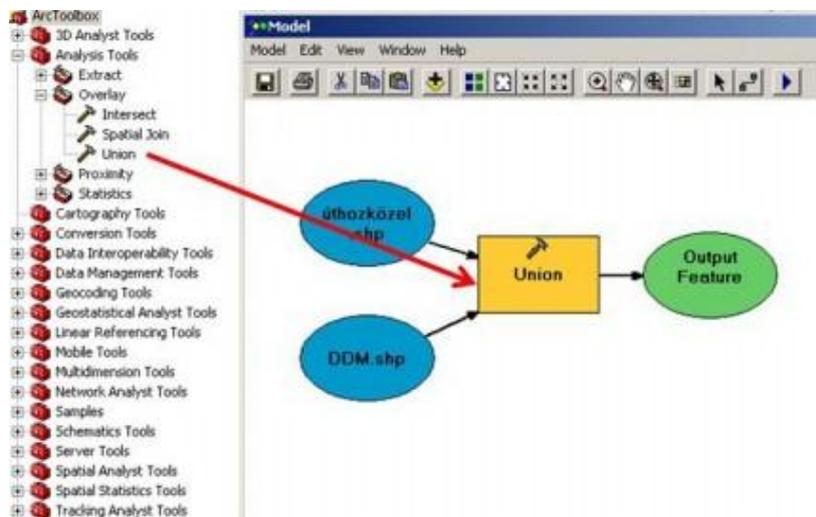


Fig.6.6. Drag and drop

The final version of the model can be saved as image (Export To Graphic).

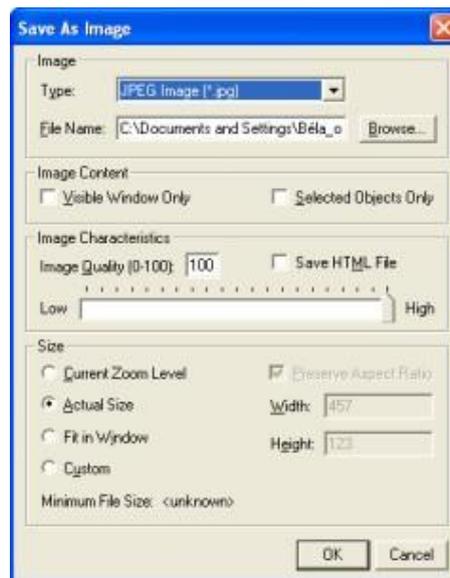


Fig.6.7. Export to graphic

The model could also be exported as Python, Java or Visual Basic script.

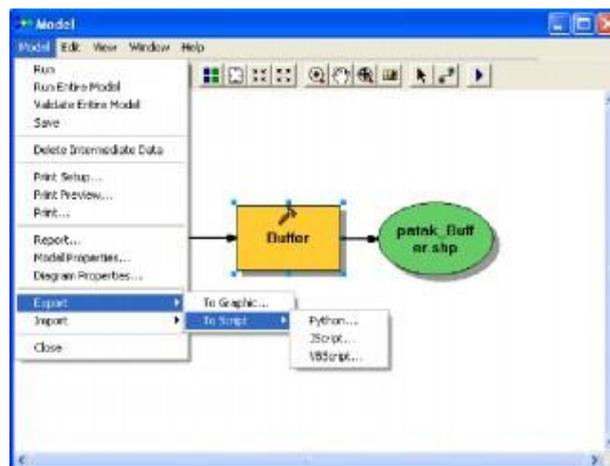


Fig.6.8. Save as script file

The model is a very efficient tool in the spatial decision support process.

What we hope you will have discovered from this section is that decision modeling provides a structured approach to GIS based decision support.

3. 6.3 Site selection case study

Aim: Site selection of a municipal landfill site, in the area specified by the local government.

It is a seemingly simple task, but the definition of the different aspects in the decision model is not so simple.

Rules: after long consultations with the professional and legal experts, the following rules should be followed:

- The distance of landfill from natural water should be more than 125 meters.
- The establishment should not be seen from the main roads.
- The distance of the site from the paved roads is max. 250 m.

- The soil type in the landfill area should be watertight!
- Slope of the site shall not be greater than 12 %.
- The area you want to use for the landfill can be meadow (grassland) or pasture.
- The area should be greater than 0.4 ha.

