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APPLICATION OF A GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR SELECTING THE LOCATION OF A COAL WASTES DUMP-A CASE STUDY

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ABSTRACT: The Gheshlagh mining region, which includes more than ten active and several abandoned coal mines, is one of the most significant regions for coal mining in northern Iran. Due to the lack of more suitable ecological and environmental strategies for coal wastes management from these mines, a large amount of wastes has been dumped in the vicinity of the mines. The primary purpose of this research is to propose a new methodology for selecting a site for coal waste piles applying GIS in the Gheshlagh region. For this, the coal waste piles have been firstly detected by field observations and based on environmental aspects. All the required maps, including farmlands, surface streams such as seasonal rivers, forests, and residential areas have been run in the ArcView software package. Finally, the best location of the site for dumping the coal wastes with an area of 27 hectares has been detected and suggested in the Gheshlagh coal region using the IDRISI software package considering environmental and economic aspects. These studies are beneficial for mine planners to reduce the environmental issues nearby the mining operations.

BACKGROUND

Coal is one of the most critical energy resources used for 50 % of global electricity production. However, it causes several environmental concerns associated with land use, waste, water, and air pollutants which are considered a long-term risk to public health. For example, the world health organization (WHO) in 2008 reported that coal pollutants had shortened around 1,000,000 lives annually worldwide (Wang et al., 2011). Among the coal pollutants, coal waste piles are one of the primary sources of these pollutants, contaminating soil and water resources in both coal regions and the surrounding areas. Indeed, the oxidation process of sulfide minerals, specifical pyrite, generates acid mine drainage (AMD), resulting in water and soil pollution from the coal waste piles. This process is very complicated, and substantial chemical, biological, and physical parameters can be involved (Molsen et al., 2005).

Iran is one of the essential coal producers in the Middle East and has a vital role in the steel industry. The primary coal resources include the Tabas coal resources, Alborz coal basin, and Kerman coal resources. The coal mines are mainly located in the Alborz coal basin, consisting of three zones: the eastern, the central, and the western Alborz located in the Semnan, Mazandaran, and Golestan provinces, respectively (Jodeiri Shokri et al. 2016). The Golestan province with 11 active mines in the Azad Shahr-Ramian and the Gheshlagh region are major coal producers in Iran. Razi, Vatan, Olang, and Kalat are the most important coal mines in the Gheshlagh region. Coal washing plants in the Gheshlagh region have produced a large volume of coal waste dumped in the area without considering environmental and economic aspects. The pollution problem also consists of land unsafe for domestic people and wildlife. Dumping has also affected the natural landscapes and tourism industry.

Over the last decade, some researchers have made considerable efforts to investigate and study the coal waste environmental problem in the Alborz coal region (Doulati Ardejani et al. (2008), (2010), Jodeiri Shokri et al., (2014); (2016 a, b); Sadeghiamirshahidi et al., (2013 a, b); Shafaei et al. (2016); Shahhosseini et al. (2013), (2016) Hadadi et al., (2019); (2020)). Doulati Ardejani et al. (2008) used geophysical and geochemical methods to detect the area affected by an abandoned coal waste pile in the Alborz Sharghi region in the eastern part. They found that the waste pile had an essential role in

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contaminating the area. However, Shafaei et al. (2015) revealed that tailing impoundments near the coal washing plant are the primary source of the local contaminant. The pyrite oxidation process occurring in the pile was also evaluated by a combination of three-dimensional (3D) geo-electrical data inversion and two-dimensional (2D) numerical modeling of long-term pyrite oxidation and multi-component reactive transportation of the oxidation products (Jodeiri Shokri et al. (2016 b)). They found that the oxidation occurred in the upper layers of the pile. Moreover, the results showed that further pyrite oxidation will generate more oxidation products that reach the pile base in the future. Finally, they also proposed a reclamation scenario by placing an impermeable cap on the pile surface.

