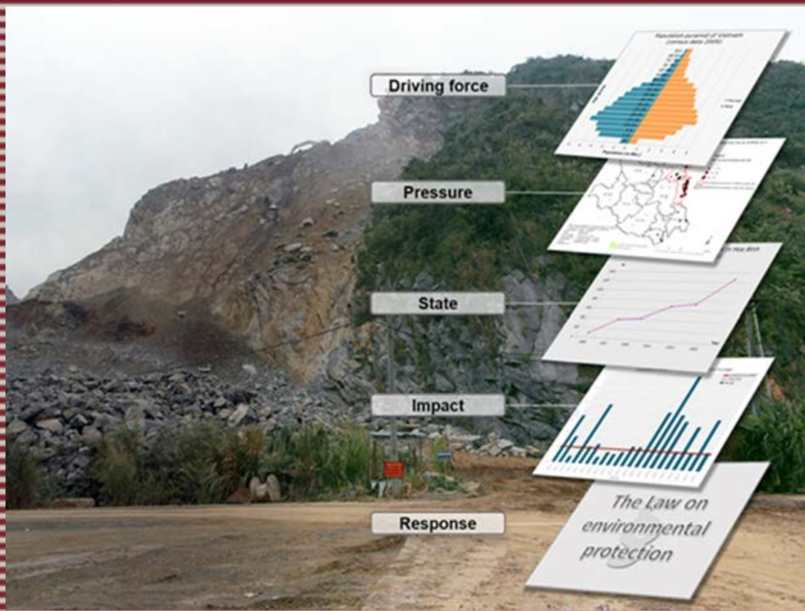
technische universität
dortmund



Monitoring of mineral resource extraction and analyzing its impacts on the environment and land cover/land use in Hoa Binh Province

MAREX Publication Series – Issue 2

IMPRINT

Monitoring of mineral resource extraction and analyzing its impacts on the environment and land cover/land use in Hoa Binh Province

Results of the project MAREX: Management of Mineral Resource Extraction in Hoa Binh Province – a Contribution to Sustainable Development in Vietnam (2015-2018)

Supported by BMBF, Grant Code FKZ 033R122A

Issue 2

Internet: www.marex-project.de

Editor, Responsible for the contents
Univ.-Prof. Dr. rer. nat. habil. Nguyen Xuan Thinh
TU Dortmund University
Department of Spatial Information Management and Modelling (RIM)
August-Schmidt-Straße 10
44227 Dortmund, GERMANY
Phone: +49 (0231) 755-2247
Fax: +49 (0231) 755-2508
E-Mail: nguyen.thinh@tu-dortmund.de
Homepage: https://rim.raumplanung.tu-dortmund.de/

Authors
M.Sc. Haniyeh Ebrahimi Salari (TU Dortmund)
Univ.-Prof. Dr. rer. nat. habil. Nguyen Xuan Thinh (TU Dortmund)

Design and Layout
Natalija Leutert

Editorial deadline August 2018

ISBN 978-3-933053-43-5

Monitoring of mineral resource extraction and analyzing its impacts on the environment and land cover/land use in Hoa Binh Province

Preface

Hoa Binh is a province in the northwestern mountain region of Vietnam, situated in the west of Ha Noi and borders the provinces Phu Tho, Ha Nam, Ninh Binh, Son La, and Thanh Hoa. Hoa Binh is known for its natural beauty, picturesque landscape and the cultural wealth, e. g. mountain villages, the Mai Chau Valley, the Ba Khan Valley, and the Black River Reservoir. These resources and scenic beauty must be preserved and sustainably managed and developed. But industrialisation, modernisation and the immediate neighbourhood to the Hanoi construction boom centre have led to massive and uncoordinated mining activities for many years in Hoa Binh with the known environmental impacts, e. g. devastation of landscape, soil degradation, loss of biodiversity, contamination of air, water and soil. The use of explosives can cause damage to nearby houses. Drilling and blasting, crushing and grinding, loading and extracting construction minerals such as limestone and basalt cause a lot of dust and noise, causing the unbearable suffering of the population in the mining area. Therefore the administration in Hoa Binh needs a monitoring system to be able to answer such questions exactly and effectively: where, what, how much is mined, what effects and the extent of the effects are determined by whom and where?

