DOI: 10.25100/eg.v0i29.14622
Espacios y Territorios

Ranking of sustainability in the environmental model of Sangan Ore Complex

Clasificación de la sostenibilidad en el modelo ambiental del complejo minero de Sangan

Ranking de sustentabilidade no modelo ambiental do Complexo de Minério de Sangan

Mehran Baettela[1]
University of Theran, Theran, Iran. baettela.m62@ut.ac.ir | 0009-0003-4636-8484

Saeed Karimi[2]
University of Theran, Theran, Iran. karimis@ut.ac.ir | 0000-0002-8465-6052

Hamidreza Jafari[3]
University of Theran, Theran, Iran. hjafari@ut.ac.ir | 0000-0002-4376-1016

How to cite? Baettela, M., Karimi, S., y Jafari, H. (2025). Ranking of sustainability in the environmental model of Sangan Ore Complex. *Entorno Geográfico*, (29), e24914622. https://doi.org/10.25100/eg.v0i29.14622

Abstract

The mining area belongs to the ecologically fragile area, whose ecological and environmental problems have aroused the concern of researchers, for this purpose, studies are conducted in the field of environmental quality, sustainability and vulnerability of the ecosystem, ecological civilization and ecological security. To select the most appropriate indicators for the development of Sangan iron ore mines, sustainable development indicators from the main set of indicators of the Sustainable Development Commission were used. The FARE technique is based on the relationship between system parameters, that is, the direction and strength of their influence. Direction is indicated by a positive or negative, indicating that the

[1] PhD Student, University of Tehran, Kish international campus.
[2] Assistant Professor, University of Tehran, Faculty of Environment, Department of Environmental Planning, Management and Education.
[3] Professor, University of Tehran, Faculty of Environment, Department of Environmental Planning, Management and Education.

considered criterion either affects or depends on another criterion. This technique was used to evaluate environmental indicators of mines. The results show that according to the opinion of experts, in the economic dimension, the share of women in direct paid employment in the mining sector has the highest weight and the income of farmers has the lowest weight. In the social dimension, the immigration rate has the highest weight and the dependency rate has the lowest weight. In the environmental dimension, Water quality has the highest weight and endangered species has the lowest weight.

Keywords: environmental model, comprehensive assessment, iron ore mining, FARE technique and sustainable development indicators

Resumen

El área minera pertenece al área ecológicamente frágil, cuyos problemas ecológicos y ambientales han despertado la preocupación de los investigadores, para ello se realizan estudios en el campo de la calidad ambiental, la sostenibilidad y la vulnerabilidad del ecosistema, la civilización ecológica y la seguridad ecológica. Para seleccionar los indicadores más apropiados para el desarrollo de las minas de hierro de Sangan, se utilizaron indicadores de desarrollo sostenible del conjunto principal de indicadores de la Comisión de Desarrollo Sostenible. La técnica FARE se basa en la relación entre los parámetros del sistema, es decir, la dirección y la fuerza de su influencia. La dirección se indica mediante un positivo o negativo, lo que indica que el criterio considerado afecta o depende de otro criterio. Esta técnica se utilizó para evaluar los indicadores ambientales de las minas. Los resultados muestran que según la opinión de los expertos, en la dimensión económica, la participación de las mujeres en el empleo remunerado directo en el sector minero tiene el mayor peso y los ingresos de los agricultores tienen el menor peso. En la dimensión social, la tasa de inmigración tiene el mayor peso y la tasa de dependencia tiene el menor peso. En la dimensión ambiental, la calidad del agua tiene el mayor peso y las especies en peligro de extinción tienen el menor peso.

Palabras claves: modelo ambiental, evaluación integral, minería de hierro, técnica FARE e indicadores de desarrollo sostenible

