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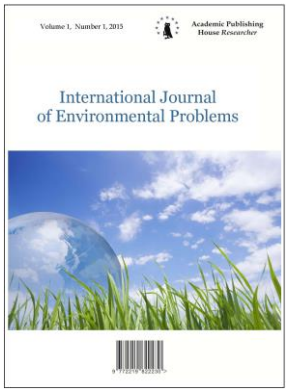

Application of Analytical Hierarchy Process (AHP) Technique to Evaluate the Combined Impact of Coal Mining on Land Use and Environment. A Case Study in the Ha Long City, Quang Ninh province, Vietnam

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Abstract

Coal mining is an important contributor to Vietnam's GDP, however, it also seriously effects on the environment. This study presents the results of impact assessment of coal mining on land use/land cover, water resources and urban landscape in Ha Long city, Quang Ninh province, North East of Vietnam. The study was conducted in the basis of an analysis of samples (12 soil samples, 5 surface water samples and 5 groundwater samples) and AHP hierarchical technique through a survey of 40 households, 30 managers and 30 technicians in the coal mining area. The results obtained in this study show that land use change in coal area of Ha Long city is proportional to annual coal production, in which agricultural land, residential land, river and stream water are the factors most affected by coal mining.

Keywords: coal mining, environment, land use, AHP, Vietnam.

1. Introduction

Mineral resources are one of the most important natural resources of each country. Minerals are the source material for many industries, such as energy production, building materials, metal, for agricultural, industrial.... Mineral mining is one of the most important economic activities in Vietnam, it also seriously affects the land cover, natural ecosystems, and human living environment at varying degrees. Ha Long City – the center of Quang Ninh province has big reserves of coal with over 530 million tons of coal and the potential for mining is huge. In recent years, environmental quality in Ha Long city is severely degraded. In fact, most of soil, water and air in coal area of Ha Long city has been infiltrated mixed in many different types of toxic, seriously affect the living environment (Ha Long City People's Committee, 2015). Up to now, there is no scientific research that has been fully evaluated about the impacts of coal mining activities in the coal mine area of Ha Long city. Therefore, the purpose of the study was to evaluate the impact of coal mining on the surrounding environment specifically on land cover/land use and water, to contribute to environmental improvement after mining and to optimize land use allocation for sustainable development.

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2. Materials and Method

The secondary data are collected at the Ha Long City People's Committee and some other related departments. These documents have been issued which related to natural and socio-economic conditions, coal mining activities and the impacts of coal mining on land use, landscape and water resources in Ha Long area.

Besides, this study examined the comments of local people (40 votes), management staff (30 votes) and technical staff of enterprises in Ha Long coal mine (30 votes) about the impact of coal mining on land use/land cover.

The study was conducted on the basis of an analysis of samples (12 soil samples, 5 surface water samples and 5 groundwater samples). Samples were collected during the survey in March 2015. Sampling sites were selected at the Nam Lo Phong waste disposal sites, surrounding area of coal mining sites, coastal areas and areas with tourist activities.

Finally, analytical hierarchy process (AHP) method was used to evaluate the impact of coal mining on soil quality and land use, water quality and landscape (Figure 1). The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. Created by Thomas L. Saaty in the 1970s, this method consists in the development of a model that reflects the workings of the human mind in the evaluation of the alternatives facing a complex decision problem. Up to now, this method has been widely applied in many fields such as land use, geology, environment, agriculture, economy and military (Adi Setiawan, 2014; Cengiz, 2009; Le Canh Dinh, Tran Trong Duc, 2011).