This leaflet presents findings, calculated and analysed results as well as the software tool developed for mining industry and administration as output of the Module 1 of the joint project “Management of Mineral Resource Extraction in Hoa Binh Province – a Contribution to Sustainable Development in Vietnam” (MAREX), funded by the German Federal Ministry of Education and Research (BMBF) and the Vietnam Ministry of Science and Technology (MoST). The responsible project partner for this module in Germany is the Department of Spatial Information Management and Modelling (RIM) of the School of Spatial Planning, TU Dortmund University. The authors Nguyen Xuan Thinh and Haniyeh Ebrahimi Salari thank Esther Bradel and Katja Schimohr. They have partly participated in the project as student assistants. We want to thank the leader of MAREX project in Vietnam, Prof. Dr. Pham Ngoc Ho from the Institute of Environment and Automation (IEA), Hanoi, and Dr. Duong Ngoc Bach, Vice Director of the Research Center for Environmental Monitoring and Modelling (CEMM) for the long-term and fruitful cooperation, especially for the many discussions, exchange of experiences and support of the field research in Hoa Binh during the three years of work on the project. Furthermore, we owe thanks to the People’s Committee and the Department of Natural Resources and Environment (DoNRE) of the Hoa Binh Province for the good cooperation, accompaniment and support of the inspections of mining sites and monitoring stations and the recording of field data, especially to the Vice Chairman of the province Dr. Bui Van Khanh and Dr. Nguyen Khac Long from DoNRE Hoa Binh.

We want also thank all members of the German MAREX Consortium, especially to the project leader, Prof. Dr. Dr. h. c. Bernhard Müller, Dr. Peter Wirth, and Dr. Georg Schiller from the Leibniz Institute of Ecological Urban and Regional Development (IOER) and Dr. Paulina Schiappacasse from the TU Dresden, for the successful conducting of the project, for the numerous inspiring and intensive discussions as well as for the joint field work in Hoa Binh. The leader of the Module 1 think we have learned a lot during the years of the project work and we have together made many lasting experiences about the implementation of projects in Vietnam.

One elementary prerequisite for monitoring and modelling the environmental impact of resource extraction is reliable information and GIS data on the current state of the mining environmental system in Hoa Binh Province. A comprehensive geo-database has been designed to support specific analysis workflows and data storage needs. Monitoring means defining study areas and measurement sites, planning and carrying out measurements, creating, analysing and evaluating indicators, and reporting in the form of texts, illustrations and maps.

In order to gain better insights into the process in the environment and into the impact relationship between mining activities and the environment, we embed the monitoring of the mining environmental system into the Driver-Pressure-State-Impact-Response (DPSIR) model.

Based on the classification of satellite images Landsat (30 m spatial resolution), Sentinel-2 (10-60 m), and SPOT 6 (1.5 m) we could provide new and valuable data on land cover and land use in Hoa Binh. Our findings show rapid and high increase of mining areas and that mining activities are especially high in the district Luong Son and where there are land use conflicts.

The measurement data, provided by Hoa Binh and IEA, from Air Monitoring Stations, Soil Monitoring Stations, Surface and Ground Water Monitoring Stations and Waste Water Monitoring Stations for the Luong Son district for two points in time (dry season and rainy season) in 2016 were imported into GIS, classified, evaluated according to Vietnamese and international limit values and visualised in the form of maps. Exceedances of limit values were detected and spatially located.

Based on the analyses and identified needs, a GIS tool in the form of a software plug-in for the open-source software QGIS was created, which can be easily and profitably applied to the management of mining activities. Three types of tools were developed: 1st Maintaining Tools, 2nd Querying and reporting tools and 3rd Analysis tools. The first component offers the possibility to monitor the licensing of mining sites in a clear and standardized way. Furthermore, standardized monitoring methods are offered and the tool produces comparable and directly usable results. The tool can be used, for example, to analyse the effects of mining sites on different land use types by means of buffer zone analyses. Furthermore, the data from monitoring stations can be automatically displayed via the recorded coordinates and evaluated on the basis of integrated official limit values. The developed tool helps to establish an organized, effective and adaptable network for monitoring and managing mining activities and thus contributes to the protection of the environment from negative impacts of mining activities. The tool is transferable to any province. It will be provided as a contribution to the development of a standardised and efficient monitoring and management system for use by local authorities and administrations in Vietnam.