Resumo

A área de mineração pertence a uma zona ecologicamente frágil, cujos problemas ecológicos e ambientais têm despertado a preocupação dos pesquisadores. Para isso, são realizados estudos no campo da qualidade ambiental, da sustentabilidade e da vulnerabilidade do ecossistema, da civilização ecológica e da segurança ecológica. Para selecionar os indicadores mais adequados ao desenvolvimento das minas de ferro de Sangan, foram utilizados indicadores de desenvolvimento sustentável do conjunto principal de indicadores da Comissão de Desenvolvimento Sustentável. A técnica FARE baseia-se na relação entre os parâmetros do sistema, ou seja, na direção e na intensidade de sua influência. A direção é indicada por um sinal positivo ou negativo, o que mostra se o critério considerado afeta ou depende de outro critério. Essa técnica foi utilizada para avaliar os indicadores ambientais das minas. Os resultados mostram que, segundo a opinião dos especialistas, na dimensão econômica, a participação das mulheres no emprego remunerado direto no setor de mineração possui o maior peso, enquanto a renda dos agricultores tem o menor peso. Na dimensão social, a taxa de imigração apresenta o maior peso e a taxa de dependência o menor. Já na dimensão ambiental, a qualidade da água possui o maior peso, enquanto as espécies ameaçadas de extinção apresentam o menor peso.

Palavras-chave: modelo ambiental, avaliação integrada, mineração de ferro, técnica FARE e indicadores de desenvolvimento sustentável

Recibido: 30 de junio de 2024 **Aceptado:** 16 de septiembre de 2024

Publicado: 1 de enero de 2025

1. Introduction

The mining area belongs to the ecologically fragile area, whose ecological and environmental problems have aroused the concern of researchers, for this purpose, they have conducted studies in the field of environmental quality, ecosystem sustainability and vulnerability, ecological civilization, and ecological security (Pessoa et al., 2023; Sohankar, 2024). In recent years, ecological risk assessments of the mining area have turned from specific to¿ comprehensive (Pan et al., 2012), which has led to the emergence of various research perspectives such as landscape (Salinas & Brugnolli, 2024; Wu et al., 2013), land degradation

(Chang et al., 2012), ecological gradient and ecological carrying capacity (Chi et al., 2021). Mining with new technologies (Mining, Minerals, and Sustainable Development, 2002); Employing skilled people (Mining, Minerals, and Sustainable Development, 2002); Preparation of important raw materials for various industries (Azapagic, 2004; Mining, Minerals, and Sustainable Development, 2002); The consensus of experts in different fields (Dold, 2008; Mining, Minerals, and Sustainable Development, 2002; Worrall et al., 2009) and government investment is accompanied (Mining, Minerals, and Sustainable Development, 2002; Worrall et al., 2009). Land use change is one of the consequences of mining. The extent of mines on the planet is less than one percent (Hooke et al., 2012), the landscape affected by mining and mineral processing extends beyond the mine site. Mining in pristine areas is a very good investment that leads to land use change and the consequences of this change on biodiversity through infrastructure and access to untouched land (Sonter et al., 2018).

2. Materials and methods

To select the most suitable indicators for the development of Sangan iron ore mines, sustainable development indicators from the main set of indicators of the Sustainable Development Commission were used (Amiri et al., 2017). The questionnaire was distributed among 20 experts from different stakeholder groups. Each participant was asked to rate the importance of each indicator on a scale of "very low" to "very high". Beneficiaries include government officials of Sangan, mine managers and engineers, professors of Khorasan Razavi province, religious leaders of Sangan region and members of local communities. Economic indicators include the length of roads, length of railways, increase in family income, farmers' income, ratio of employment to population, share of women in direct wage employment in the mining sector and the ratio of annual electricity consumption in the mining sector to the total energy consumption in Khaf city (Amiri et al., 2017). Social indicators include access to basic health facilities, access to drinking water, access to electricity and other energy sources, under-five mortality rate, nutritional status of residents, immunization against childhood infectious diseases, net enrollment rate in primary education, Net female high school enrollment rate, adult illiteracy rate, population growth rate, migration rate, dependency rate, telephone and internet users, number of drug users and life expectancy (Amiri et al., 2017). Environmental indicators include Water quality, average depth of underground aquifers, water consumption in Sangan mining complex, waste water production, air quality, solid waste production, the ratio of hygienically disposed solid waste to total production solid waste, protected areas, species at risk and area The land is devoted to mining activities (Amiri et al., 2017).

2.1. Factor Relationship Technique (FARE)

This method is based on the relationship between system parameters, that is, the direction and strength of their influence. Direction is indicated by a positive or negative, indicating that the considered criterion either influences or depends on another criterion (meaning that the criterion's influence potential either grows or decreases). This relationship is positive when the considered criterion accumulates the potential of another criterion and thus increases its influence potential. It can be seen from the figure below that in case (a), the first criterion takes part of the potential of the second criterion, therefore, their relationship is expressed as +8. In case (b), the considered criterion transfers part of its potential to the second criterion of the system, so the relationship between the first and the third criterion will be estimated as -9. Therefore, as shown in the figure below, in case (a), criterion 1 is more important than criterion 2, while in case (b), on the contrary, it is less important (see Figure 1).

