TOOLS FOR LANDFILL SITING

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SUMMARY: Conflict between uses of land makes the search for a potential new landfill site complicated. Numerous criteria must be taken into consideration in the landfill siting and weights must be assigned to each of them. Even though there are several support systems for Multi-Criteria Evaluation (MCE), there are no guidelines how to select and weigh criteria in a landfill siting. A landfill siting experiment was carried out in the county of Norrbotten, northern Sweden. The result shows that a wide variation of criteria can develop even in a well defined siting situation.

1. INTRODUCTION

Regardless of recycling and other measures to make better use of materials, the final destination of society's material streams is the environment, either in the form of a landfill site or as direct recipient, e g the atmosphere. Landfills are designed with the aim of leaving waste there eternally. In regional planning, this means that there is a long term competition between uses of land, which makes the search for potential new landfill sites complicated.

Numerous criteria must be taken into consideration in landfill siting, involving technical, economic and environmental issues. The final decision will be taken by a small group not expert in all fields. Case studies in Sweden show that the basis for decision is quite inconsistent among different local authorities. Priorities differ with perspectives and policies, and the policies change over time, sometimes much shorter time spans than that of a landfills operative life. There are no universally accepted guidelines for which criteria should be considered in a landfill siting process and how their relative importance should be judged. In this study we have aimed to look at the impact of such perspective variations and also the tools used in the landfill siting process, key issues are:

- What different selection criteria can develop from a given siting task?
- How does a tool like GIS influence the process?

Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 6 - 10 October 2003

2. METHOD

2.1 Definition of relevant criteria

Five groups of students at Luleå University of Technology were challenged to identify suitable sites for a hazardous landfill in the area of Norrbotten, Northern Sweden (figure 1).

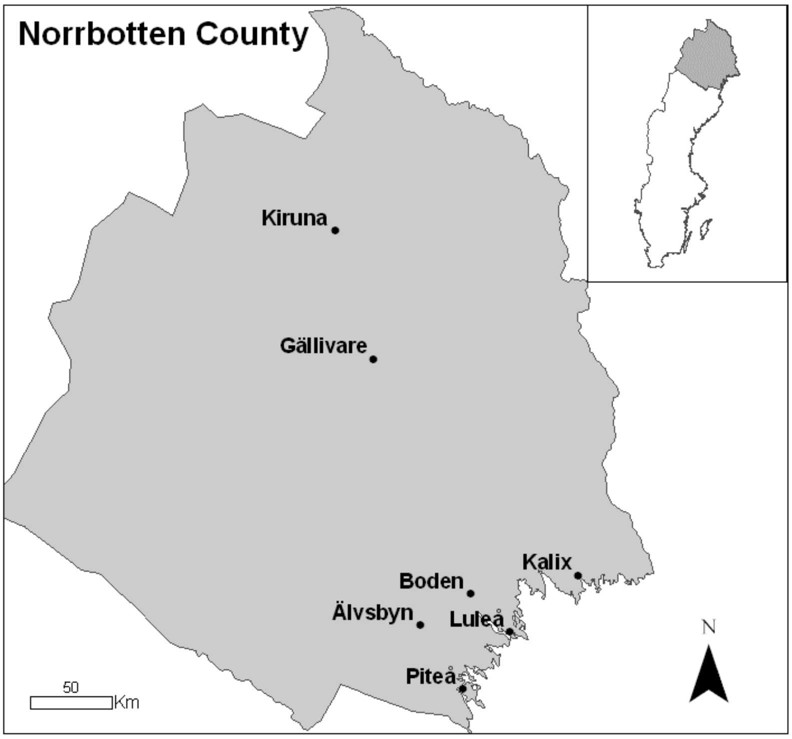

Figure 1. Location of the landfill search area, Norrbotten County, northern Sweden.

A flowchart of the used method is illustrated in figure 2. As a first step, a problem analysis was done. This would identify the overall structure of the problem.