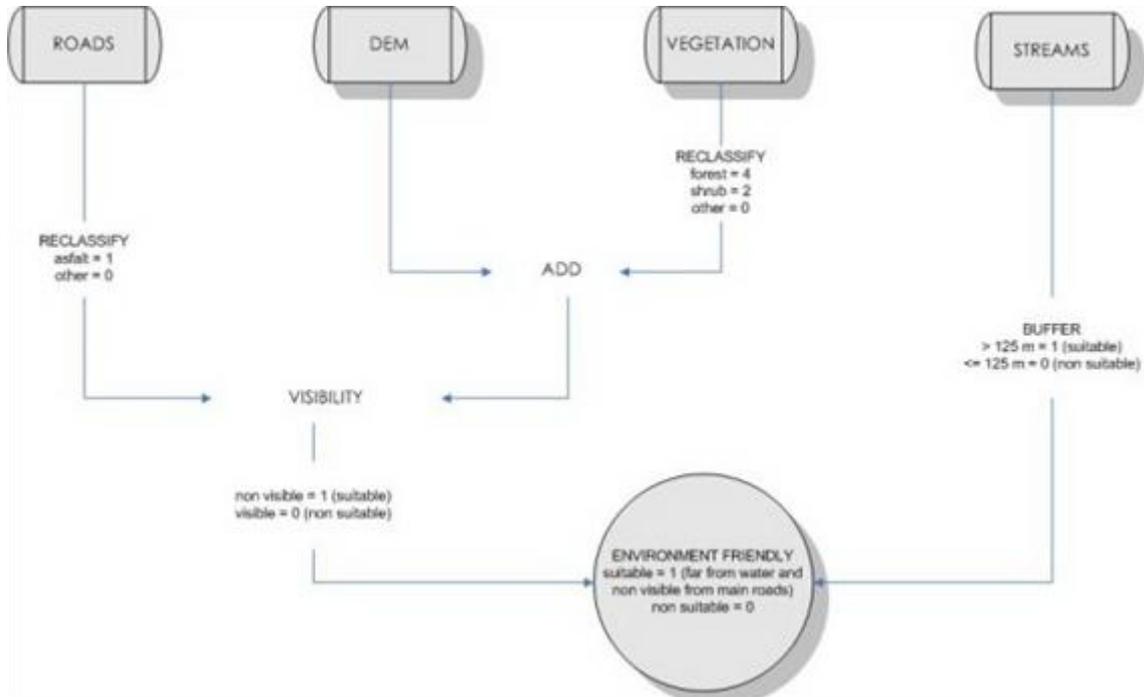


Fig.6.9. The first part of the decision model results environment friendly areas

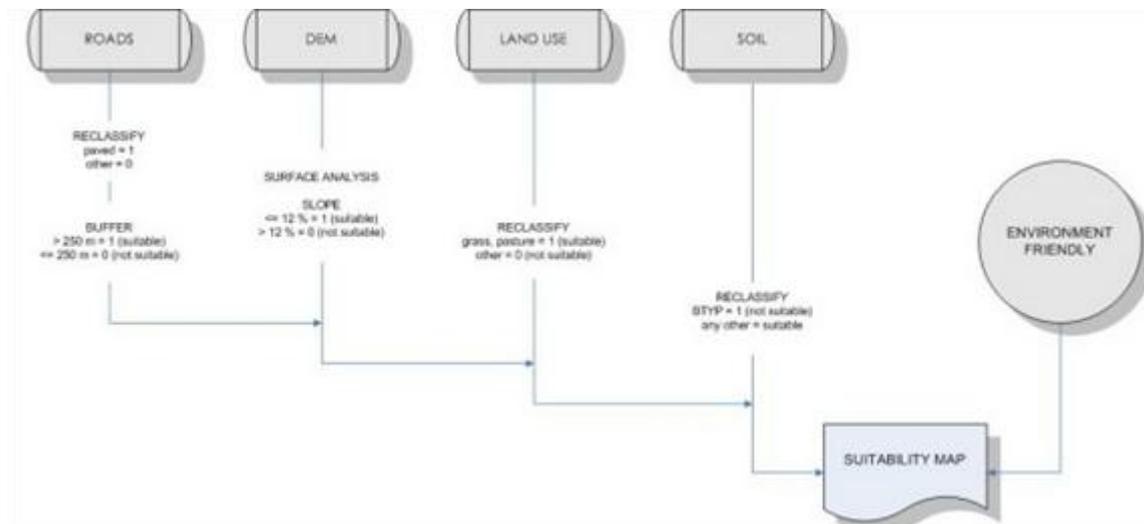


Fig.6.10. The refinement will search for areas, where the site development is cost effective.