In central Alborz, Shahhosseini et al. (2013), used geochemical and mineralogical characterization for a coal waste pile surrounding the Anjir Tangeh coal washing plant in Zirab, Mazandaran Province. The results showed that the pyrite oxidation process has occurred at the depth of the pile. The results also revealed that the subsequent leaching of the oxidation products such as Mn, Zn, Cu, Cd, Pb, and Ag are the most important contaminants in this area. Doulati Ardejani et al. (2014) also presented a numerical multi-component reactive model for pyrite oxidation in this pile.

In the western Alborz, Doulati Ardejani et al. (2010) investigated pyrite oxidation and AMD generation by geochemical and numerical methods in the Azad Shahr–Ramian region. They also studied the impact of AMD on the quality of the surface water bodies, investigated by taking samples and analyzing them for hydro-geochemical parameters. The results from the geochemical analyses of water and coal samples and numerical simulation showed that pyrite oxidation and acid generation were taking place in this region.

Despite the valuable research, the literature reviews revealed a lack of research in associated with finding the best location of coal waste piles in the Alborz coal basin. For this reason, in this research, we propose a new methodology to find the best site location of the coal wastes piles using the GIS technique in the Gheshlagh region.

SITE DESCRIPTION

The Gehshlagh region is located 40 km from Shahrood and 7 km off the Azad Shahr-Shahrood road, northeast Iran (**Figure 1**). Gheshlagh and Vatan mines are the main coal mines in the area. Due to the presence of only one coal washing plant located in the vicinity of the mines focus has been on both mines. The topography of the mining area is rough. The weather is very cold in winter and moderate and humid in summer. The average annual precipitation at the site has been 702 mm over a 10-year period. The study area is located in Khoush Yeylagh 1:100,000 geological sheet. Coal seams in the Gheshlagh mine are interbedded with Upper Triassic– Lower Jurassic argillites, siltstones, and sandstones of the Shemshak formation. The coal seam is bounded by dolomite limestone on the lower part (Elica formation) and by thick layers of limestone (Lar formation) on the upper part (Geological Survey of Iran 2002). **Figure 1** shows the geographical location of the Gheshlagh coal mine.

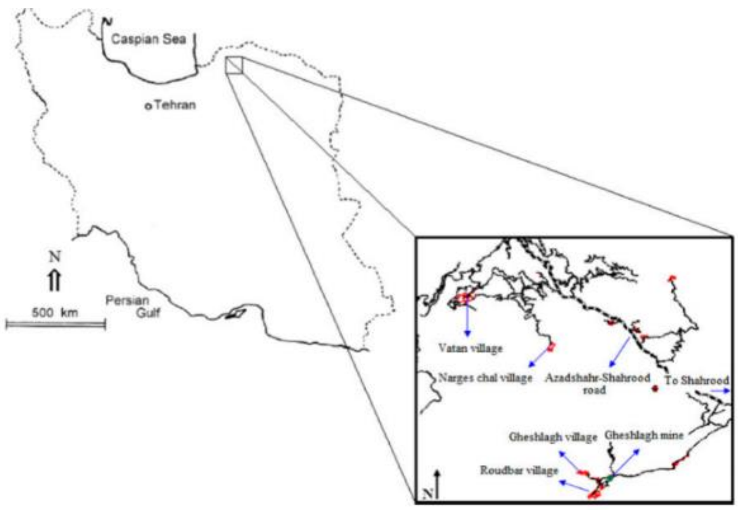

Figure 1: Geographical situation of the Gheshlagh mine (Doulati Ardejani 2010)

Characterization of the coal waste piles in the area

Coal processing in the region has caused many waste piles and posed many environmental concerns. For example, the biggest pile is located adjacent to the river flowing through the mine site. This may increase the risk of AMD generation and transportation of the oxidation products which may be affected by the surface and underground water bodies in the area. A general view of the coal waste piles is shown in **Figure 2**. Unfortunately, the waste produced by the coal washing plant is mostly dumped in two places. At the first location, due to the presence of several hills in the northern part of the area, the waste is dumped in the foothills. At the second location, the waste is transported to flat areas in the nearby lands where they are dumped and degraded to leave space for more wastes. Field observations also revealed that the mining activities produced many environmental problems, such as lack of soil vegetation around the waste dumps, discharge of mine effluents and water drainage, the formation of waste disposal sites near rivers, watercourses and agricultural and forest areas, and deterioration of the natural landscape. Moreover, due to high precipitation in the area, the leaching and transportation of heavy metals may be facilitated in the area.