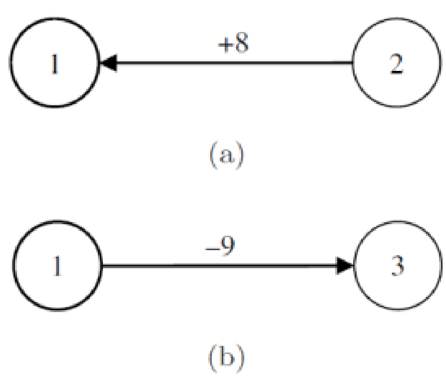

Figure 1. Relationship between system criteria

Source: Ginevičius (2011)

The FARE technique was introduced in 2011. This technique is among the methods of weighting criteria. In the figure below, as an example, we have 6 criteria that have been rated by experts. Then, based on the scale of 1 to 10, the degree of relationship between the criteria and the most important criterion (criterion 1) has been determined (see Figure 2).

Criteria	1	3	2	5	4	6
1		+9	+8	+7	+4	+3

Figure 2. Ranking of criteria by experts in FARE method

Source: Ginevičius (2011)

Then the amount of transfer of the above-mentioned effects is also determined that each number above must be subtracted from the number 10. For example, criterion number 3 must be transferred by +1 unit to criterion number 1 in order to compensate for the deficit (see Figure 3).

Criteria	1	3	2	5	4	6
1		+1	+2	+3	+6	+7

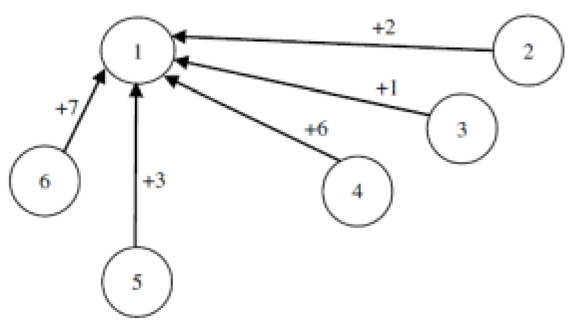

Figure 3. The extent of the transfer of effects

Source: Ginevičius (2011)

Finally, by applying the steps of this method, the final weight of the criteria is obtained, which is shown in the figure below, and the final sum of the weights is equal to one (see Figure 4).

Criteria	1	2	3	4	5	6	Total
The relationship between the main (first) criterion with other system's criteria		+2	+1	+6	+3	+7	$P_1 = 19$
Weights of criteria ω_i	0,23	0,19	0,21	0,11	0,17	0,09	$\sum_i^n \omega_i = 1.0$

Figure 4. Final weight of criteria

Source: Ginevičius (2011)

3. Results

According to the opinion of experts in the economic index, the contribution of women in direct paid employment in the mining sector is more important than all criteria. In the next step, it was determined to what extent the rest of the criteria are related to the criterion of direct paid employment in the mining sector. Based on the following spectrum, the degree of connection was determined (see Table 1).

Table 1. Linguistic spectrum of FARE method

Corresponding number	Verbal expression
1	Almost nothing
2	Very weak
3	Weak
4	Below average
5	Average
6	Above average
7	Strong
8	very strong
9	Almost absolute
10	Absolute

Source: Own elaboration

3.1. Determining the weight of sustainability dimensions by FARE

First, the potential impact of dimensions is determined. In the next step, the dimensions are ranked by experts based on their importance. According to experts, the order of dimensions is environmental, economic and social. Interrelationships between system dimensions (Table 2) are quantified based on their rank using Table 1. Table 3 indicates potential impact transferred to the first main criterion.

Table 2. Interrelationship between sustainability dimensions

	Social	Economical	Environmental
Environmental	3	2	0

Source: Own elaboration

Table 3. Potential impact transferred to the first main criterion

	Social	Economical	Environmental	Pi
Environmental	3	2	0	5
Economical	1	0	-2	-1
Social	0	-1	-3	-4

Source: Own elaboration

Finally, the weight of the dimensions was determined and tabulated in Table 4.