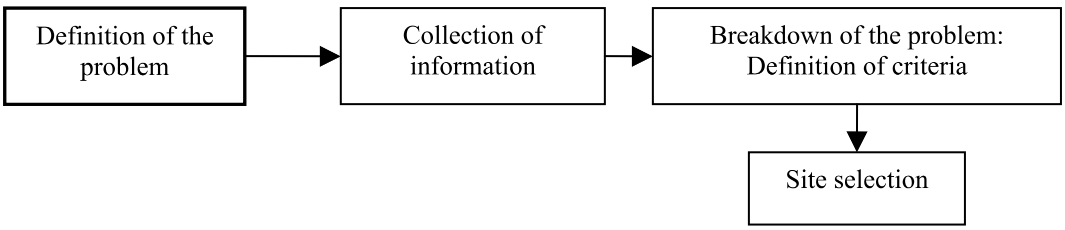

Figure 2. Steps that will lead to site selection.

The students were given instructions which included a definition of the search area and information about factors that should be included in the analysis:

- distance between landfill and settlements
- occurrence of surface water, ground water, costal water and protected land areas
- geological and hydro geological conditions on and around the site
- existing and pending laws and regulations
- transport systems and communication

The step of information collection included lectures and seminars in landfill technology, hydrology, geology, laws, regulations and transport mechanisms. Local information was collected from authorities and regional planning offices. Exercises in using the ESRI software ArcInfo 8.2 were also carried out.

The relevant criteria for the selection were identified, and divided into a more detailed grad of subcriteria and sub subcriteria (figure 2). The next step was to systematically evaluate and give weight to each criterion.

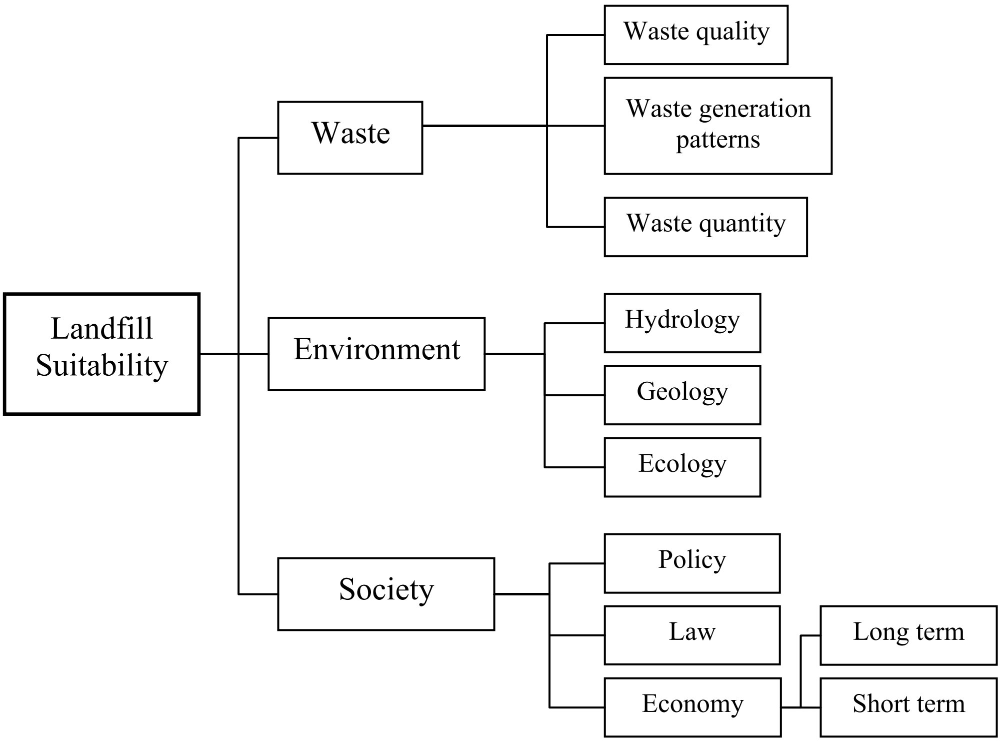

Figure 3. Relevant factors for landfill suitability were identified and divided into subareas.

2.2 The site selection

Once the criteria were selected and given weights, a first rough selection was done in a Geographical Information System (GIS). GIS involves tools for spatial analysing and to sort, analyze and interpret geo referenced maps. In the experiment it was used for determination of "positive areas" and "negative areas" (figure 3). Table 1 show the data layers available for the analyses. Detailed development plans were not available in a digital format for this area and had to be analyzed by studying paper maps in different scales and quality.