Figure 2: General View of the wastes piles in the Gheshlagh coal region

MATERIALS AND METHODS

Geographic information systems (GISs) are computer software and hardware systems that allow users to capture, store, analyze and manage spatially referenced data. GISs have transformed the way spatial (geographic) data, relationships, and patterns in the world are able to be interactively processed, analyzed, mapped, modelled, visualized, and displayed for an increasingly large range of users, for a multitude of purposes. Finding the best site locations for cement, mineral processing plants, oil, and gas refinery plants or landfill is one of the GIS applications which is ordinarily used in prefeasibility studies and pre-planning designing of a project. The best locations for waste dumps should deal with some critical factors. Osanloo and Ataei (2003) described the most important factors such as the pile capacity, amount and volume of the waste, the time, cost and type of waste haulage from the plant to pile, topography conditions, facility access for workers, and environmental concerns which affect the site selection for waste rock disposal. In this paper, site selection of the best location for dumping waste has been conducted using the GIS technique. The first step is for all required local maps sheets in scales 1: 25,000 including the farmlands, residential areas, floods, available wastes piles, transportation and communications roads, rivers, and stream sediments to be exported to the ArcView software package. Some assumptions, to find the best site location was defined in ArcView. Then, each map is run in ArcView and all results, in Bitmap format, are exported to the Terrset software package.

IDRISI GIS COMPONENT IN TERRSET

There are two basic types of layers in GIS: raster image layers, and vector layers. The raster image layers has been used in this research. TerrSet is a PC grid-based system that offers tools for researchers engaged in analyzing earth system dynamics for effective and responsible decision-making for environmental management, sustainable resource development, and equitable resource allocation. The IDRISI GIS component in TerrSet provides a very rich set of tools for the assessment of distance across space including Euclidian distance, non-Euclidian cost distance where the effect of friction to movement is accommodated, to anisotropic cost distance where the friction is different in various directions. The IDRISI GIS includes a wide selection for filtering, pattern analysis, and determining rates and directionality of change (such as slope and aspect). The latter can be used to describe force vectors. Tools are provided for the combination of these force vectors to derive resultant forces (Eastman, 2015).

The main factor in IDRISI is to give a code to each of the quantitative parameters, explained before in the text. Integer values can be used to represent quantitative values or can be used as codes ranging from 0 to 255 for categorical data types (Eastman, 2015). Indeed, waste maps indicating the best site for dumping the waste will record considering six types on a particular map. Since IDRISI images are stored in numeric format, these types can be given integer codes 1, 2, 3, 4, 5, and 6 respectively. Moreover, the required quantitative parameters such as transportation and communication roads have been also specified by a type of color which was zero coddings in this research. Finally, if there is any overlapping current of the obtained maps, the best location of the wastes pile would be found.

Rivers and surface sediments map

The rivers can have an effect on the process to find the best site for the optimum pile in an area. Therefore, the rivers and surface sediment maps should be prepared for the area to be studied if in a forest area, having a high amount of precipitation with persistent seasonal and permanent rivers (**Figure 3**).