Table 4. The actual effect (P_i^f) and the weight of the criteria

	P_i^f	Weight
Environmental	25	0.42
Economical	19	0.32
Social	16	0.27

Source: Own elaboration

Interrelationships between different components of the Environmental dimension of the system (see Table 5) were quantified based on their rank. Table 6 shows the potential impact of different components of the Environmental dimension of the system transferred to the first main criterion.

Entorno Geográfico | N° 29 | Enero – Junio 2025 | pp. 1-18 | e24914622 | https://doi.org/10.25100/eg.v0i29.14622

Table 5. Interrelationship between different components of the Environmental dimension of the system

	Water quality	Average depth of underground aquifers	Sewage production	The ratio of disposed sanitary solid waste to total production solid waste	Protected areas	Water consumption in Sangan mining complex	The area of land devoted to mining activities	Air quality	Solid waste production	Endangered species
Water quality	0	1	1	2	2	3	4	5	6	7

Source: Own elaboration

Table 6. The potential impact of different components of the Environmental dimension of the system transferred to the first main criterion

	Water quality	Average depth of underground aquifers	Sewage production	The ratio of disposed sanitary solid waste to total production solid waste	Protected areas	Water consumption in Sangan mining complex	The area of land devoted to mining activities	Air quality	Solid waste production	Endangered species	Pi
Water quality	7	6	5	4	3	2	2	1	1	0	31
Average depth of underground aquifers	6	5	4	3	2	1	1	0	0	-1	21
Sewage production	6	5	4	3	2	1	1	0	0	-1	21
The ratio of disposed sanitary solid waste to total production solid waste	5	4	3	2	1	0	0	-1	-1	-2	11
Protected areas	5	4	3	2	1	0	0	-1	-1	-2	11
Water consumption in Sangan mining complex	4	3	2	1	0	-1	-1	-2	-2	-3	1
The area of land devoted to mining activities	3	2	1	0	-1	-2	-2	-3	-3	-4	-9
Air quality	2	1	0	-1	-2	-3	-3	-4	-4	-5	-19
Solid waste production	1	0	-1	-2	-3	-4	-4	-5	-5	-6	-29
Endangered species	0	-1	-2	-3	-4	-5	-5	-6	-6	-7	-39

Source: Own elaboration

Finally, the weight of the dimensions was determined and tabulated in Table 7.

Table 7. Actual effect (P_i^f) and weight of different components of the Environmental dimension of the system

	P_i^f	Weight
Water quality	121	0.13
Average depth of underground aquifers	111	0.12
Sewage production	111	0.12
The ratio of disposed sanitary solid waste to total production solid waste	101	0.11
Protected areas	101	0.11
Water consumption in Sangan mining complex	91	0.10
The area of land devoted to mining activities	81	0.09
Air quality	71	0.08
Solid waste production	61	0.07
Endangered species	51	0.06

Source: Own elaboration

Interrelationships between different components of the social dimension (see Table 8) were quantified based on their rank. Table 9 shows the potential impact of different components of the social dimension transferred to the first main criterion.

Table 8. Interrelationship between different components of the Social dimension

	Immigration rate	Access to electricity and other energy sources	Access to drinking water	Immunization against childhood infectious diseases	Mortality rate under five years	Nutritional status of residents	life expectancy	Access to basic health facilities	Phone and Internet users	Net enrollment rate in primary education	Net enrollment rate of women in high school	Number of drug users	Population growth rate	Adult illiteracy rate	Dependency rate
Immigration rate	0	10	10	10	10	9	8	8	8	7	7	6	5	5	4

Source: Own elaboration

Table 9. The potential impact of different components of the social dimension transferred to the first main criterion

