A GIS multi-criteria evaluation for Identifying Potential Hotspots of Abandoned Coal Mining Contamination in the Forest of Dean, UK.

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Aims

To identify the locations of potentially contaminated runoff accumulation associated to abandoned coal mine drainage in the Forest of Dean (FOD) and secondly, to classify specific mines that could be of most concern due to surrounding environmental characteristics.

Objectives:

- Identify variables that influence runoff and examine how the constituents within contaminated coal mining runoff, such as heavy metals, act in the environment.
- Undertake a thorough literature review to ensure a comprehensive scientific opinion was used for the modelling process.
- Complete a customised Weighted Suitability Model using the software ArcGIS Pro, to identify potential hotspots.

Methods

A GIS-based study was carried out to create a Weighted Suitability Model using data obtained from online sources and official bodies (Figure 1 & Table 1). The parameters of the model were decided after an extended literature review. The spatial analysis was carried out using the software ArcGIS Pro (Figure 1).

Table 1. Input data, sources & weightings for model

Input Data	Source	Weighting
Slope	Edina Digi Maps	40%
Topsoil Carbon Stock	Landis	20%
Soil Type	Landis	20%
Land Use	Edina Digi Maps	10%
Geology	BGS	15%
Mine Locations	The Coal Authority	-

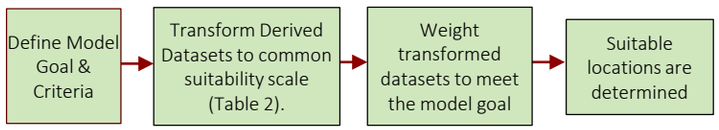

Figure 1. Weighted Suitability Workflow. Instructions provided by Ersi Training (2021).

Table 2. Suitability scores

Suitability score	Suitability description
0-20	Very small possibility of contamination hotspot
20-40	Small possibility of contamination hotspot
40-60	Likely to detect contamination hotspot
60-80	Very likely to detect contaminated runoff hotspot
80-100	Highly fitting contaminated runoff hotspot

The following tools and processes were also used to complete the full analysis:

- Digitalisation
- Flow Accumulation
- Zonal Statistics
- Reclassification
- Symbology

Data was extracted and further analysed in Excel.

Figure 2. Contaminated runoff is often witnessed in many locations of the FOD. Historically, the FOD's abandoned coal mines have been hindered by the excessive amounts of water encountered underground which often generates poor quality drainage (Bowen, 1991; Mamurekli, 2010).

The results from the GIS analysis identify the suitability for runoff sinks, assumed to be contaminated by poor quality coal mine drainage, on a scale of 0 -100 (lowest = 16.1, highest = 94.5) (Figure 3).

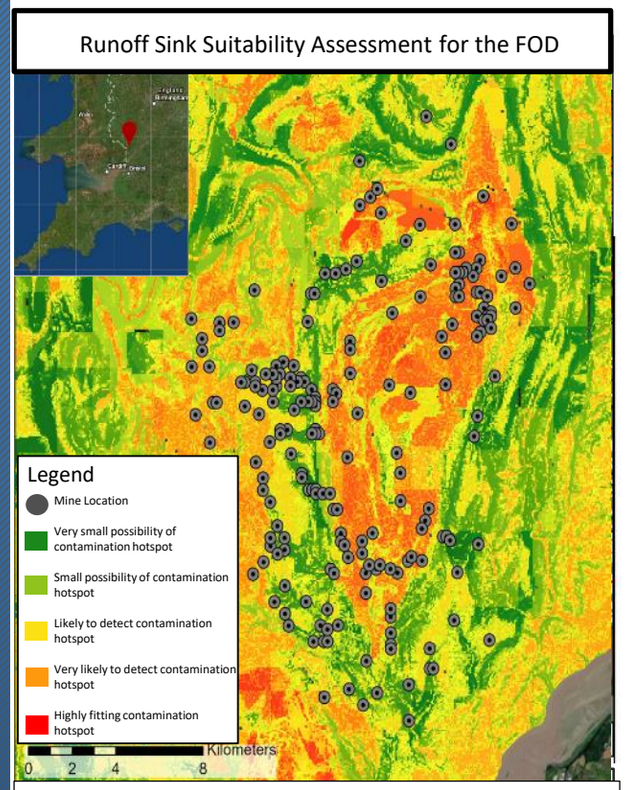

Figure 3. Suitability Model of the studied area showing suitability locations and hotspots for potentially contaminated runoff in relation to mine locations. Suitability classification descriptions modified from Bagdanaviciute, et al. (2012).