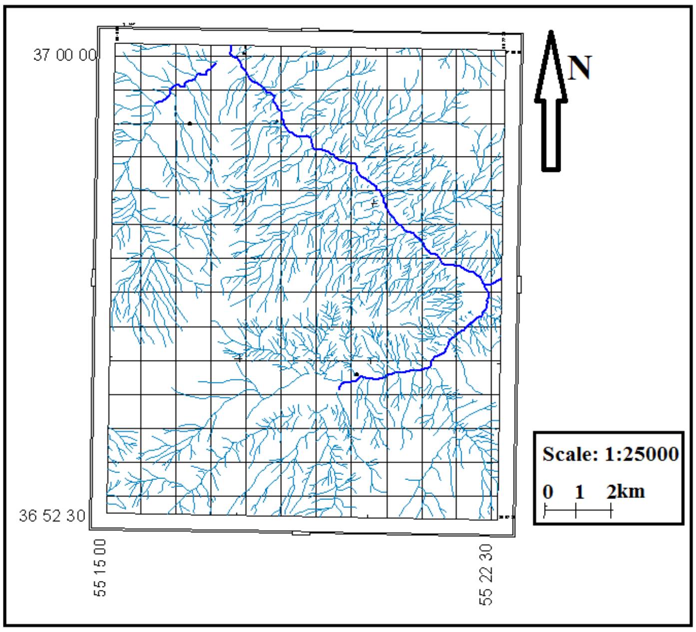

Figure 3: Rivers and surface map in the area

Farmlands map

Agricultural, specifically rice and cereal cultivation is prevalent in the area because of the abundance of water in the region and ideal weather conditions. Pollutants caused by the accumulation of wastes can pollute agricultural water and damage the plants. Therefore, a map of local agricultural lands should be considered as an important map (**Figure 4**).

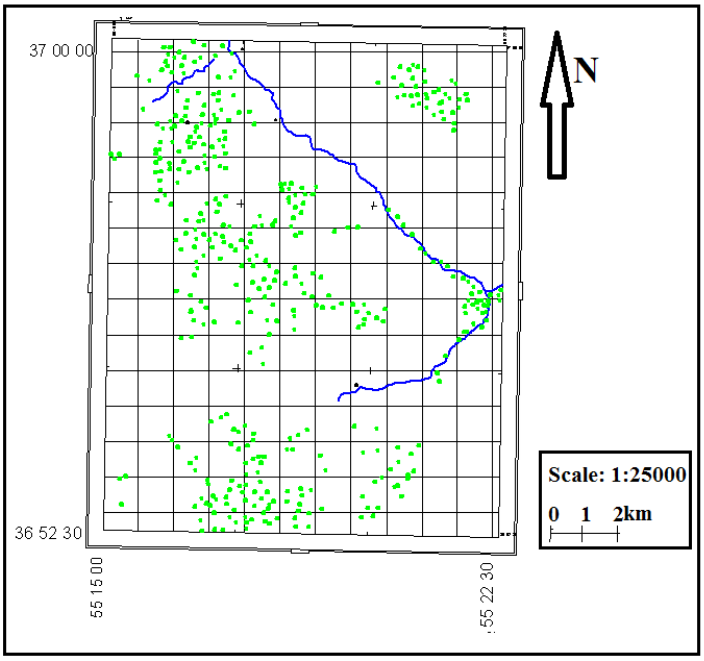

Figure 4: The Farmlands map in the area

Residential map

Due to the close proximity of the villages within the region to the coal mines and coke producers, the residential map plays an important role in determining the best site for the pile (**Figure 5**).

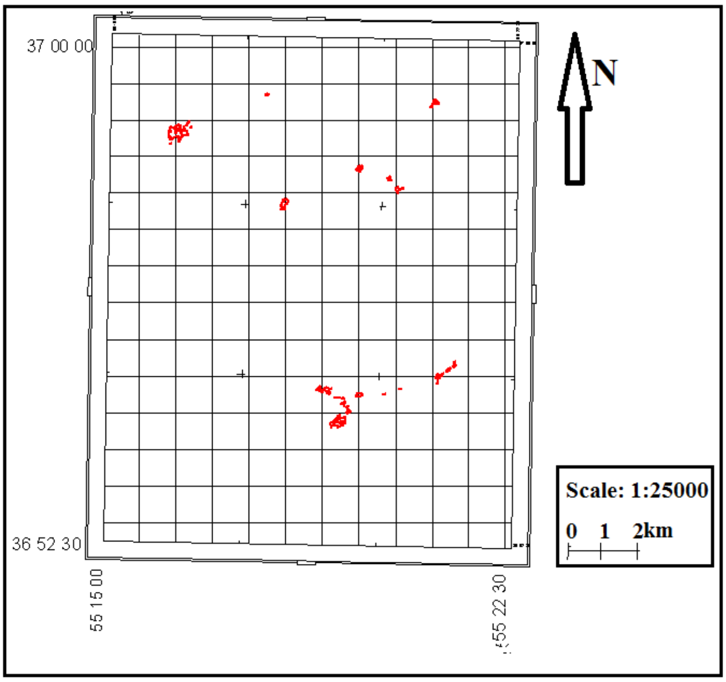

Figure 5: The residential map in the area

Transportation and communications roads map

As the selected location is far from transportation roads, it is not economically practical to transport waste for long distances or construction new roads, the current road map of the area is also one of the determining factors in locating the pile (**Figure 6**)