4. 6.4 Decision support by GIS

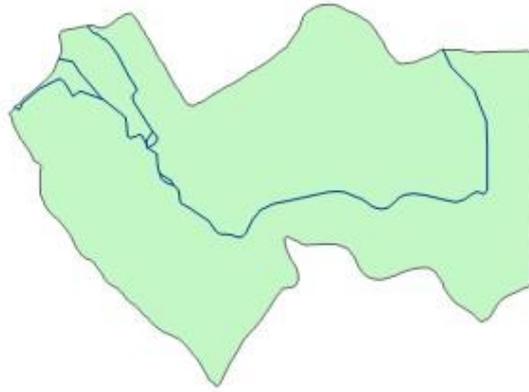


Fig.6.11. The boundary defined by the local government. There is a stream on the area.

Environment friendly

A 125 meters buffer was generated by ArcMap ArcToolbox / Proximity / Buffer.

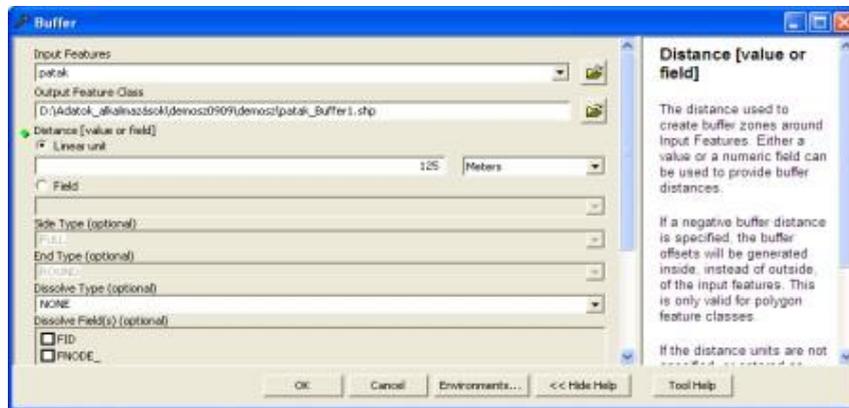


Fig.6.12. Buffer wizard



Fig.6.13. Buffer zone - Areas, closer than 125 m to the stream

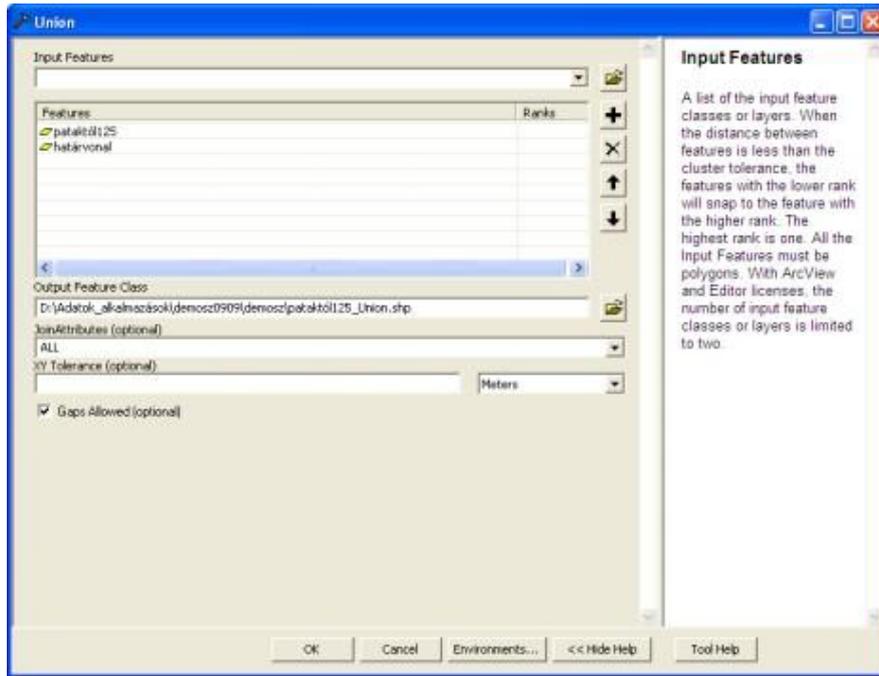


Fig.6.14. UNION – overlay boundary and the buffer to the stream

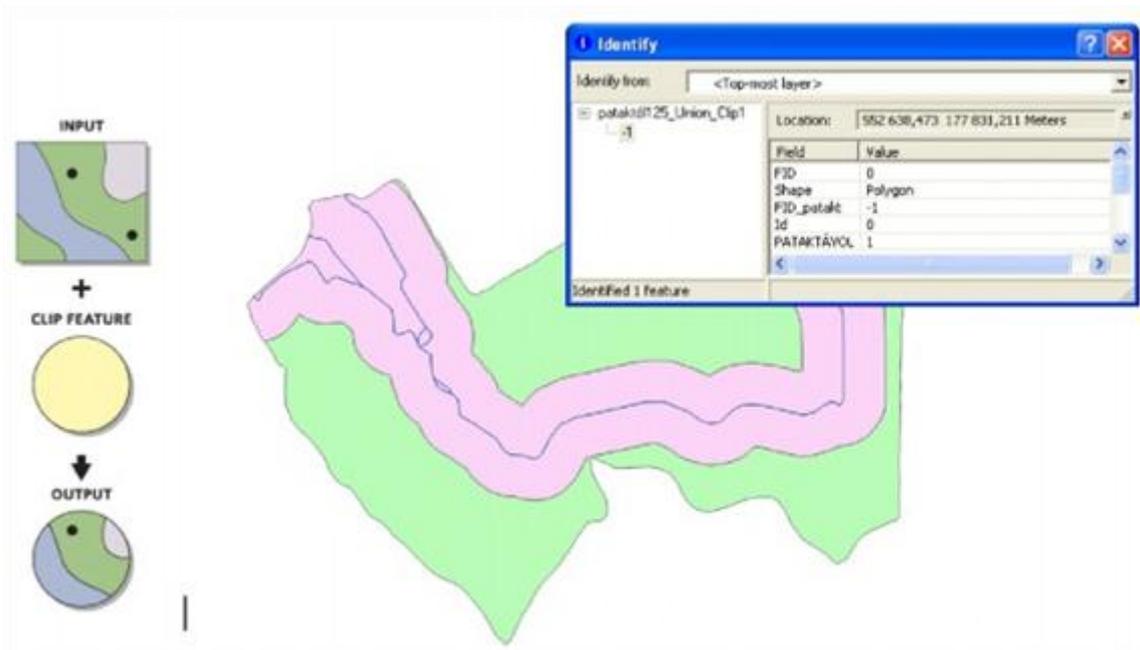


Fig.6.15. CLIP – eliminate areas outside of the boundary