The importance of this work is also reflected in the Viet Nam Prime Minister's decision 16/2007 to approve the master plan for the monitoring system for resources and the environment up to 2020.

Table of contents

Table of Figures

List of Tables

1 Introduction

Vietnam has recently placed a strong emphasis on urban development (Sudmeier-Rieux et al. 2015) which requires extensive construction minerals in order to meet the increasing need for housing and urban infrastructure development. Therefore, intensive extraction of mineral resources used as construction is inevitable in Vietnam. National statistics of Vietnam also reflect that mining is one of the important economic activities, since mining contributes 9.61% to Vietnam's GDP (2015), (General Statistics Office Of Vietnam 2016). Despite economic profit, the production of mineral raw materials can generate negative environmental and social impacts (Mancini and Sala 2018). Devastated landscapes, soils degradation, loss of biodiversity and the environmental pollution are adverse effects due to mining and quarrying (Notesco et al. 2014). Such environmental problems intensify in the mining regions close to metropolitan areas, where there is a rising demand for building materials due to rapid urbanization. In recent years, mineral reserves in Hoa Binh has been enormously extracted to meet the need of growing industries in Hanoi as the political, economic and cultural center of the country (Schneider et al. 2018). Consequently, various environmental problems have happened in Hoa Binh. Therefore, there is a need for urgent mitigation measures. Effective mitigation measures require effective data collection, storage and analysis. However, there is a lack of a well-established database and tools much needed for an environmental mining management system in Hoa Binh.

Hence, the first step of the project is the gathering of necessary data from various sources and the establishment of a Geo-database. The second step includes analyzing and modeling the mining-environmental-system of Hoa Binh Province based on Driver-Pressure-State-Impact-Response (DPSIR) approach. The DPSIR framework is used as a functional analysis scheme to study cause-effect relationships in connection with environmental and natural resource management problems (Ness et al. 2010). The third step is the development of an indicator-system to report the present situation of the mining-environmental system. Remote sensing techniques and Geographic Information Systems (GIS) are employed to identify and investigate the spatial distribution of the mines as well as the changes in their operating area over time. The next step is to analyze, model and evaluate the environmental impact of mining sites, and the land use conflicts caused by mining activities. Using mathematical and GIS-based models, the impact of resource extraction on nature and the environment is modeled. In the final step, a monitoring system based on open source software is developed.

Module 1 of the joint BMBF project Management of Mineral Resource Extraction in Hoa Binh Province – a Contribution to Sustainable Development in Vietnam (MAREX) – deals with environmental monitoring of mining activities and developing software tools for mining industry and administration in the province Hoa Binh, Vietnam. The responsible project partner for this module in Germany is the Department of Spatial Information Management and Modelling (RIM) of the School of Spatial Planning, TU Dortmund University (see Figure 1).

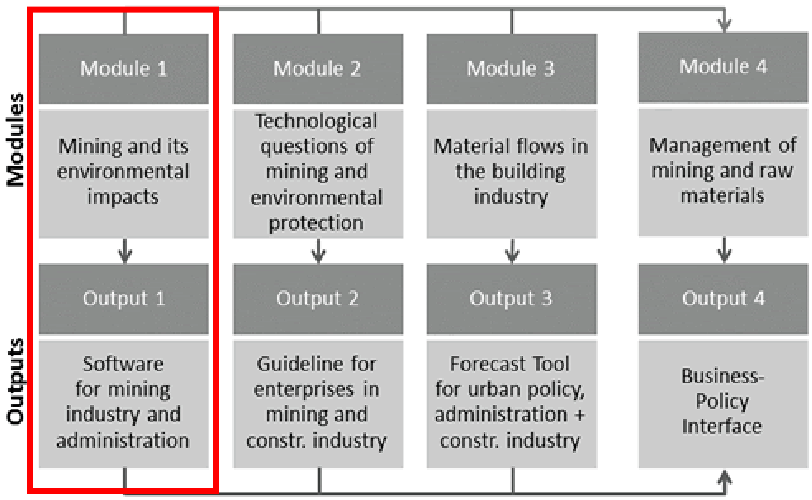


Figure 1: Module 1 of the BMBF project MAREX (Source: IOER 2015)