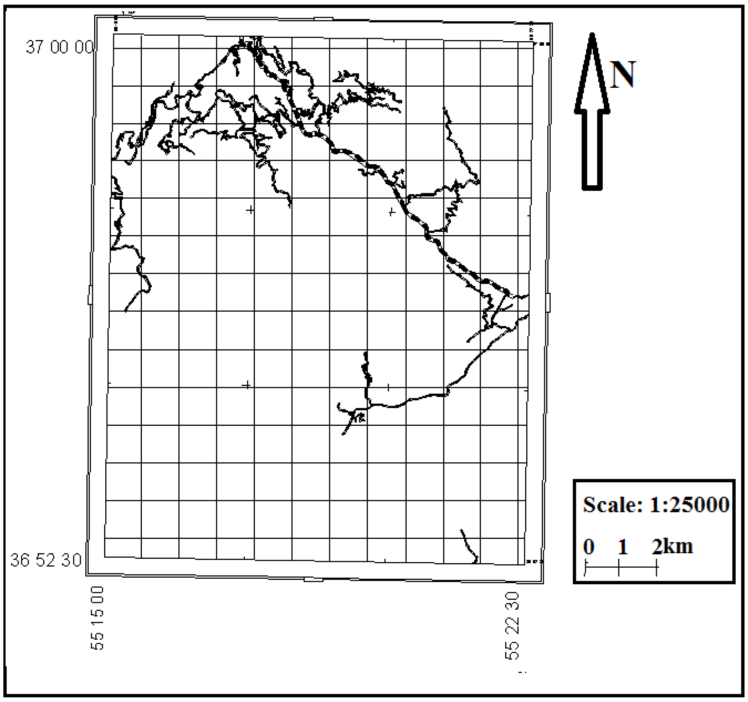

Figure 6: The roads map in the area

Flooding map

Several floods have occurred in the area. Moreover, field observation shows that several wastes piles are located nearby local rivers. Therefore, considering the flooding map is necessary for this research (**Figure 7**).

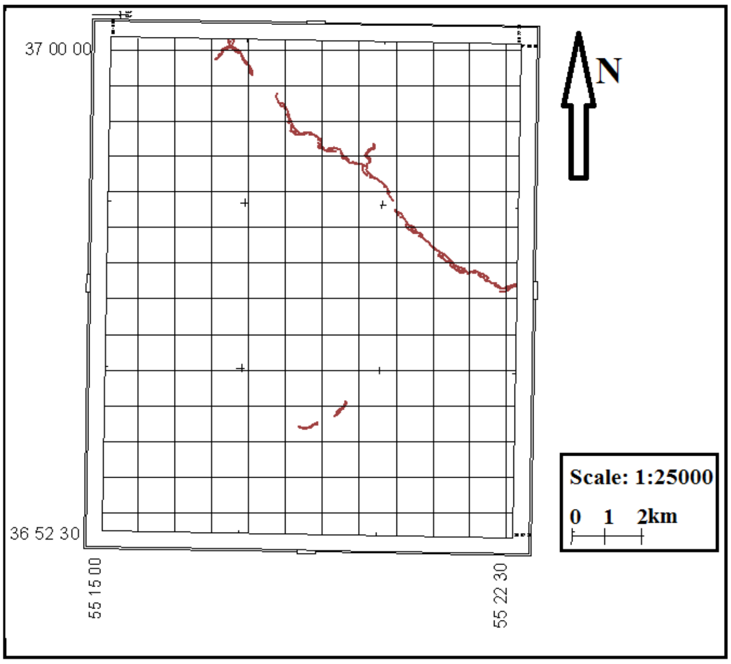

Figure 7: The Flooding map of the area

Forest area

There are more than 10,000 hectares of forest area specifically in the northeast and the southwest of the selected area. Pollutants especially acid mine drainage (AMD) which are result from the existed piles can affect the forest area in the long term (**Figure 8**).

