Literature Review on the GIS-Based Modelling and Assessment of Mining-Induced Hazards

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A systematic approach has been adopted in this literature review to study the GIS-based modelling and assessment of mining-induced hazards. In order to conduct the online research, various groups of words were used in combinations such as (a) GIS, Graphic Information System, mapping technology, remote sensors, geological study techniques, GIS software, remote sensing application, efficacy, (b) mining induced hazards, mining-related ground deformation, geo-hazards due to mining, and (c) effects, harms, consequences, upshot, impact. Different search engines and electronic databases, including Taylor & Francis, Springer, Wiley, Economic Papers, Social Science Research Network, JSTOR, SAGE's, Science Direct, PsychLit, EconLit, ERIC, Google Search, Google Scholar, and Elsevier, were used for empirical research. After an extensive search, the following core and seminal studies were found relevant to the topic under discussion.

Core Literature

The first piece of core literature chosen for incortion into the research work is the study of Zahiri (2006). It revolved around the coal mining-induced rock falls due to ground subsidence (Zahiri, 2006). To map the areas of potential mine subsidence effects, this study provided a quantitative Geographic Information System (Zahiri, 2006). The methodology provided a quantitative predicted tool for assessing the mining-induced risks associated with sensitive mine planning. It derived a probabilistic model of rock fall as a result of ground subsidence in the mining areas (Zahiri, 2006). The basic steps of the proposed quantitative Geographic Information System methodology included understanding the rock fall occurrence, processing the available data, evaluating the spatial relationship between rockfall occurrence and controlling factors, and combining these factors with the Geographic Information System maps of probabilities (Zahiri, 2006).

Moving forward, the study of Oh et al. (2011) was carried out in Kangwon-do in Korea. Thus, the study has been limited to abandoned mines in the area. The study was aimed at determining the causes of ground subsidence in those abandoned mines and the areas around them (Oh et al., 2011). Spatial data concerning geology, topology, subsidence area and various other grounds were collected using the Graphic Information System. Based on the collected data, a raster database was formed; sensitivity analysis and frequency ratio model were employed to determine the importance of the extracted factors (Oh et al., 2011).

The study revolves around the ground subsidence hazards associated with the mining activities in the

selected area (Oh et al., 2011); these hazards include the formation of depression due to the sudden collapse of the ground. They might also include compaction of sediments, i.e., slow subsidence of the ground around the Earth's surface. The literature survey of the study indicated that a vast majority of work done in the relevant field had been focused on empirically analyzing the ground subsidence hazards using artificial neural networks, fuzzy algebra, statistics, geotechnical and geological probability and investigations in tandem with the application of the Geographic Information System (Oh et al., 2011). Therefore, this study has been focused on analyzing the relationship between geotechnical and geological factors and the occurrence of ground subsidence hazards in mine-related areas due to operational activities. The results of this study will be used to map the subsidence hazards in other areas. However, the study is limited to the mining area of Kangwon-do, which has an abundance of abandoned mines. Thus, the future implication of the study lies in the fact that it can be used to predict ground subsidence in other areas (Oh et al., 2011).

In 2012, Khalifa and Arnous presented a systematic assessment of hazardous mine waste transport, which contains deposits of copper, iron and magnesium. The study was aimed at assessing and monitoring the environmental effects of such mining activities in the area of Um Bogma – a mineralized locality in west central Sinai. To achieve this objective, multi-temporal spectral remote-sensing sensors have been used by researchers (Khalifa & Arnous, 2012); these sensors are modular instruments composed of 4 spectrometers for the collection of radiations from the earth's surface. The radiations are simultaneously collected in 102 bands, i.e., Therm al-InfraRed, Mid-InfraRed, Near-InfraRed, and Visible.

The literature review of the study has indicated that many hazardous elements such as zinc, lead, manganese, copper, and iron are dispersed in the environment due to the mining of magnesium in the area specified in the study (Khalifa & Arnous, 2012). Simultaneously, more heavy metals such as sulfur, selenium, and arsenic are dispersed in the environment as well. It also indicates that mining activities can result in acid drainage, which consequently, due to the biological, chemical and physical processes, disrupts the movement of chemicals through the environment (Khalifa & Arnous, 2012). This movement plays a critical role in contaminating the soil and water with pollutants in the area under study. The tunnels and shafts are filled up with mine drainage which results in future problems of underwater contamination (Khalifa & Arnous, 2012).

The multi-temporal spectral remote-sensing sensors have been used by researchers for assessing and monitoring the environmental effects of commercial mining activities in the location under discussion (Khalifa & Arnous, 2012). The process includes the steps of identifying the contaminated areas, discriminating the contaminated areas using specific image processing, and, as the last step, studying the effects of mining-related activities on the environment. Remote sensing techniques have been proven to be a successful choice for this study due to the fact that they identified and detected changes related to acid mine problems in the area under study and the associated area as well (Khalifa & Arnous, 2012). Such techniques efficiently and quickly identify pollution sources, accurately target site evaluation and ground-truthing activities, identify specific pollution characteristics, and provide a technical and scientific foundation to suggest regional remediation plans.

