5D: a GIS-based approach for determining and displaying the degree of operational difficulty of demining

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Abstract

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.
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, Server for Explosives Remnants of 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.

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.

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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 mechanical 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, dogs 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 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.

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 to identify factors that help 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, inputted with datasets obtained from different sources and applied to the entirety of Mozambique. This case study focuses on mechanical de-mining, on the basis of a fictive machine with medium class characteristics (length 4.7 m; working approximated by 800 sq m/hr in topsoil, 500 sq m/hr in sand, 840 sq m/hr in gravel) commonly used in many countries.

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.

### Inputs
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. GlobCover and GLWD are likely to restrict demining activities, since they represent crowded locations or areas frequented by civilians. The roads layer is found as a line shapefile and contains various categories of roads, from freeways to primary roads. Unlike POI, roads are likely to facilitate activities, since they increase the access of demining resources to hazardous areas.

**GlobCover** is a global land cover map available for two periods, December 2004–June 2006 and January–December 2009. Data is missing for only 1% of total land area. GlobCover has been used in many fields of work (e.g., crop mapping, assessment of global forest cover and estimations of biomass burning emissions) and is easy to apply to a country like Mozambique. In the present case, this dataset was used to identify human activity such as farming and urban settlement. GlobCover is freely available online for noncommercial use at a 300 m resolution (Figures 1 and 2, pages S5–S15). Each pixel represents a 300 m × 300 m cell and holds a value indicating the category of land cover found at the position where it is located (see Figure 1, page S2). For instance, Category 14 corresponds to rain-fed croplands, Category 160 to sparse vegetation and Category 200 to bare areas (Figures 2 and 3, page S3). The data is in Tagged Image File Format (TIF) and the spatial reference is the World Geodetic System 1984 (WGS 1984). It can be downloaded by country. It was developed on the basis of government and commercial data sources and benefited from the contribution of volunteers worldwide. From this database, the case study on Mozambique uses the points of interest and roads layers. The POI layer stores information about the location of different features such as airports, train stations, hospitals, post offices, shops, telephone boxes, car parks, etc. In the mine action framework, POI are likely to restrict demining activities, since they represent crowded locations or areas frequented by civilians. The roads layer is found as a line shapefile and contains various categories of roads, from freeways to primary roads. Unlike POI, roads are likely to facilitate activities, since they increase the access of demining resources to hazardous areas.

**GLWD**. GLWD is a hydrogeological dataset derived from the Shuttle Radar Topography Mission. This dataset includes vector and raster data such as river networks, watershed boundaries, drainage directions and flow accumulation. The HydroSHEDS dataset covers almost the entire globe, but it requires a manual download region by region. It can be used noncommercially. For this case study, the river network was used, provided in the form of river lines stored in shapefiles. The data resolution is 15 arc-seconds, approximately 500 m.

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**Administrative Boundaries**. Administrative boundaries can be found on the Internet in the form of free global datasets. These layers include countries, regions, and subregions. They are likely to restrict demining activities, since they represent crowded locations or areas frequented by civilians. The roads layer is found as a line shapefile and contains various categories of roads, from freeways to primary roads. Unlike POI, roads are likely to facilitate activities, since they increase the access of demining resources to hazardous areas.

**OpenStreetMap**. OpenStreetMap is a distributed open content license. Data is available at the global level in vector format and in WGS 1984. It can be downloaded by country. It was developed on the basis of government and commercial data sources and benefited from the contribution of volunteers worldwide. From this database, the case study on Mozambique uses the points of interest and roads layers. The POI layer stores information about the location of different features such as airports, train stations, hospitals, post offices, shops, telephone boxes, car parks, etc. In the mine action framework, POI are likely to restrict demining activities, since they represent crowded locations or areas frequented by civilians. The roads layer is found as a line shapefile and contains various categories of roads, from freeways to primary roads. Unlike POI, roads are likely to facilitate activities, since they increase the access of demining resources to hazardous areas.

**Reclassify to raster**. The classification of input data is converted to raster format. Raster data offer a geographic perspective in a rectangular grid. This allows for the calculation of physical risk. Each pixel contains an elevation value. The DEM can be obtained online in the form of a 5 × 5 tile mosaic (it is approximately 110 km) and, in use is restricted to noncommercial distribution. It is provided in the WGS 1984 coordinate system. For an easier download, using the “Topo View” interface is recommended. Slopes are derived from the DEM. Each pixel contains a slope value in degrees or percentages.