The visibility study was done by an external application and the not visible areas were imported into the database.

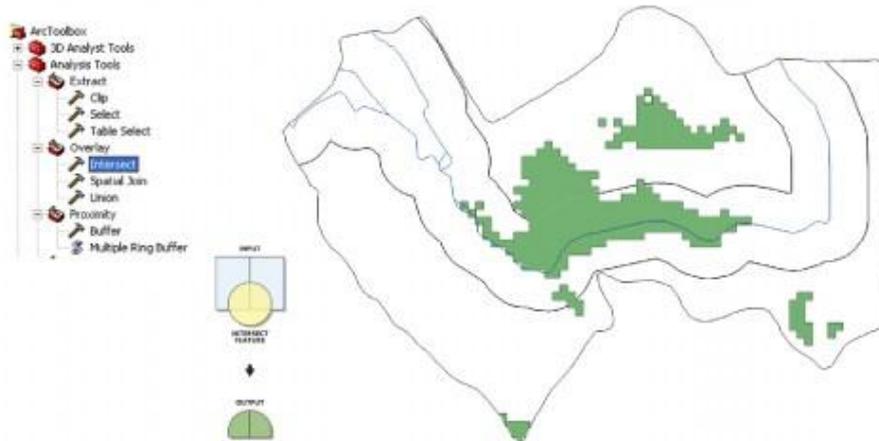


Fig.6.16. INTERSECT – overlay of the buffer zone and the results of the visibility

The attribute data table will contain all three columns, which describe the information (within the boundary, far from streams and non-visible from main roads). We should open a new column in the table, and multiplication of these values by „Field Calculator” will result „0” for not suitable, „1” for suitable polygons.