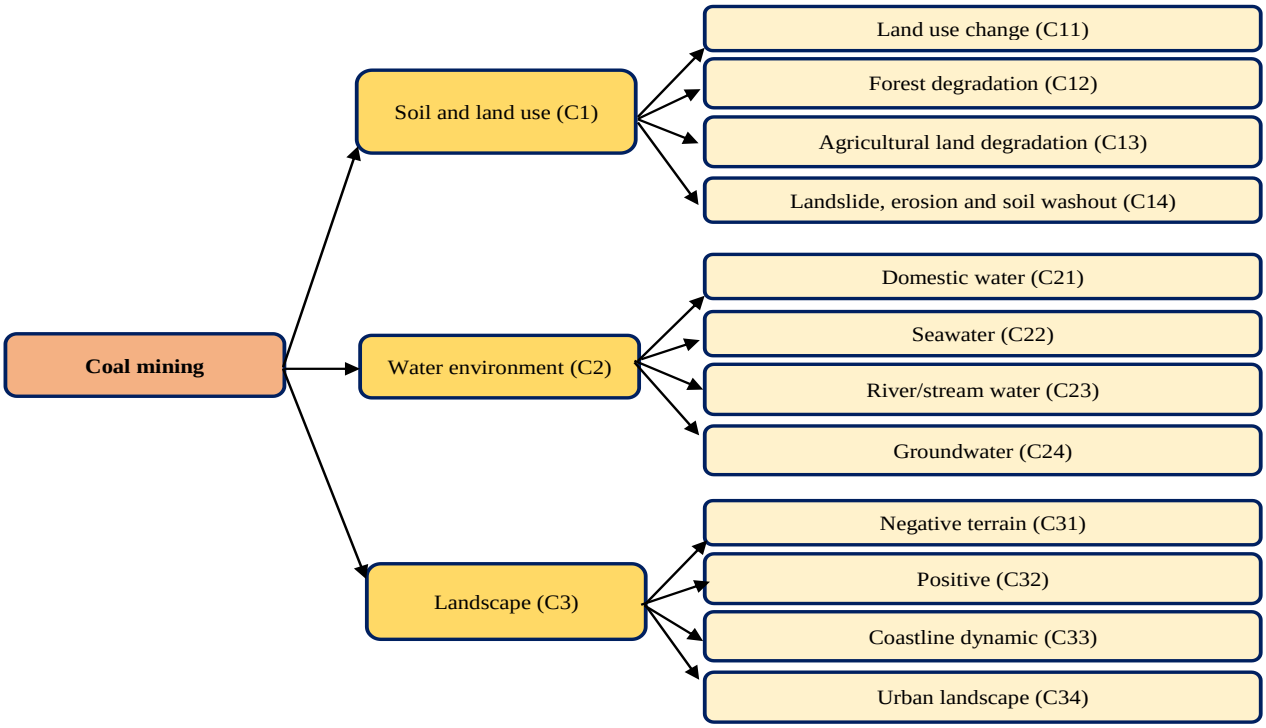

Fig. 1. The variables used in AHP model

3. Results and Discussion

There are numerous damaging environmental impacts of coal that occur through its mining, preparation, combustion, waste storage, and transport. The results of the component impact assessment show that coal mining has the strongest impact to the agricultural and residential land, water resources and landscape. Therefore, the combined impact assessment of coal mining activities in coal area of the Ha Long city is based on three groups: land use, water resources and landscape (Figure 1).

a) Pairwise comparison (Saaty's AHP) amd calculating the AHP weight (order = 1) (factors affected)

The results of the AHP calculations show that land use (w = 0.79) was the most strongly affected by

coal mining. Water resources (w = 0.13) and landscapes (w = 0.08) are secondary and tertiary factors, which affected by coal mining. The CI value (<0.01) reflects the rationality in the calculation (Table 1).

Table 1. Pairwise comparison (Saaty's AHP) and the weight of impact of coal mining on environment (Saaty's matrix of order 1)

Factor	Variable	C1	C2	C3	Weight (Wi)	Level of impact
Land use	C1	1	4	7	0,79	1
Water resources	C2	1/4	1	3	0,13	2
Landscape	C3	1/7	1/3	1	0,08	3

The weight values of AHP are verified by comment of people using survey votes. The results show that land resources and land use are the most strongly affected by coal mining (40/40 votes), water resources is secondary (38/40) and landscape (25/40) is tertiary affected by coal mining (Table 2).

Table 2. Summary of survey result of impact of coal mining on the environment

Factor	Number of votes	Rate of votes (%)
Land use	40/40	100
Water resources	38/40	95
Landscape	25/40	62,5

b) Pairwise comparison (Saaty's AHP) amd calculating the AHP weight (order = 2)

After determination of the impact of coal mining activities on the factors of matrix of order 1, this study assesses the level of impact in each major level.

The first is the impact on agricultural land and residential land. This group has four components which are determined to be most affected by coal mining: forest appropriation, forest degradation, waste rock and landslide.