	Immigration rate	Access to electricity and other energy sources	Access to drinking water	Immunization against childhood infectious diseases	Mortality rate under five years	Nutritional status of residents	life expectancy	Access to basic health facilities	Phone and Internet users	Net enrollment rate in primary education	Net enrollment rate of women in high school	Number of drug users	Population growth rate	Adult illiteracy rate	Dependency rate	P
Immigration rate	0	10	10	10	10	9	8	8	8	7	7	6	5	5	4	107
Access to electricity and other energy sources	-10	0	0	0	0	-1	-2	-2	-2	-3	-3	-4	-5	-5	-6	-43
Access to drinking water	-10	0	0	0	0	-1	-2	-2	-2	-3	-3	-4	-5	-5	-6	-43
Immunization against childhood infectious diseases	-10	0	0	0	0	-1	-2	-2	-2	-3	-3	-4	-5	-5	-6	-43
Mortality rate under five years	-10	0	0	0	0	-1	-2	-2	-2	-3	-3	-4	-5	-5	-6	-43
Nutritional status of residents	-9	1	1	1	1	0	-1	-1	-1	-2	-2	-3	-4	-4	-5	-28
life expectancy	-8	2	2	2	2	1	0	0	0	-1	-1	-2	-3	-3	-4	-13
Access to basic health facilities	-8	2	2	2	2	1	0	0	0	-1	-1	-2	-3	-3	-4	-13
Phone and Internet users	-8	2	2	2	2	1	0	0	0	-1	-1	-2	-3	-3	-4	-13
Net enrollment rate in primary education	-7	3	3	3	3	2	1	1	1	0	0	-1	-2	-2	-3	2
Net enrollment rate of women in high school	-7	3	3	3	3	2	1	1	1	0	0	-1	-2	-2	-3	2
Number of drug users	-6	4	4	4	4	3	2	2	2	1	1	0	-1	-1	-2	17
Population growth rate	-5	5	5	5	5	4	3	3	3	2	2	1	0	0	-1	32
Adult illiteracy rate	-5	5	5	5	5	4	3	3	3	2	2	1	0	0	-1	32
Dependency rate	-4	6	6	6	6	5	4	4	4	3	3	2	1	1	0	47

Source: Own elaboration

Finally, the weight of the dimensions was determined and tabulated in Table 10.

Table 10. Actual effect (P_i^f) and weight of different components of the social dimension

	P_i^f	Weight
Immigration rate	247	0.12
Access to electricity and other energy sources	97	0.05

Access to drinking water	97	0.05
Immunization against childhood infectious diseases	97	0.05
Mortality rate under five years	97	0.05
Nutritional status of residents	112	0.05
life expectancy	127	0.06
Access to basic health facilities	127	0.06
Phone and Internet users	127	0.06
Net enrollment rate in primary education	142	0.07
Net enrollment rate of women in high school	142	0.07
Number of drug users	157	0.07
Population growth rate	172	0.08
Adult illiteracy rate	172	0.08
Dependency rate	187	0.09

Source: Own elaboration

Interrelationships between different components of the Economical dimension (see Table 11) were quantified based on their rank. Table 12 indicates the potential impact of different components of the Economical dimension transferred to the first main criterion.

Table 11. Interrelationship between different components of the Economical dimension

	the share of women in direct paid employment in the mining sector	Employment to population ratio	Increase family income	The ratio of annual electricity consumption in the mining sector to the total energy consumption in Khaf city	The length of the roads	The length of the railway	Farmers' income
the share of women in direct paid employment in the mining sector	0	1	2	4	5	6	7

Source: Own elaboration

Table 12. The potential impact of different components of the Economical dimension transferred to the first main criterion

	The share of women in direct paid employment in the mining sector	Employment to population ratio	Increase family income	The ratio of annual electricity consumption in the mining sector to the total energy consumption in Khaf city	The length of the roads	The length of the railway	Farmers' income	Pi
The share of women in direct paid	0	1	2	4	5	6	7	25

employment in the mining sector								
Employment to population ratio	-1	0	1	3	4	5	6	18
Increase family income	-2	-1	0	2	3	4	5	11
The ratio of annual electricity consumption in the mining sector to the total energy consumption in Khaf city	-4	-3	-2	0	1	2	3	-3
The length of the roads	-5	-4	-3	-1	0	1	2	-10
The length of the railway	-6	-5	-4	-2	-1	0	1	-17
Farmers' income	-7	-6	-5	-3	-2	-1	0	-24

Source: Own elaboration

Finally, weight of dimensions were determined and tabulated in Table 13.