This first selection of sites involved Boolean overlay. By using logical operators such as intersection (logical AND) and union (logical OR), the maps are combined. The result will be a map with suitable and unsuitable areas. It is a rough method, but was used to eliminate areas which definitely are not to be considered.

Table 1. Layers of raw data available for the site selection.

Layers
Administrative divisions
Built-up areas and facilities
Roads
Railways
Land use and vegetation cover
Hydrography
Lithological composition of soils
Laws and regulations

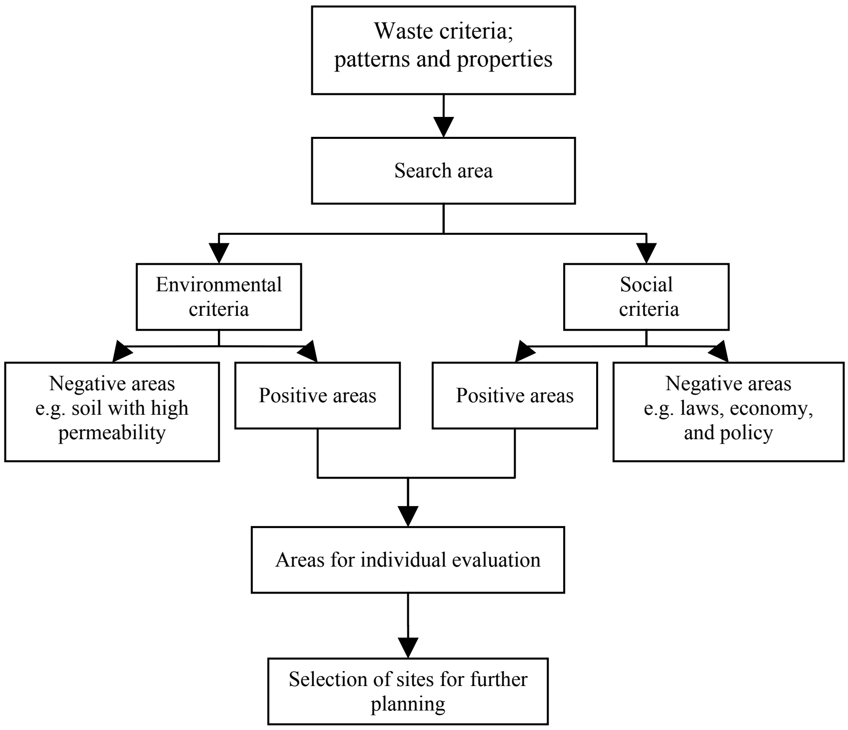

Figure 4. Site selection procedures.

The positive alternatives were evaluated separately and in detail. The criteria are standardized to a common numeric range, and then combined by weighted average.
Assume 5 criterion and 18 alternatives:

$$S = \begin{pmatrix} S_{1,1} & S_{1,2} & \dots & S_{1,18} \\ S_{2,1} & S_{2,2} & \dots & S_{2,18} \\ \dots & \dots & \dots & \dots \\ S_{5,1} & S_{5,2} & \dots & S_{5,18} \end{pmatrix}, \quad W = \begin{pmatrix} w_1 \\ w_2 \\ \dots \\ w_5 \end{pmatrix}$$

$$0 \le s_{i,j} \le 10$$

$$WS = W^T S \quad , \quad WS = (ws_1 \quad ws_2 \quad \dots \quad ws_5)$$

The rows will express the criteria and the columns express the alternatives. The elements of matrix S (the weights of the factors) should be normalised, for instance between 0 and 10. A weight vector W, which express the importance of each criterion is created and $WS=W^TS$ is computed. The alternative(s) in WS with maximum value are selected.

3. RESULTS AND DISCUSSION

The results from the case study made by the students at Luleå University of Technology show that weighing and identification of the criteria are conclusive for the final result. None of the groups finished at the same area, even though given the same background information and method for the selection (figure 5).

The proximity to population centres and the waste generation patterns gave most effect in the site selection (figure 5 and 6). Norrbotten is a sparsely populated county, and the landfill cannot be too far from the population centres for e.g. transport of staff for the landfill. A buffer of 50 km around larger cities excluded ~45% of Norrbotten.Two sources of hazardous waste were identified; polluted soil from remediated areas (mainly connected to the coastline) and ashes from the waste incinerators in Kiruna and Boden. The advantages that come with being close to the waste source were considered to be important to all groups. The suggested sites that weren't close to the waste source had good communication by train and followed the railroad.