2 Overview of case study Hoa Binh Province

The Hoa Binh Province is in the North West part of Vietnam and borders south-west of *Hanoi* (see Figure 2). The province covers an area of about 4660 km^2 with a population of 831.300 inhabitants and a population density of 181 persons/km^2 2016. The province has 11 administrative districts namely: Da Bac, Mai Chau, Tan Lac, Lac Son, Kim Boi, Luong Son, Lac Thuy, Thuy Yen, Ky Son, Cao Phong and Hoa Binh City with 210 communes, wards and towns. (GENERAL STATISTICS OFFICE of VIET NAM 2016).

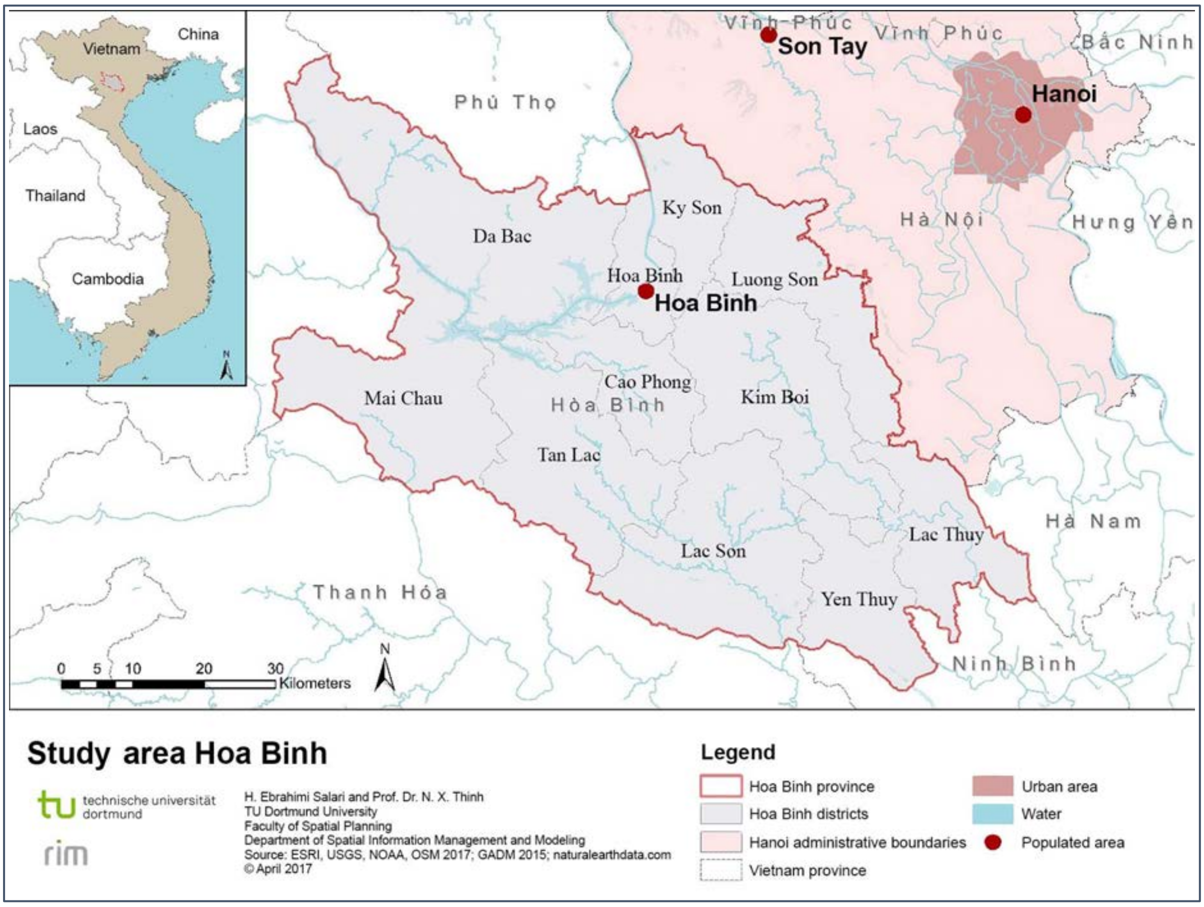


Figure 2: Study area Hoa Binh (Source: own illustration)

3 Materials for the development of the geo-database and analysis

A comprehensive geo-database has been designed to support specific analysis workflows and data storage needs.