The results of the study on the hazardous effects of mining activities in the area of Um Bogma using the multi-temporal spectral remote-sensing sensors have indicated a positive use and impact of the temporal imagery in the field of study of mining-related contamination (Khalifa & Arnous, 2012). The temporal imagery can directly be used through rock and mineral mapping of the waste and residual from mining-related operational activities. It also covers the relevant contaminated areas (Khalifa & Arnous, 2012). The results indicated that apart from spoil heaps and mill tailing, soil contamination in the area decreases downstream, which consequently affects the biodiversity, groundwater quality, and socioeconomics othe f Um Bogma (Khalifa & Arnous, 2012). The future implications of the study include evaluation of the intensity of contamination from a geo-environmental and digital image processing point of view (Khalifa & Arnous, 2012).

Seminal Literature

The future implications of the study presented by Khalifa and Arnous (2012) concerning the evaluation of the intensity of contamination were incorporated into the upcoming studies. A more recent study in this regard was carried out by Kim et al. in 2016. This study expanded the already existing literature by presenting the Total Mine Hazards Index. A previous index was presented by the Mine Reclamation Corporation in 2009-10. However, it was an over-simplified index which included a limited number of hazards for up to five grades only. Therefore, the current study under discussion used the Graphic Information System to collect data and present the index that was later proved to be successful enough to be applied to mine in need of attention and also the ones that have been abandoned (Kim et al., 2016).

The literature review of the study by Kim et al. (2016) presented an overview of the past studies in a systematic manner. It primarily indicated that determining which mines and associated hazards are dangerous is critical for mine reclamation planners. Such information is essential for determining the intensity of possible contamination sourced by a mine (Kim et al., 2016).

The study has been based in abandoned mine areas in Korea. Five areas of problems were identified, including mine water, waste rock dumps, mine tailings, deforestations, and mine subsidence (Kim et al., 2016). The Graphic Information System was used in combination with the statistical testing results of the mine-related hazards. A database of the Graphic Information System was utilized in the analysis, which included information on road maps, land cover data, and topographic data (Kim et al., 2016). The presented index was applied to a specific region in Korea, i.e., Gangwon-do province (Kim et al., 2016); the same area has been studied by Oh et al. (2011) as well.

The study developed a new index which included five areas of problems, including mine water, waste rock dumps, mine tailings, deforestations, and mine subsidence (Kim et al., 2016). This index, which is continuously estimated using a Graphic Information System and statistical testing, has been presented as compensation for the quantitative problems associated with the previous index presented by the Mine Reclamation Corporation. The results of the study showed that the presented

Total Mine Hazards Index could be applied to the area under study to identify the mines which are in need of any kind of attention (Kim et al., 2016). Since the index has the ability to comprehensively quantify the nature and extent of such hazards, it also supports mine reclamation planning with regard to the abandoned mines in the area under study (Kim et al., 2016). My reclamation planning is used to restore land mined in the past to a reusable state, either natural or economical. However, the only practical problem associated with this index is that it has only been applied to abandoned mines in a specific region covered under the study; it must be applied to other areas in order to support its evidential value (Kim et al., 2016).

The most seminal work on the topic under discussion is the 2017 study by Sui et al., which has focused on the mining-induced hazards related to forests, water and soil, i.e., potentially toxic elements. The study has suggested using the Geographical Information System to support the decision of reforestation after deforestation in order to reduce the mining-induced hazards primarily affecting forests and, thus, soil and water (Sui et al., 2017). The reason why the Geographic Information System has been selected for this purpose lies in the gradual progression of the studies related to water pollution, soil contaminants, and deforestation due to mining-related operational activities based on this particular methodology, which explains what belongs where (Sui et al., 2017).

Concluding Summary

Geographic Information System explains what belongs where; it is the best practical tool for mapping mining-induced hazards. Based on its vast spread applicability, the method has been used in past studies for understanding and analyzing various types of mining-related hazards, including both environmental and health hazards. The first study in this regard is by Zahiri (2006), which revolved around coal mining-induced rock fell due to ground subsidence and provided a quantitative Geographic Information System. The next study is by Oh et al. (2011), which is aimed at determining the causes of ground subsidence in those abandoned mines and the areas around them. The future implication of the study lies in the fact that it can be used in predicting ground subsidence in areas other than Kangwon-do.

This research gap was filled by Khalifa and Arnous in 2012, who presented a systematic assessment of hazardous mine waste transport and studied the environmental effects of such mining activities in the area of Um Bogma. Primarily, this study is focused on analyzing health-related hazards, including disruption of the movement of chemicals through the environment, which results in contamination of water and soil with pollutants. The future implications of the study presented by Khalifa and Arnous (2012) concerning the evaluation of the intensity of contamination were incorporated in the seminal study of Kim et al. (2016). This study presented the Total Mine Hazards Index. The index has the ability to comprehensively quantify the nature and extent of such hazards and also supports mine reclamation planning with regard to abandoned mines. The most recent work has been done by Sui et al. (2017). The study has suggested using the Geographical Information System to support the decision of reforestation after deforestation.