The primary objective of this article is to present an analytical method—a map—for the evaluation and visualization of the degree of operational difficulty for demining contaminated areas. By weighing various datasets, a new dataset is created and classified into four ordinal categories of demining difficulty: low, medium, high, and extreme. From this dataset, macro statistics can be obtained and used first as a step to determine the percentage of land that may be cleared in a region or a country. With a given technique and a specific level of operational difficulty, the percentage of surface deemed extreme to demine is also estimated. In a second step, the interpretation of information regarding operational difficulty may contribute to improving decision-making to better target clearance operations in the field. This method is applicable for demining with machines, animals, or human beings.

Clearance operations highly depend on environmental, geographic and socioeconomic conditions. These conditions make demining easier, more difficult or nearly impossible. This article proposes an analytical method called 5D (Determining and Displaying the Degree of Operational Difficulty of Demining), which classifies degrees of difficulty as low, medium, high or extreme.

5D: A GIS-based Approach for Determining and Displaying the Degree of Operational Difficulty of Demining

by Pierre Lacroix and Rocío Escobar | University of Geneva

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The Geneva International Centre for Humanitarian Demining is collaborating with the University of Geneva to explore the feasibility of displaying the impact of explosive remnants of war in contaminated countries through maps, without revealing the ERW’s exact locations. This project, which serves as a regional component of the Global Information System for War Information Systems, also aims to develop geographical information system tools and methods to identify where populations are most at risk. In addition, SERWIS endeavors to Determine and Display the Degree of Operational Difficulty of Demining (5D) on account of realistic and measurable terrain criteria, such as land cover, slope, distance to sensitive points of interest, distance to roads, hydrology, etc. By combining such geospatial datasets into a multi-criteria process at the macro level, this project is meant to refine the evaluation of a country or region’s demining capacity and help improve demining efficiency. Results provided by the model can act as a good starting point for operational teams that wish to prepare their intervention in the field. Decision-makers can use the model for determining the order in which contaminated areas are to be cleared and which tools should be used.

Examples

Thanks to the human, financial, and technological support of international organizations, an area of 52 sq km was cleared in Mozambique between 2002 and 2007, using 15 demining machines. Since 2005, the number of international collaborators and donors has declined, which has decreased Mozambique’s demining capacity. In late 2008, the overall mine-affected surface remained at an estimated 10 sq km, while the demining capacity was estimated at 2 sq km per year. According to these figures, clearance of all mine-affected areas would take approximately five years. This raises a number of challenges. How can this duration be reduced? Which method (mechanical, dog detection or manual) would be most suitable for the given area, and what would be the level of operational difficulty for a given type of machine?

As a hypothesis for our model, we assume that demining is strongly dependent on geographic, environmental and socioeconomic conditions.

Some of them, such as severe gradients and dense and/or high vegetation, may limit the use of certain demining tools. For example, hill-climbing capacity of demining machines is limited to a certain degree of slope. Tiller performance is reduced among dense vegetation, and large tree trunks and is highly dependent on ground softness, rock content and distance to paved roads. Human activity may also influence use of clearance machines. For example, human activity may facilitate mechanized demining, such as the development of roads and bridges providing better access to hazardous areas. When using animal detection methods, complicating factors include terrain, humidity, slopes and scent contamination.

All of these factors are also likely to affect the degree of difficulty in employing manual clearance methods, although to a lesser extent. Geographical data that can act as a direct indicator of the degree of difficulty are available for most of these factors. This paper focuses on mechanical demining, but does not present a future focus on other tools or methods. For each tool, developing a model of operational difficulty requires involving both geographers and experts on the tool in question. This enables the identification of appropriate layers of geographical data and the individual role of these layers in the model. For instance, a geographic layer on the ferromagnetic qualities of the soil might be a good input into a model indicating the difficulty of using metal detectors, but that same layer is likely not useful when estimating the difficulty of using animal detection. Only an expert on manual demining can determine which layers a geographer proposes are relevant for manual demining. These models are also likely to depend on the local environment. The factors that make manual demining difficult in one country are likely not exactly the same in another country.

Objectives

The primary objective of this article is to present an analytical method—a map—for the evaluation and visualization of the degree of operational difficulty for demining contaminated areas. By weighting various datasets, a new dataset is created and classified into four ordinal categories of demining difficulty: low, medium, high, and extreme. From this dataset, macro statistics can be obtained and used first as a step to determine the percentage of land that may be cleared in a region or a country. With a given technique and a specific level of operational difficulty, the percentage of surface deemed extreme to demine is also estimated. In a second step, the interpretation of information regarding operational difficulty may contribute to improving decision-making to better target clearance operations in the field. This method is applicable for demining with machines, animals or human beings.