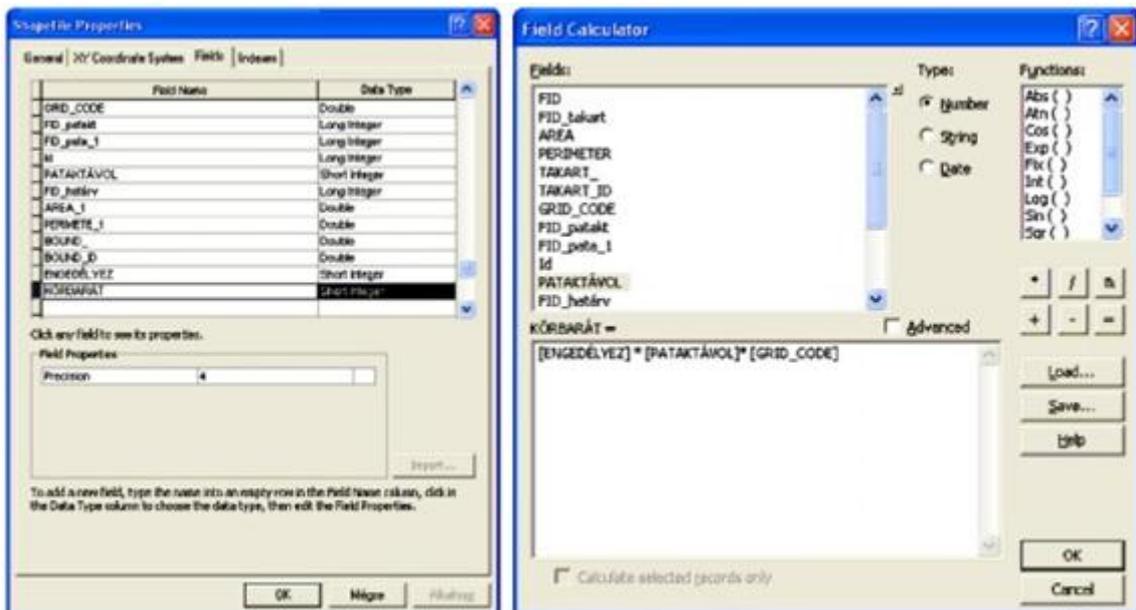


Fig.6.17. Using Field Calculator

The result is shown in the following figure. The green areas are the potential sites fulfilling the environmental criteria.

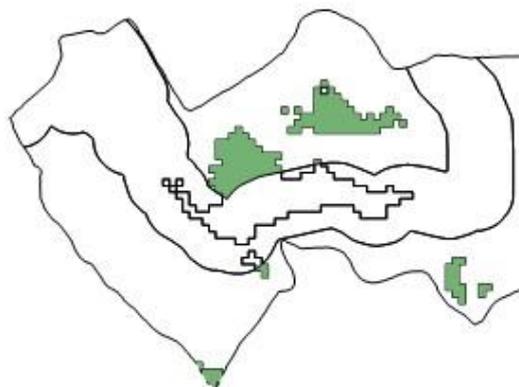


Fig.6.18. Environment friendly areas (green).

Aspects of cost effectiveness

The first aspect of the inexpensive accommodation of the site, that it should be closer than 250 m to paved roads (asphalt and macadam). Soil roads are excluded. This operation can be done by Buffer. A SUITROAD column will have a value of 1 the area is suitable.