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

Table 2. Degree of operational difficulty of demining.
Table courtesy of the authors.

The Model
As shown in Figure 4 (pages 54–55), the model is composed of (i) input data, (ii) tools, (iii) outputs and (iv) parameters. Input data include Mozambique’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. During this conversion, a 200 m resolution is applied to recognize the original data precision (Table 1, above) while keeping the model performing at macro scale. Given that they represent quantitative or qualitative factors not in the same units, the six raster layers need placement on a similar ordinal scale. For this reason, they are reclassified to four categories that are meant to represent the four degrees of operational difficulty (Table 2, above). To do this, each pixel is assigned a value from 0 to 3 (Table 3, page 57). The reclassified layers are weighted and combined to a new “Operational Difficulty” raster. Weights are expressed in percentages (e.g., 20% or 50%, see Table 4, page 57). The higher the weight, the higher the influence the layer is on the degree of operational difficulty.

Outputs of the model are the green oval in Figure 4 and correspond to data generated by the execution of model tools, including the final map on the extreme right of the model. The final map (Figure 5, left) is generated by reclassifying the “Operational Difficulty” raster on a scale from 0 to 3 and is composed of 200 m x 200 m pixels, where each is assigned a value representing an ordinal degree of operational difficulty of demining: low, medium or extreme. Areas where demining is set as extreme hold the value 0 and are colored in dark brown (e.g., lakes, rivers, dense vegetation, high degree of slope, etc.). Areas where demining is considered very difficult are colored in brown and assigned the value 1. A value of 2 indicates medium difficulty (in orange) and a value of 3 indicates low difficulty (e.g., buffers around roads in yellow).

In Figure 4 (pages 54–55), model parameters can be identified by the letter P above a blue or a green oval, offering the user the option specifying the value before running the model. Administrative limits are placed into parameters, because the model is meant to be applied to any country and region 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).

Elephantia (the Model)
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 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 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) can be added as inputs according to data availability and user needs.

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 also be overlaid with other information such as hazardous areas, population densities, internally displaced populations.

Table 3. Classification of the input layers in four categories of operational difficulty.
Table courtesy of the authors.
The 5D model is a first approach for modeling operational difficulty. For decision-makers and operators, especially in financial terms, 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, deminers should be aware that modification of one parameter could affect the outputs of the model significantly. See endnotes page 67.

Conclusion

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, deminers should be aware that modification of one parameter could affect the outputs of the model significantly. See endnotes page 67.

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

Mine Detection Rats: Effects of Repeated Extinction on Detection Accuracy

This article describes the performance of Giant African Pouched Rats where reinforcement (reward) or extinction (no reward) conditions affected landmine identification. Accuracy deteriorated quickly in the absence of reinforcement, suggesting that reinforcement is essential.

by Amanda Mahoney, Amy Durgin, Alan Poling (Western Michigan University, APOPO), Bart Weste,ns, Christophe Cox, Tass Tewelde, TeKimiti Gilbert (APOPO)

The mine detection rats in Mozambique work on training fields and actual minefields (operational sites). The training field comprises several 100 sq m, 200 sq m and 400 sq m boxes indicated by ropes along each side. Between zero and four deactivated landmines are buried within each box. The rats are attached to a rope (via a harness) held by two handlers on either side of the box. The rats walk across the box they are searching. When an indication response (pausing and digging) occurs within 1 m of a landmine, the trainer clicks to signal reinforcement and food is delivered. When the rats are used operationally, the location of mines (and other explosive remnants of war) is unknown prior to clearance operations. Therefore, knowing whether an indication response is correct (i.e., within 1 m of a mine) or incorrect is impossible. To avoid the possibility of reinforcing incorrect responses and thereby potentially reducing the rat’s subsequent detection accuracy, no reinforcers are delivered when the rats are used operationally.

In technical terms, the rats work under extinction (no reinforcement) conditions when used operationally and under differential reinforcement (food reinforcement for correct responses, no reinforcement for incorrect responses) conditions during training. Extinction inevitably weakens previously reinforced responses. For this reason, the rats rotate between the training field and the operational site. The rationale for this arrangement is that reinforcement of correct responses on the training field will sufficiently strengthen such behavior to compensate for the response-weakening effects of extinction at the operational site. The rats’ performance at the operational site strongly suggests that this is the case, but we have not systematically evaluated the extinction effects, though studies