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A model was developed in a geographical information system called ArcGIS®. The model contains seven input layers, which can be found on the Internet in the form of free global datasets. These layers include land cover, slope, points of interest, roads, rivers, lakes, and national boundaries. The model does not aim to estimate financial cost, hence the use of the term operational difficulty. A cost assessment would require data collection and analysis on a local level, while the 3D model holds national and regional relevance. For the same reason, the model does not attempt to calculate physical risk.

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Resolution 300 m 3 arc-seconds
Source Derived from the Medium-resolution Imaging Spectrometer (MERIS) on board the European Space Agency’s Envisat platform

As shown in Figure 4 (pages 54–55), the model is composed of (1) input data, (2) tools, (3) outputs and (4) parameters. Input data include Monashe’s administrative limits and the six layers described above: land cover, slope, POI, roads, rivers and lakes. A blue oval symbolizes each input data in Figure 4. Orange rectangles represent the model tools in Figure 4. Each rectangle corresponds to a particular step in the model workflow, e.g., extraction on a given area, conversion from vector to raster, raster reclassification, weighting and generation of the final map.

Input data are first extracted on the entirety of Mozambique. A conversion tool is then used to transform the four input vector layers (POI, roads, rivers and lakes) to raster layers for further cell-by-cell analysis. Since environmental, geographical and social-economic factors not in the same units, the six raster layers need placement in the world. Environmental, geographical and socio-economic factors (land cover, slope, POI, roads and hydrology) are applied using parameters as well, because they may influence operational difficulty of demining in different ways for different study areas while using different demining techniques. It is possible to add further parameters to the model: other factors (e.g., human settlements, temperature gradients, conflict zones, etc.), the weights of Table 3, the weights of Table 4, and so on. The underlying complexity of the workflow (Figure 4, pages 54–55) is hidden from the users (e.g., decision-makers and operators) who only interact with the system through this set of parameters (Figure 6, page 58).

The model is a powerful tool that can calculate in 30 minutes an operational difficulty layer of the entirety of Mozambique (about 800,000 sq km), with a 200 m resolution. In addition, the model is flexible, user-friendly and does not require advanced GIS skills from its users. It holds national and regional relevance, and is potentially applicable to any mine-affected country. Since environmental, geographical and socio-economic conditions vary from one region to another, the input data, the area of study and the weights can be set as the model’s parameters. Other parameters (e.g., human settlements, temperature gradients, soil types and characteristics, elevation, conflict zones, etc.) can be added as inputs according to data availability and user needs. 9,10

The main output of the model is a map. With it, users have an overview of the situation in their area of work at a glance. The map can be overlaid to data availability and user needs. 9,10

Table 1. Main characteristics of the input datasets.
Table courtesy of the authors.

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<th>Characteristic</th>
<th>GlobCover</th>
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<th>OpenStreetMap</th>
<th>HydroSHEDS</th>
<th>GLWD</th>
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<tr>
<td>Source</td>
<td>Derived from the Medium-resolution Imaging Spectrometer (MERIS) on board the European Space Agency’s Envisat platform</td>
<td>Developed on the basis of government and commercial data sources and the contribution of volunteers around the world</td>
<td>Developed by the University of Kassel, Germany and WF</td>
<td>Developed by WWF’s Conservation Science Program</td>
<td>Developed by WWF’s Conservation Science Program</td>
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<tr>
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<td>Slope</td>
<td>Water bodies</td>
<td>Lakes</td>
<td>Land</td>
</tr>
</tbody>
</table>

Table 2: Degrees of operational difficulty of demining.
Table courtesy of the authors.

Category          | Degrees of operational difficulty of demining |
-------------------|-----------------------------------------------|
Low                | High                                            |
Medium             | Low                                            |
High               | Extreme                                        |
Extensive          | Impossible                                     |

Table 3: Classification of the input layers in four categories of operational difficulty. Table courtesy of the authors.

Figure 5. This output raster represents the operational difficulty of demining in Mozambique for a fictive demining machine with medium class characteristics, as is commonly used in many countries. Figure courtesy of the authors.

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output raster map for each degree of operational difficulty. For example, the overall surface with a low degree of difficulty is directly read into the output raster. This kind of information may be significant for decision-makers and operators, especially in financial terms. With further work, in fact, this model opens the possibility to estimate the financial implications of their operational choices.

Conclusions
The 5D model is a first approach for modelling an operational difficulty of demining at a macro level. The model was developed in ArcGIS® Desktop, which is readily available in most mine-affected countries. Users interact with the model via an intuitive and graphical interface by using a set of parameters that can be modified each time the program runs, especially the area of study and input factors. Even if the workflow may seem complex, the model does not require intensive GIS skills.

The resulting map is a good starting point for decision-makers and operators to refine their evaluation of the degree of operational difficulty and improve efficiency in their work. However, this tool is intended as a guide, and real-world political or economic factors may lead to or prevent demining activities in a way that may disagree with the tool. In addition, decision-makers should be aware that modification of one parameter could affect the outputs of the model significantly.

Figure 6. Parameters provided to users at the execution of the model. Figure courtesy of the authors.