Table 13. Actual effect ($\boldsymbol{P_i^f}$) and weight of different components of the Economical dimension

	P_i^f	Weight
The share of women in direct paid employment in the mining sector	85	0.20
Employment to population ratio	78	0.19
Increase family income	71	0.17
The ratio of annual electricity consumption in the mining sector to the total energy consumption in Khaf city	57	0.14
The length of the roads	50	0.12
The length of the railway	43	0.10
Farmers' income	36	0.09

Source: Own elaboration

4. Discussion and conclusion

In this study, the FARE method was used in order to prioritize the criteria in the Environmental model (sustainability dimensions). The steps of this method are mentioned in detail in the materials and methods section. Based on the obtained results, in the economic dimension, the share of women in direct paid employment in the mining sector has the highest weight and farmers' income has the lowest weight. Direct employment refers to those who are employed by the company that is the owner and head of the mine. Contractor employees are usually included in this statement if their usual place of work is in a mine (Östensson, 2014). Therefore, women have a great influence in this sector. The results of Assan &

Muhammed (2018) showed that households living near mining sites engage in less agricultural activities because large tracts of agricultural land have been lost due to mining operations. A study by Moffatt and Baker (2013) found that the proposal of a mine in a farming community can have a strong negative psychological impact and put an already at-risk group at greater risk for suicide. Obviously, there are some stresses due to the nature of the society, such as an agricultural society with close family ties that go back many generations. In the social dimension, immigration rate has the highest weight and dependency rate has the lowest weight. Mining settlements are often located in areas with limited economic activities, and mining is essentially the only viable employment option for most residents – especially the migrant population (Magill, 1964; Marais & Cloete, 2013). The closure of mines is often accompanied by significant emigration from the city and the region, which is now economically depressed (Magill, 1964). An alternative outcome is the occurrence of intra-urban migration after mine closure. Ex-miners often have to move to a new home (Bastia, 2011). In the Environmental dimension, water quality has the highest weight and endangered species has the lowest weight. Northey et al. (2016) reported that mining operations have significant adverse effects on water quality. Mining with risks such as: possible flooding of pits, uncontrolled discharges and catastrophic collapse of water pollution control dams. Khan et al. (2013) stated mining poses a great risk to people's access to clean drinking water. Acid mine drainage is a mineral waste that is mostly produced from gold, coal and copper mining operations. Regmi et al. (2009) mentioned that this wastewater is characterized by low pH and high heavy elements. According to a study by Mulopo (2015), acid mine drainage is characterized by total dissolved solids, high sulfate, and high levels of heavy metals, especially iron, manganese, nickel, and cobalt. Acidic water drainage occurs when mining operations related to pyrite (iron disulfide) materials are exposed to oxygen and water (Mhlongo et al., 2018).

5. Bibliographical references

Amiri, R., Kretschmann, J., Martens, P., & Langefeld, O. (2017). *Sustainable strategic management of Sangan iron ore mines in Iran* [Doctoral Thesis, Rwthaachen University]. https://tinyurl.com/48auh45n

Assan, J., & Muhammed, A. (2018). The impact of mining on farming as a livelihood strategy and its implications for poverty reduction and household well-being in Ghana. *International Journal of Development and Sustainability*, *7*(1), 1-20. https://tinyurl.com/y5r6nhab

Azapagic, A. (2004). Developing a framework for sustainable development indicators for the mining and minerals industry. *Journal of Cleaner Production*, *12*(6), 639-662. https://doi.org/10.1016/S0959-6526(03)00075-1

Bastia, T. (2011). Should I stay or should I go? Return migration in times of crises. *Journal of International Development*, *23*(4), 583-595. https://doi.org/10.1002/jid.1794

Chang, Q., Qiu, Y., Xie, M., & Peng, J. (2012). Theory and method of ecological risk assessment for mining areas based on the land destruction. *Acta Ecologica Sinica*, *32*(16), 5164-5174. https://doi.org/10.5846/stxb201108031140

Chi, M., Zhang, D., Zhao, Q., Yu, W., & Liang, S. (2021). Determining the scale of coal mining in an ecologically fragile mining area under the constraint of water resources carrying capacity. *Journal of Environmental Management, 279*, 111621. https://doi.org/10.1016/j.jenvman.2020.111621

Dold, B. (2008). Sustainability in metal mining: from exploration, over processing to mine waste management. *Reviews in Environmental Science and Bio/Technology*, *7*(4), 275-285. https://doi.org/10.1007/s11157-008-9142-y

Ginevičius, R. (2011). A new determining method for the criteria weights in multicriteria evaluation. *International Journal of Information Technology & Decision Making, 10*(06), 1067-1095. https://doi.org/10.1142/s0219622011004713