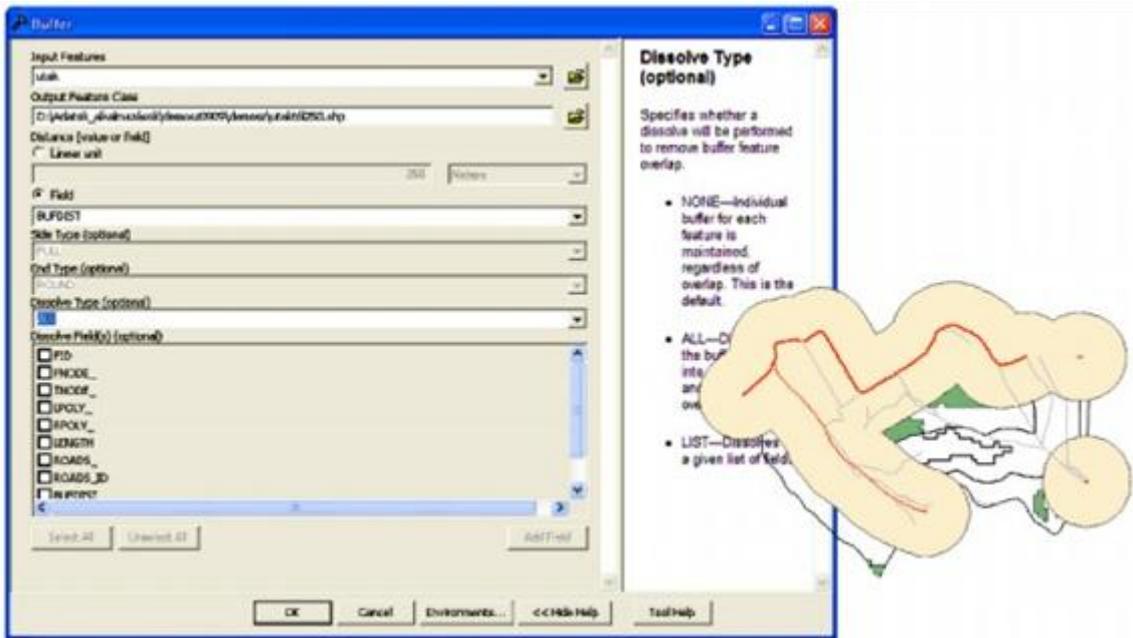


Fig.6.19. Close to main roads

Within the soil database if the soil type is „1”, it means the soil is watertight (SUITSOIL = 1). The unnecessary boundaries can be deleted by the use of DISSOLVE.

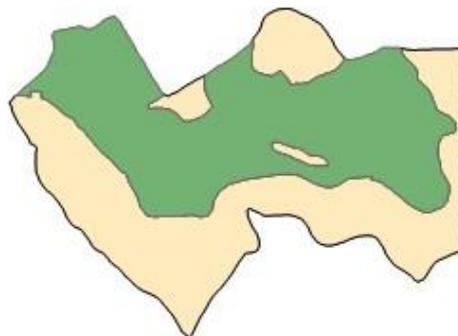


Fig.6.20. Watertight (green) areas are suitable

From the slope database it is important to select the polygons, where the slope is less than 12%. Let us give PLAIN = 1 to the attribute table.

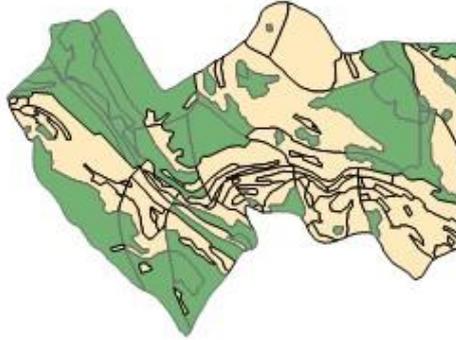
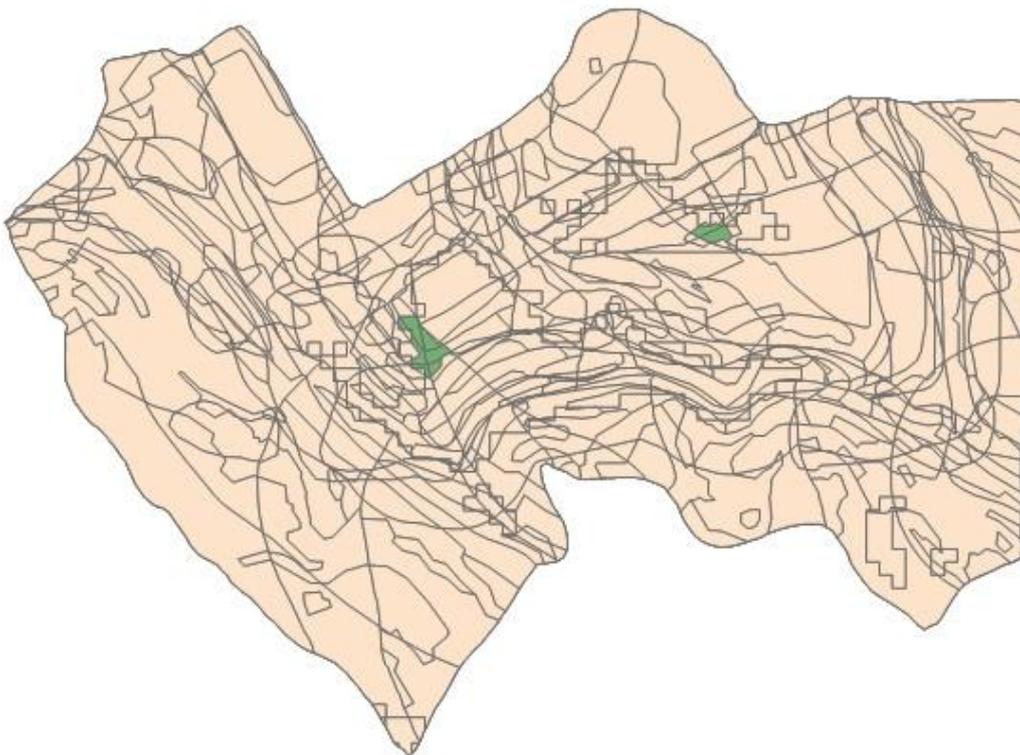