The geo-database includes both spatial and non-spatial datasets with different formats as follows (see Figure 3):

- Feature classes such as administrative land use data, satellite-based land use data, administrative layers etc.
- Raster data such as elevation data, historical satellite data, etc.
- Excel tables of legal mining sites
- Word-data such as reports on monitoring data and laws and regulation on limit values for contamination.

The database also includes several self-developed tools for data storage and management, query and analysis, which also provide visualizations and reports.

In the following, basic datasets incorporated in the database are introduced.

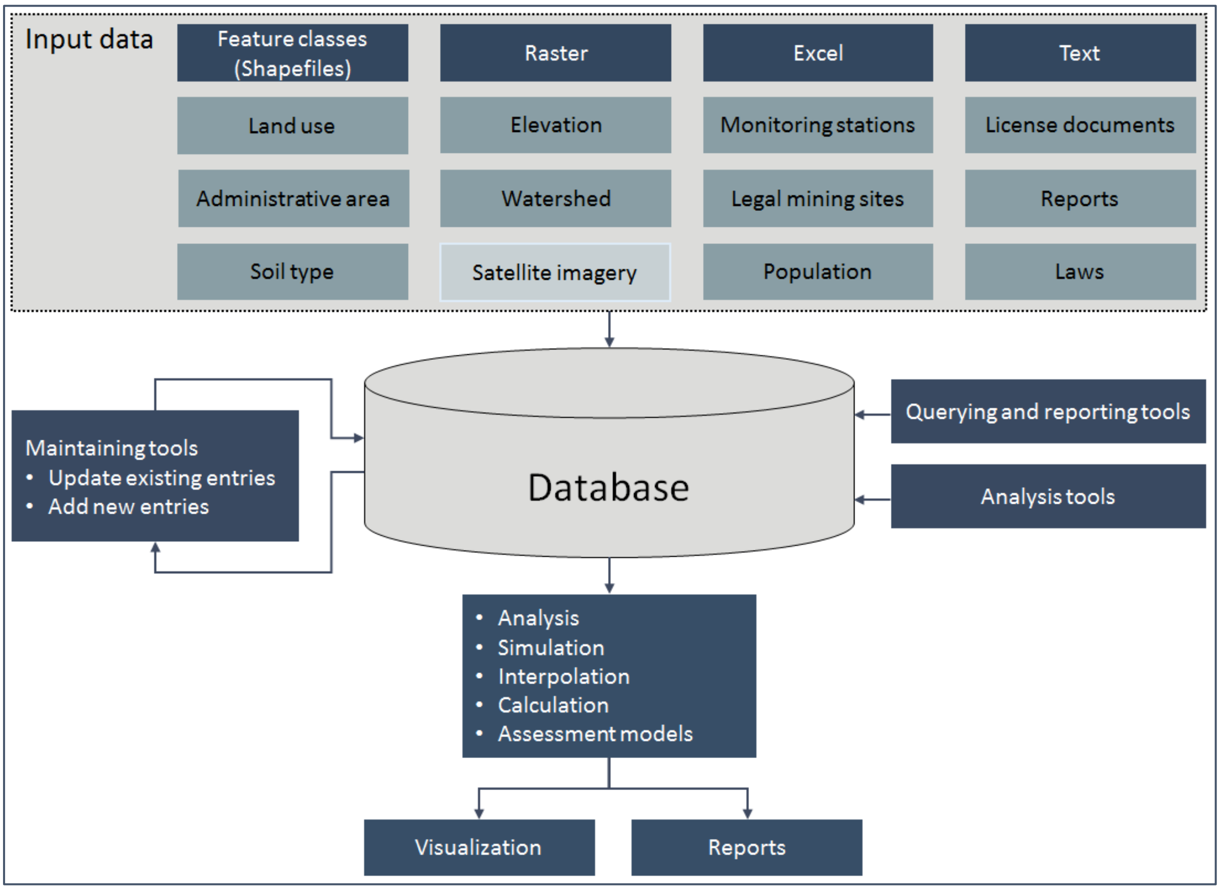


Figure 3: Structure of a well-organized database (Source: own illustration)

3.1 Administrative boundaries

Administrative borders of Vietnam are obtained from the Global Administrative Areas (GADM) (https://gadm.org). GADM provides maps and spatial data for all countries and their sub-divisions.