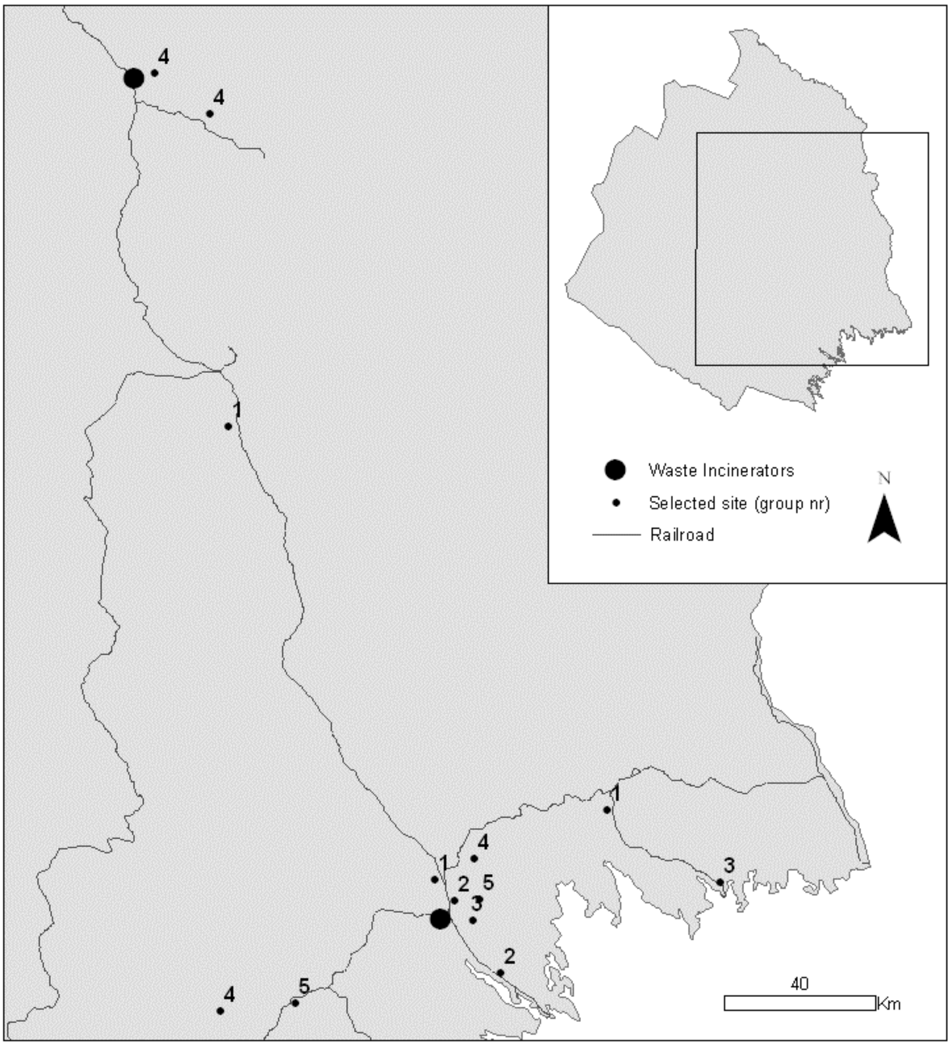

Figure 5. Sites selected by the different groups.