Fig.6.21. Green areas have a slope, less than 12%.

In the land use map we are looking for meadow or pasture ($CHEAP = 1$). The following figure shows the results of the reclassification.

After the preparation of the thematic layers of cost effectiveness, we should overlay them by UNION. The result is shown in the following figure. This database has already 1244 polygons.

Those polygons will be adequate, where all of the attributes is set to 1. Using multiplication function similarly to the environment friendliness, we produce the results $mind1 = 1$.



6.23. The green areas fulfill each condition

Removing all boundaries, where $mind1 = 1$, the remaining polygons are the possible sites for waste disposal.

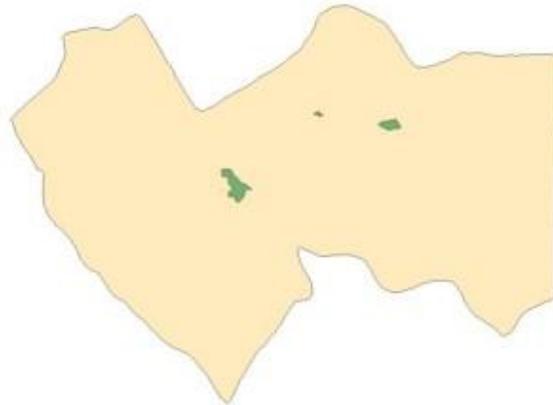


Fig.6.24. Potential sites for waste disposal

To find the area of polygons, the Measure command can be used. We are looking for those of which are larger than 0.4 ha.

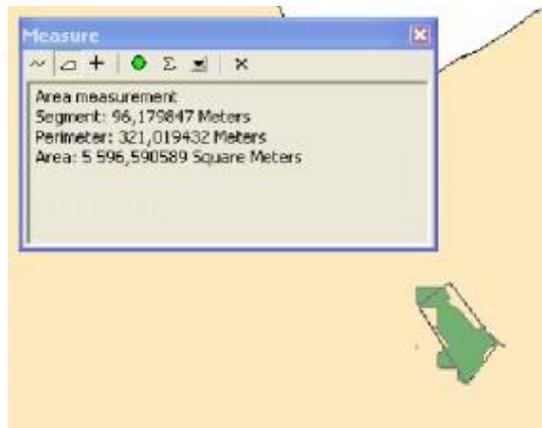


Fig.6.25. Area measurement

Then, eligibility test could be carried out on the ground to verify finally the suitability. To find the places on the field, some additional data is needed. Therefore, the following figure shows additionally to the potential areas the roads and the streams.