3.2 Geologic map of Hoa Binh

Figure 4 shows the geological map of Hoa Binh which describes the rocks, structures and minerals which exist in Hoa Binh. The area consists of several geologic formations mainly composed of limestone, conglomerate, sandstone, aphyric basalt, magnesium-high basalt, silty sandstone, and black clay shale (Tien Bui et al. 2012). The geological map shows that the Hoa Binh Province has high mineral resource potential for mining activities.

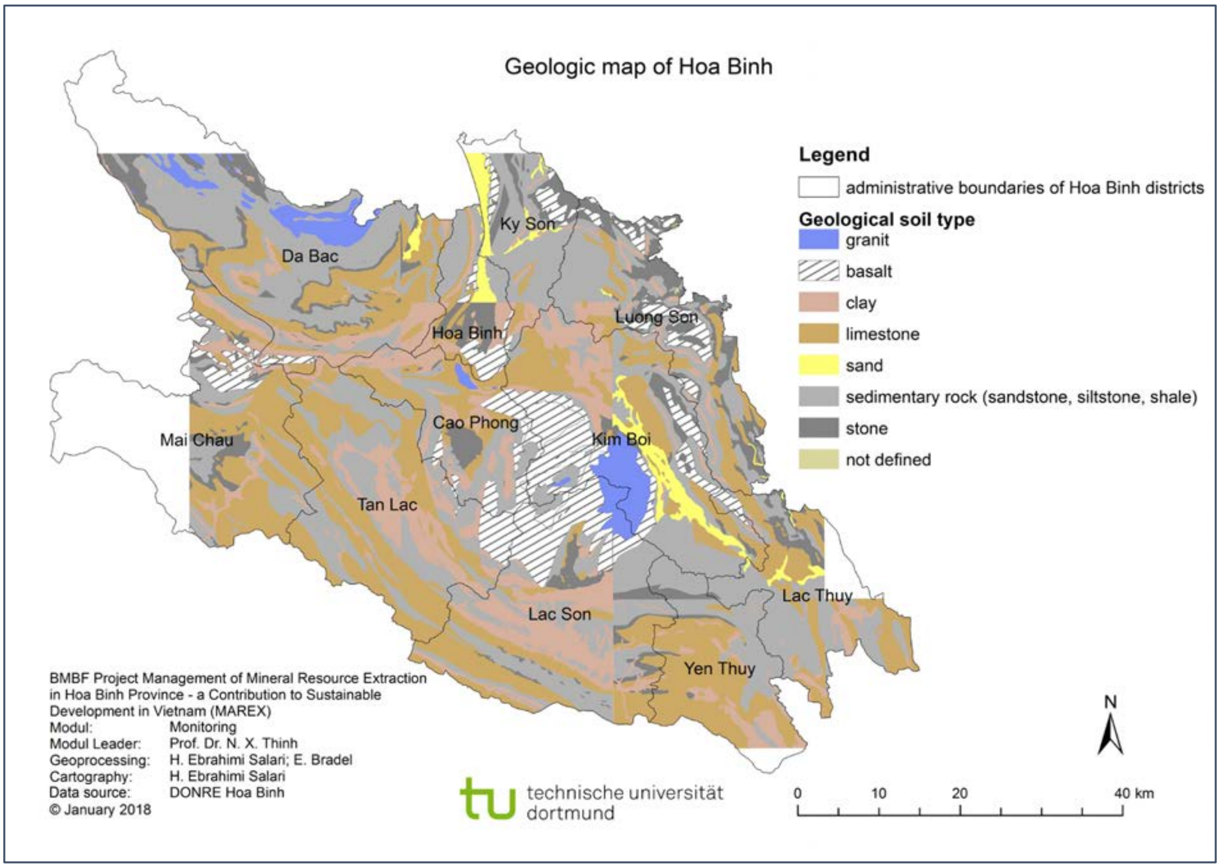


Figure 4: Geologic map of Hoa Binh (Source: own illustration)

3.3 Elevation data

The ASTER GDEM 2 dataset is used for remote sensing analysis and 3-D modelling of the landscape. ASTER GDEM v2 was released on October 17, 2011 and covers Earth's land surfaces between 83° North and 83° South with a spatial resolution of approximately 30 meters (METI and NASA 2017). According to the ASTER GDEM 2, elevation in the province Hoa Binh varies from -69 to 1530 m (see Figure 5).