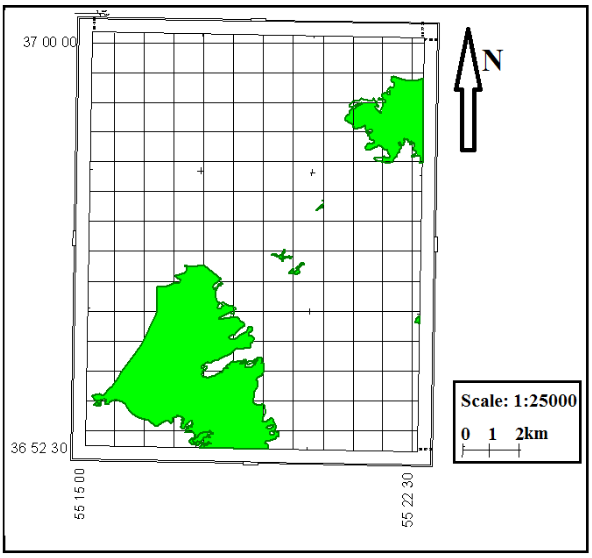

Figure 8: The forest area in the region

Satellite image of the area

As mentioned, the ArcView software can read and support raster formats (imagery). For this, a satellite image of the area including a pixel network grid (73496×11114) is used as the background for the maps (**Figure 9**).

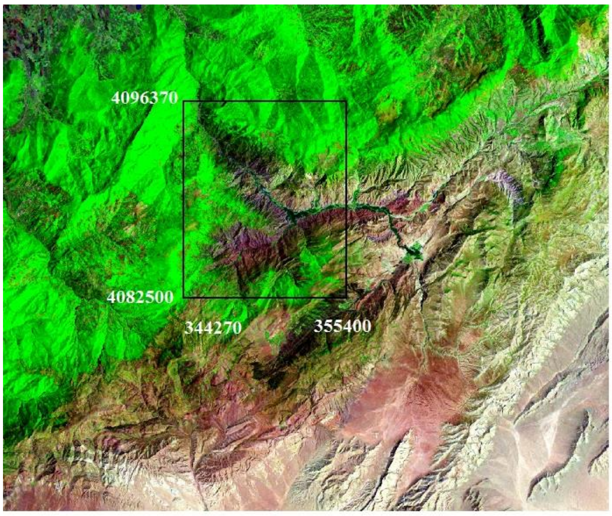

Figure 9: The satellite image of the area

Some assumptions for site selection

The following six conditions are considered for the selection of the best site for dumping the waste in the area due to the huge forested area, high precipitation, the level of the water table, and several rivers:

- Due to the high cost and time associated with building and maintaining transportation roads, the site location should not be more than 6 kilometers from the coal mine.
- The site location should be at least 2 kilometers away from any residential areas.
- The suggested pile should be at least 0.5 kilometers away from local rivers due to the possibility of AMD generation and leaching of its' products.

- The location should not be more than 1.5 kilometers from the main roads.
- Any agriculture area should be at least 0.5 Km away from the proposed site.
- Any forest area should be at least 1 Km away from the site.

Preparation of edited map based on supposed conditions in IDRISI software package

In this step, the surrounded area of each map, described in sections 3-1 to 3-7, should be valued using the maps derived from the ArcView software. Coding number 1 is assigned to the areas if they meet each condition. If not, they should have zero codings. Codes on each map should be as per **Table 1**.