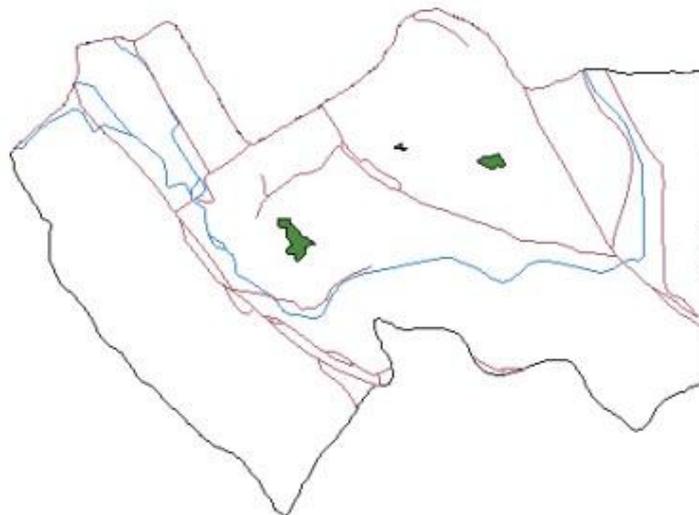


Fig.6.26. Potential sites

How could the potential areas to increase? For example, if the decision makers are satisfied with the areas where only 4 or 5 of the conditions are met.

More color, more nuanced picture can be reached the way, if you do not multiply, but add together the suitability data in the attribute table. The results thus obtained, shows that the decision space is significantly enlarged, which may lead the decision makers to thinking in a more flexible manner.

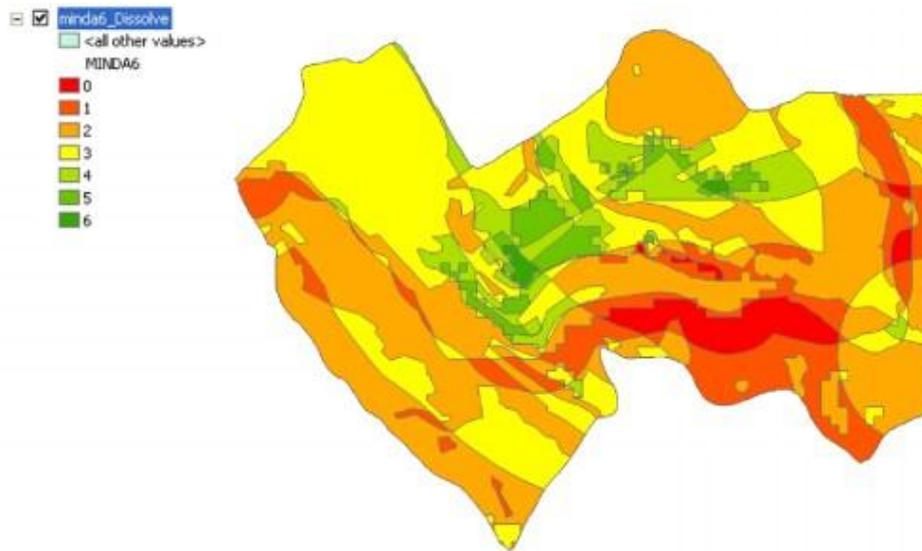


Fig.6.27. Summing up the suitability values of the thematic layers, the result is changing from 0 to 6

The examples presented provide an overview of the GIS operations. The network analysis has not been involved in the decision process, which can be designed. We did not use air pollution modeling to have environmental impacts. These are quite complicated GIS operations; therefore, we will deal with them during the lecture.

There is to be hoped that, through the preparation of this case study, you realized that the spatial analysis may be very complex. The GIS model is flexible enough to add additional criteria to the decision process.

5. 6.5 Summary

In the previous modules, our goal was to introduce step by step, how to get the information from the data. You have learned the basics spatial thinking and the basics of GIS analysis; you are in the possession of knowledge in spatial information services. This module aimed to deepen this knowledge, to integrate the lessons learned, and to provide experiences in the field of spatial decision support.

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Review questions

1. What is the essence of the decision model?

2. Explain the use of the ModelBuilder!
3. What is the essence of decision modeling supported by GIS?
4. How is the site planning decision-making model?
5. What are the inaccuracies in proposed decision model?
6. How do you refine the proposed decision model?
7. What are the other important environmental aspects of the waste disposal site selection?
8. What additional criteria in respect of the cost-efficiency take important?
9. What data sources you would suggest in building the waste disposal database?

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