Results & Summary of Findings

The outcome shows that 83.14% of the study area is between the categories of likely to detect contamination hotspot (40-60) and highly fitting contaminated runoff hotspot (80-100) (Figure 3 & Table 3).

Table 3. Percentage of the study area and area size within each suitability category.

Suitability score	% of the study area (%)	Area (km^2)
0-20	0.60	4.8
20-40	16.24	130.5
40-60	47.85	384.5
60-80	32.97	264.9
80-100	2.32	18.6

The **second analysis** shows that of a total of 210 abandoned mines recorded within the study area, 84 are located in regions considered as very likely to detect contamination hotspot and therefore, are areas of environmental concern in regard to coal mine drainage. 110 abandoned mines have also been identified to be above the mean suitability score of 55 (Figure 4 & 5).

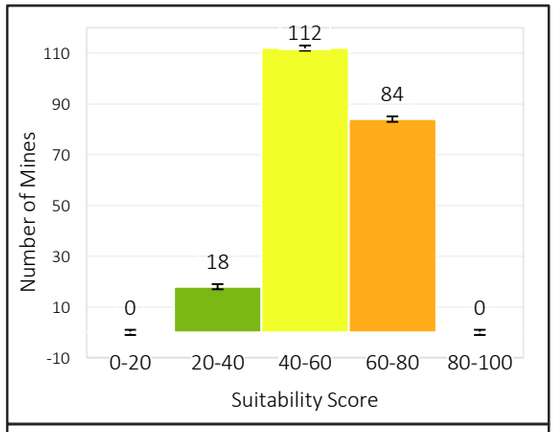

Figure 4. Mean suitability score of mine buffer zones. Error bars represent a standard deviation of 1.07.

Runoff sink suitability for mine buffer zones in the FOD.

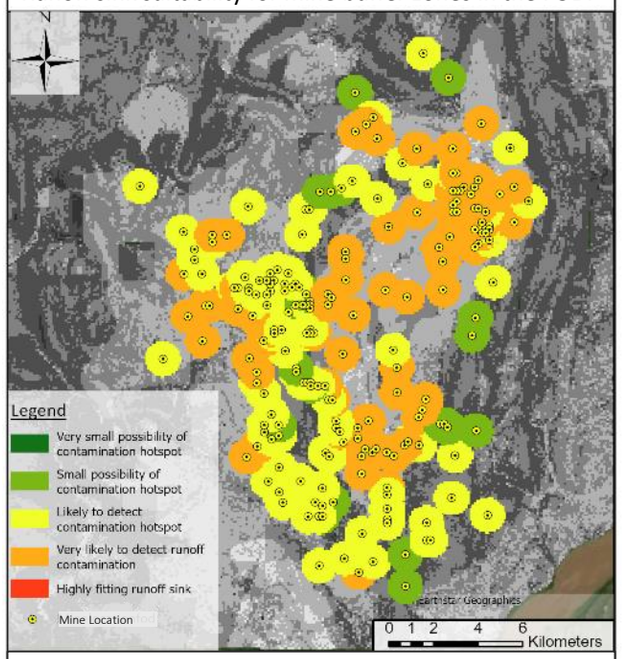

Figure 5. Suitability locations for mining buffer zones, showing the mean suitability score of the zones.

The environmental variables that greatly influence the likelihood of areas to become sinks for contaminated mine drainage are:

- Clayey based soils
- Topsoil carbon stock of 25-35%.
- Mudstone/sandstone geology type.
- 0-15% slope.
- Land use classification of water & impervious ground.

Key findings:

- ❑ More than half of the study area of the FOD is above the mean suitability score of 55 (areas where it is likely to detect contaminated runoff hotspots).
- ❑ 84 mines are within areas that are identified as locations that could be of most environmental concern in regard to abandoned mine drainage.

References: Bagdanaviciute, *et al.* (2012) GIS-based land suitability analysis intergrating multi-criteria evaluation for the allocation of potential pollution sources. *Environmental Sciences.* (68) 10, pp. 124-134. [Accessed 01 March 2021]. Mamurekli, D. (2010) Environmental impacts of coal mining and coal utilization in the UK. Acta Montanistica Slovaca []. 15. [Accessed 12 March]. 2021]. Bowen. C. R (1991) Shallow holes and mine drainage in the Forest of Dean. Gloucestershire Society for Industrial Archaeology Journal [online]. pp.17-27. [Accessed 20 March 2020]. online