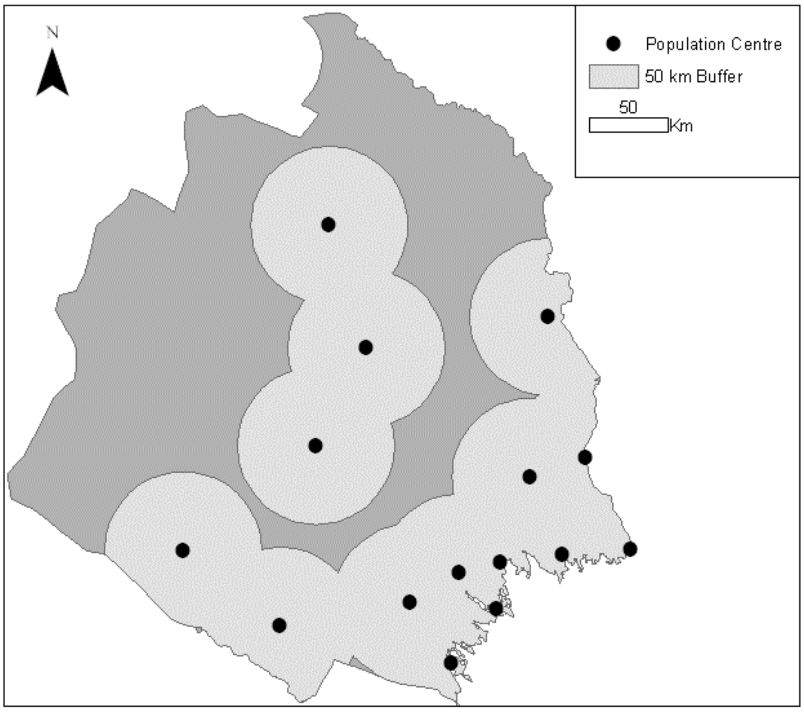

Figure 6. Buffer around population centres.

The largest variations among the groups are connected to the environmental criteria. The groups that considered a clay layer as the best natural barrier (group 3, 5), were at the same time excluding ~99% of the total area, since the Norrbotten area only has ~1% of clay. The clay is mainly situated along the river valleys leading to the coastline. The groups that considered fine grained till or peat as barrier got a higher grade of selection possibilities.

The students had no experience in using the GIS software before the experiment, and were forced to understand the underlying operations under a short time. This was a problem, which lead to frustration and unnecessary time consuming operations. One group used the tool for the GIS analysis and found several suitable sites, but suggested that the existing landfills in the area should be further expanded anyway. They could have lost the unprejudiced view, and excluded areas that could be more suitable for waste treatment. In that case, the students in this group could represent the decision makers that will steer the selection to an already decided goal.

Clearly, the information is vital to the process of decision making and we rarely have perfect information. Lack of information lends an increased importance to available information, and in particular such information that is readily available in georeferenced data-sources. The quality of the between data sources, and all criteria won't have a georeferenced source. GIS is clearly useful when ranking issues like hydrogeology, geology, land use and proximity to waste and populations. A large number of complex data can be explained, analyzed and presented in a foreseeable way and serve as a good illustrative tool in the landfill siting process.

Most criteria one can either arrive at numbers, e g for transport distances or size of aquifer affected, but these steps there are qualitative issued that must be judged by some criterion. The strategy for the selection and expression of such criterion becomes a key problem, and was conclusive for the final result in the experiment. Even though methods for using GIS and Multi-Criteria Evaluation (MCE) (Siddiqui et al. 1996) in landfill siting are developed and some of the GIS software includes tools for MCE (Ceballos-Silva et al. 2003), the identification and weighing of the criteria must be done by hand. The use of GIS in may decrease the transparency of the decision making process and the illustrative power of GIS can be an obstacle in the democratic process (Sengupta et al. 2003).

5. CONCLUSIONS

The result shows that a wide variation of criteria can develop even in a well defined siting situation. To ensure that the decision makers take consistent and right decisions, detailed guidelines for selection and assigning weights to the criteria.

By using a GIS, spatial analysing of geo referenced maps can be done effective. It can also serve as a good illustrative tool in the landfill siting process. But information is vital to the process of decision making and information is seldom perfect. How this affect the result must be further investigated. If model and measurement error is assumed to be randomly and normally distributed, they can be calculated. The robustness of the decision rule specification is on the other hand more difficult to handle.

ACKNOWLEDGEMENTS

The research described in this paper was founded by the Centre for Applied Geographical Information Technology (CTgIT). We would like to thank the students in the project course "Location and operation of landfill" that were brave enough to allow us to try out our ideas. The authors are grateful to the county administrative board in Norrbotten who assisted with map material and data for the GIS analysis, as well as SWECO, Lantmäteriet and Swedish Projectfactory who supported with ideas and knowledge throughout the project.

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