Hooke, R., Martín, J., & Pedraza, J. (2012). Land transformation by humans: A review. *GSA Today*, *22*(12), 4-10. https://doi.org/10.1130/GSAT151A.1

Khan, S., Shahnaz, M., Jehan, N., Rehman, S., Shah, M., & Din, I. (2013). Drinking water quality and human health risk in Charsadda district, Pakistan. *Journal of Cleaner Production*, *60*, 93-101. https://doi.org/10.1016/j.jclepro.2012.02.016

Magill, D. (1964). *Migration and occupational mobility from a Nova Scotia coal mining town* [Master's thesis, McGill University]. https://tinyurl.com/3kxwe8tm

Marais, L., & Cloete, J. (2013). Labour migration, settlement and mine closure in South Africa. *Geography*, *98*(2), 77-84. https://doi.org/10.1080/00167487.2013.12094371

Mhlongo, S., Mativenga, P., & Marnewick, A. (2018). Water quality in a mining and water-stressed region. *Journal of Cleaner Production*, *171*, 446-456. https://doi.org/10.1016/j.jclepro.2017.10.030

Mining, Minerals, and Sustainable Development. (2002). *Breaking New Ground: Mining, Minerals and Sustainable Development (MMSD) Final* Report. Earthscan. https://tinyurl.com/mreswjnu

Moffatt, J., & Baker, P. (2013). Farmers, mining and mental health: The impact on a farming community when a mine is proposed. *Rural Society*, *23*(1), 60-74. https://doi.org/10.5172/rsj.2013.23.1.60

Mulopo, J. (2015). Continuous pilot scale assessment of the alkaline barium calcium desalination process for acid mine drainage treatment. *Journal of Environmental Chemical Engineering*, *3*(2), 1295-1302. https://doi.org/10.1016/j.jece.2014.12.001

Northey, S., Mudd, G., Saarivuori, E., Wessman-Jääskeläinen, H., & Haque, N. (2016). Water footprinting and mining: Where are the limitations and opportunities? *Journal of Cleaner Production*, *135*, 1098-1116. https://doi.org/10.1016/j.jclepro.2016.07.024

Östensson, O. (2014). The employment effect of mine employees' local expenditure. *Mineral Economics*, *27*, 135-142. https://doi.org/10.1007/s13563-014-0056-6

Pan, Y., Wang, Y., Peng, J., & Han, Y. (2012). Research progress in ecological risk assessment of mining area. *Shengtai Xuebao/Acta Ecologica Sinica*, *32*(20), 6566-6574. https://doi.org/10.5846/stxb201110191553

Pessoa, A., Silva, S., & Barbosa, I. (2023). Mapping of areas vulnerable to flooding in Tejipió basin river, in Pernambuco, Brazil. *Entorno Geográfico,* (26), e22413055. https://doi.org/10.25100/eg.v0i26.13055

Regmi, G., Indraratna, B., & Nghiem, L. (2009). Long-term Performance of a Permeable Reactive Barrier in Acid Sulphate Soil Terrain. *Water, Air, & Soil Pollution: Focus*, *9*, 409-419. https://doi.org/10.1007/s11267-009-9230-1

Salinas, E., & Brugnolli, R. (2024). Methodological proposal for landscape management in the Formoso river basin, Ms/Brazil. *Entorno Geográfico,* (27), e23413330. https://doi.org/10.25100/eg.v0i27.13330

Sohankar, Z. (2024). Evaluating the safety and aesthetic of a city park (Case study: Saee Park in Tehran). *Entorno Geográfico*, (28), e24013342. https://doi.org/10.25100/eg.v0i28.13342

Sonter, L., Ali, S., & Watson, J. (2018). Mining and biodiversity: key issues and research needs in conservation science. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1892), 20181926. https://doi.org/10.1098/rspb.2018.1926

Worrall, R., Neil, D., Brereton, D., & Mulligan, D. (2009). Towards a sustainability criteria and indicators framework for legacy mine land. *Journal of Cleaner Production*, *17*(16), 1426-1434. https://doi.org/10.1016/j.jclepro.2009.04.013

Wu, J., Qiao, N., Peng, J., Huang, X., Liu, J., & Pan, Y. (2013). Spatial variation of landscape eco-risk in open mine area. *Acta Ecologica Sinica*, *33*(12), 3816-3824. https://doi.org/10.5846/stxb201207301083