Table 1: The given codes 0 and 1 to each prepared map

Type of map	Code 1 is given for the areas	Code 0 is given for the areas
Mines	0 to 5 Km far away the mine	For the area which are more than 5 Km away the mine.
The residential areas	from zero to 2 km	For the areas which have distance more than 2 Km
The rivers	More than 0.5 Km	From 0 to 0.5 km
The roads	From 0 to 1.5 Km	More than 1.5 Km
The farmlands	More than 0.5 Km	From 0 to 0.5 Km
The forest areas	More than 1 Km	From 0 to 1 Km

Figure 10 shows the prepared map after applying the codes in the IDRISI software package. The green and grey parts in the results have codes 1 and 0, respectively. Indeed, the green parts are the results. Finally, overlaying parts of the maps suggest the best location of the pile. Unfortunately, we can only have two maps to determine overlaying areas using the IDRISI software. Therefore, the overlaying maps are as follow:

- **Figure 11 (b1)** shows the overlaying map between mines and residential maps.
- The overlaying map between the maps of the rivers and roads is depicted in **Figure 11 (b2)**.
- **Figure 11 (b3)** represents the overlaying map between the farmlands and the forest areas.
- The overlaying map between maps of (b1) and (b3) is described as (C1).

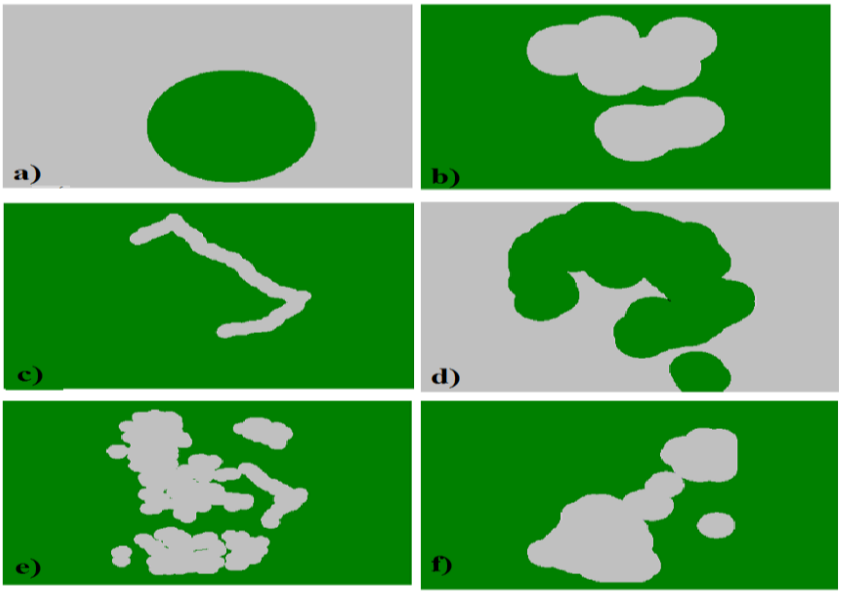

Figure 10: the prepared map after applying the codes in the IDRISI software package

Finally, the best location for dumping the waste in the area would be the overlaying map between maps of c1 and b3.

As seen in **Figure 12**, only a small area has all conditions and assumptions met. The specification of the selected area is:

- 3400 m away from the Gheshlagh mine,
- 2200 m away from the first residential area,

- 630 m distance from the nearest road,
- 770 m far from the river,
- 680 m away from the nearest farmland,
- 1365 m distance from the nearest forest area,
- The geography coordination of the proposed file is 4089500 and 352930 for longitude and latitude respectively.