If CI value less than 0.1, then the calculation result is accepted. It can be seen that the weight of landslide factor is highest (w = 0.54), that is the coal mining activities have the strongest impact on the removal of rock material on the surface of the mining area. This not only affects mining operations but also affect the environment and landscape of coal mining activities. Soil pollution due to waste rock has the second highest weight value (w=0.31). The impact of these two factors is not as strong as that of waste rock and landslides (w = 0.17 and 0.13).

Pollution from coal mining may have a negative impact on surface water and groundwater. The results obtained show that the impact of coal mining on river and stream water resources is strongest (w=0.53). Groundwater (w=0,31), sea water (w=0,11) and domestic water (w=0,05) are less affected from coal mining activities.

Table 3. Pairwise comparison (Saaty's AHP) and the weight of impact of coal mining on land use (Saaty's matrix of order 2)

Factor	Variable	Forest appropriation (C_{11})	Forest degradation (C_{12})	Waste rock (C_{13})	Landslide (C_{14})	Weight W(i)	Level
Forest appropriation	C_{11}	1,00	2,00	0,25	0,17	0,09	3
Forest degradation	C_{12}	0,50	1,00	0,20	0,13	0,06	4
Waste rock	C_{13}	4,00	5,00	1,00	0,50	0,31	2
Landslide	C_{14}	6,00	8,00	2,00	1,00	0,54	1
Total		11,50	16,00	3,45	1,79	1,00	

(CI = 0,01)

Table 4. Pairwise comparison (Saaty's AHP) and the weight of impact of coal mining on water resources (Saaty's matrix of order 2)

Factor	Variable	Domestic water (C_{21})	Sea water (C_{22})	River/stream water (C_{23})	Groundwater (C_{24})	Weight W(i)	Level
Domestic water	C_{21}	1,00	0,33	0,13	0,17	0,05	4
Sea water	C_{22}	3,00	1,00	0,20	0,25	0,11	3
River/stream water	C_{23}	8,00	4,00	1,00	3,00	0,53	1
Groundwater	C_{24}	5,00	6,00	0,33	1,00	0,31	2
Total		11,50	16,00	3,45	1,79	1,00	

(CI =0,08)

Coal mining has also affected the landscape, in which urban landscape is the most affected by coal mining activities (w = 0.5). Meanwhile, the coastline change is not much affected by coal mining (w = 0.07).

Table 5. Pairwise comparison (Saaty's AHP) and the weight of impact of coal mining on landscape (Saaty's matrix of order 2)

Factor	**Variable**	**Negative terrain (C_{31})**	**Positive terrain (C_{32})**	**Coastline dynamic (C_{33})**	**Urban landscape (C_{34})**	**Weight W(i)**	**Level**
Negative terrain	C_{31}	1,00	0,33	2,00	0,25	0,12	3
Positive terrain	C_{32}	3,00	1,00	5,00	0,50	0,31	2
Coastline dynamic	C_{33}	0,50	0,20	1,00	0,17	0,07	4
Urban landscape	C_{34}	4,00	2,00	6,00	1,00	0,50	1
Total		8,50	3,53	14,00	1,92	1,00	

(CI = 0,01)

To verify the results obtained by application of AHP technique for assessing the impact of coal mining activities on environment and land use/land cover, in this study we use the information collected through the social survey. The questionnaire was designed with 7 questions, the respondents are the people who live in areas directly and indirectly affected by coal mining (40 questionnaires in Ha Tu, Ha Lam and Ha Khanh wards). The results which obtained show that all questionnaires were selected that "coal mining causes landslides" in coal area of Ha Long city. Most questionnaires were selected that "coal mining causes soil pollution and forest degradation". Finally, the factors that most people consider least affected by coal mining activities are domestic water (15/40 votes), negative terrain (15/40 votes), positive terrain (15/40 votes) and coastline change (10/40 votes).

4. Conclusion

Based on this study, it shows that coal mining has a great impact on natural resources and environment in Ha Long city, Quang Ninh province, especially for land use, water resources and urban landscape. Land use change in Ha Long city is proportional to coal production. Soil erosion and landslide not only affected the quality of soil, but also threatening the resilience and the plan for reverting and reusing in coal mining areas. Waste disposal sites in study area (Nam Lo Phong, Chinh Bac, Ha Tu…) were located near residential areas, coastlines, upstream and seriously affecting the water quality.

The results obtained in this paper can be used to assess the impact of coal mining on natural resources and the environment and to help managers to take measures to minimize these negative effects.

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