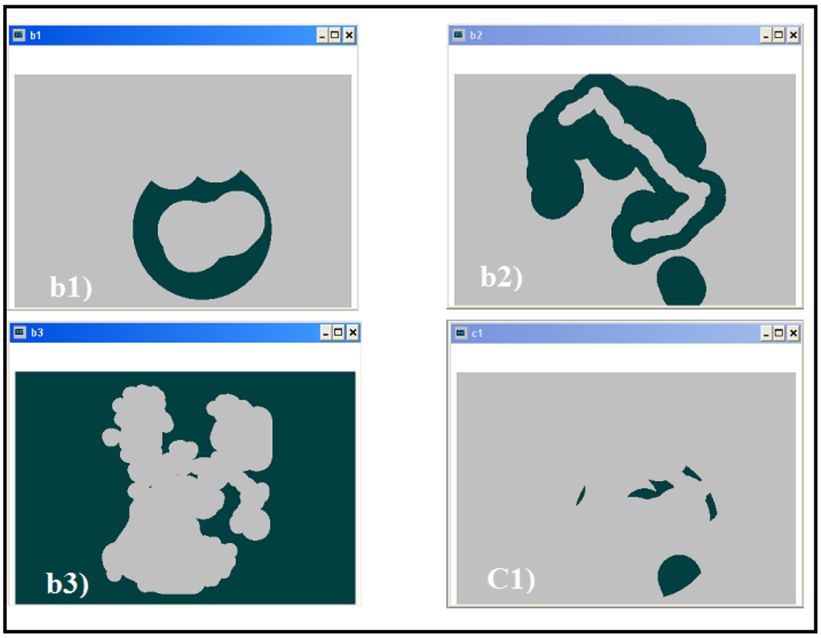

Figure 11: The overlaying maps between the results

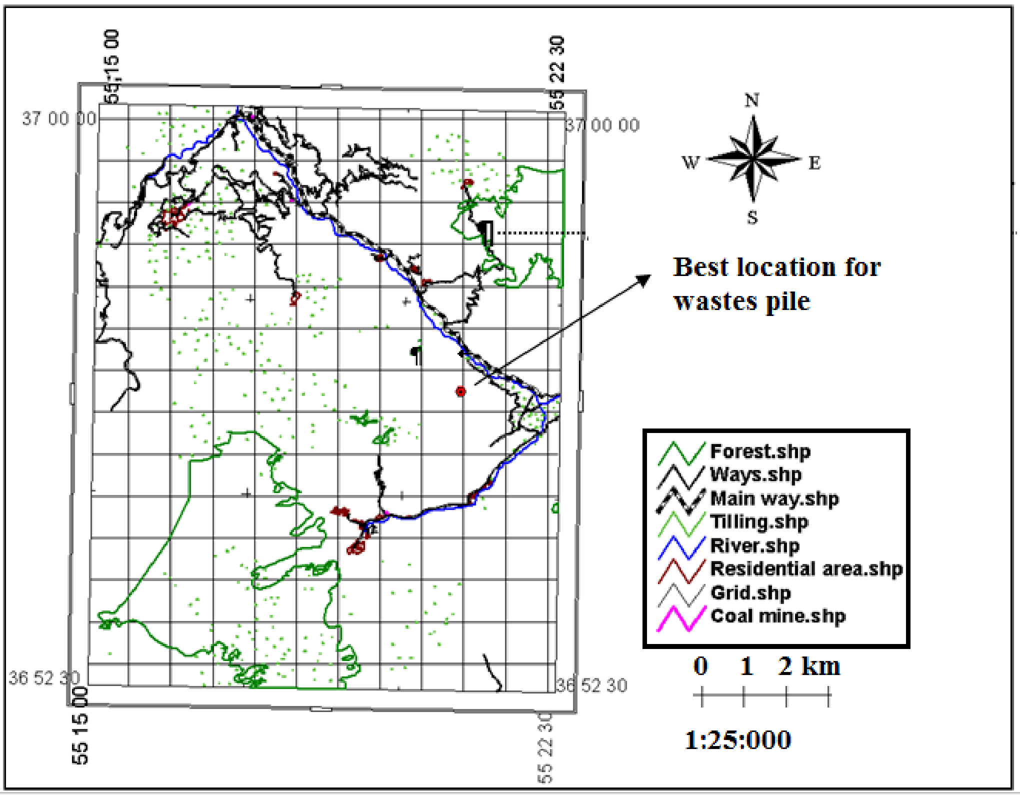

Figure 12: The best location of the suggested wastes piles

CONCLUSIONS

In this paper, the environment and mines of the Azad-Shahr were investigated briefly. The field observation revealed more than ten active coal mines and several abandoned mines in the area, producing a large amount of waste. The waste was dumped without any environmental aspects considered. This waste will generate many environmental concerns in the area in the long term. For wasting management, we first prepared required maps of the region's residential, farmlands, rivers, floods, roads, mines, and forest areas. Then these maps were imported to the ArcView software. The resulting maps were then exported to the IDRISI software package. After considering some assumptions and coding, a map of the results that indicated the best location for the waste pile was generated. Eventually, the suggested area with 27 hectares was selected near the Gheshlagh mine.

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