3.4 Administrative land use data

The administrative land use data of Luong Son for 2015 includes several categories and sub categories; 8 main categories of the administrative land use map are residential area, public purposes, specific purposes, non-agricultural business, agricultural land, forest, unused land and water bodies. The mineral activities belong to the category of non-agricultural businesses (see Figure 6).

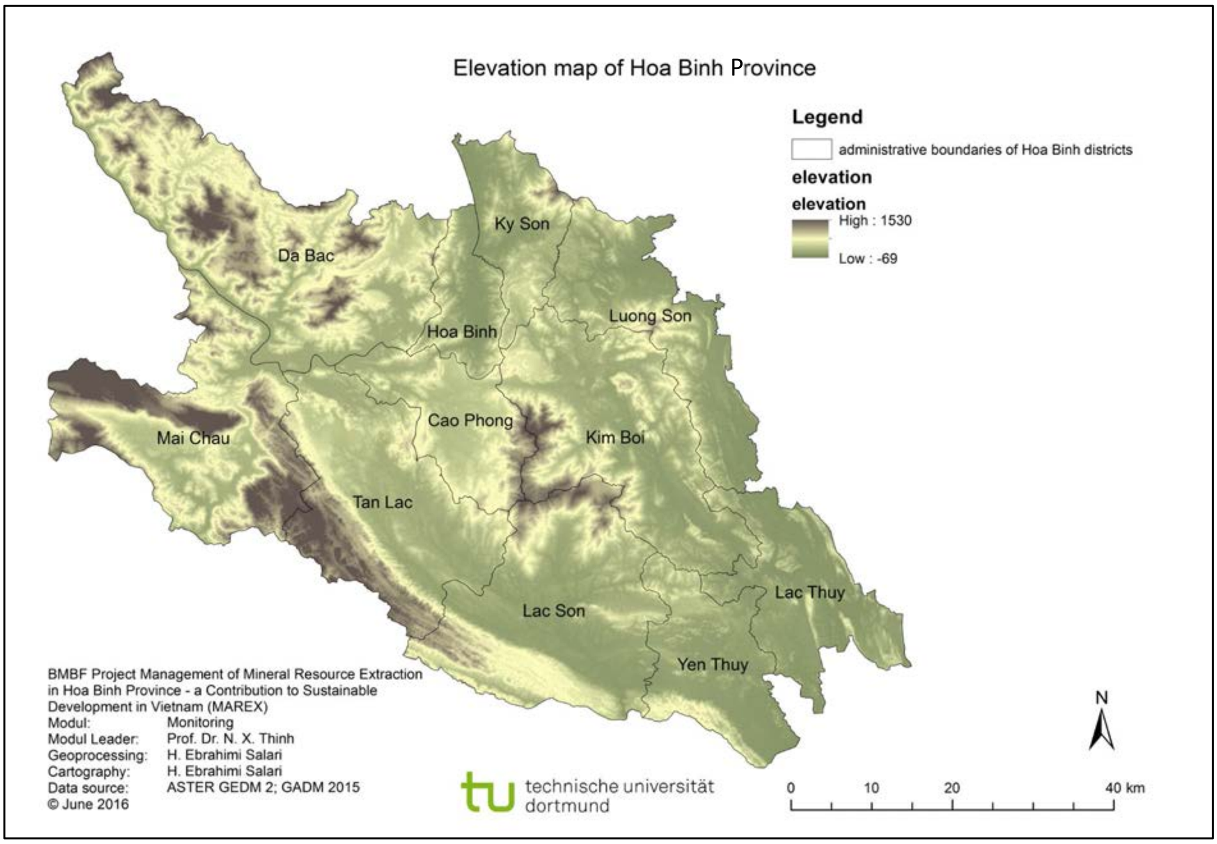


Figure 5: Elevation map of the Hoa Binh Province (Source: own illustration)

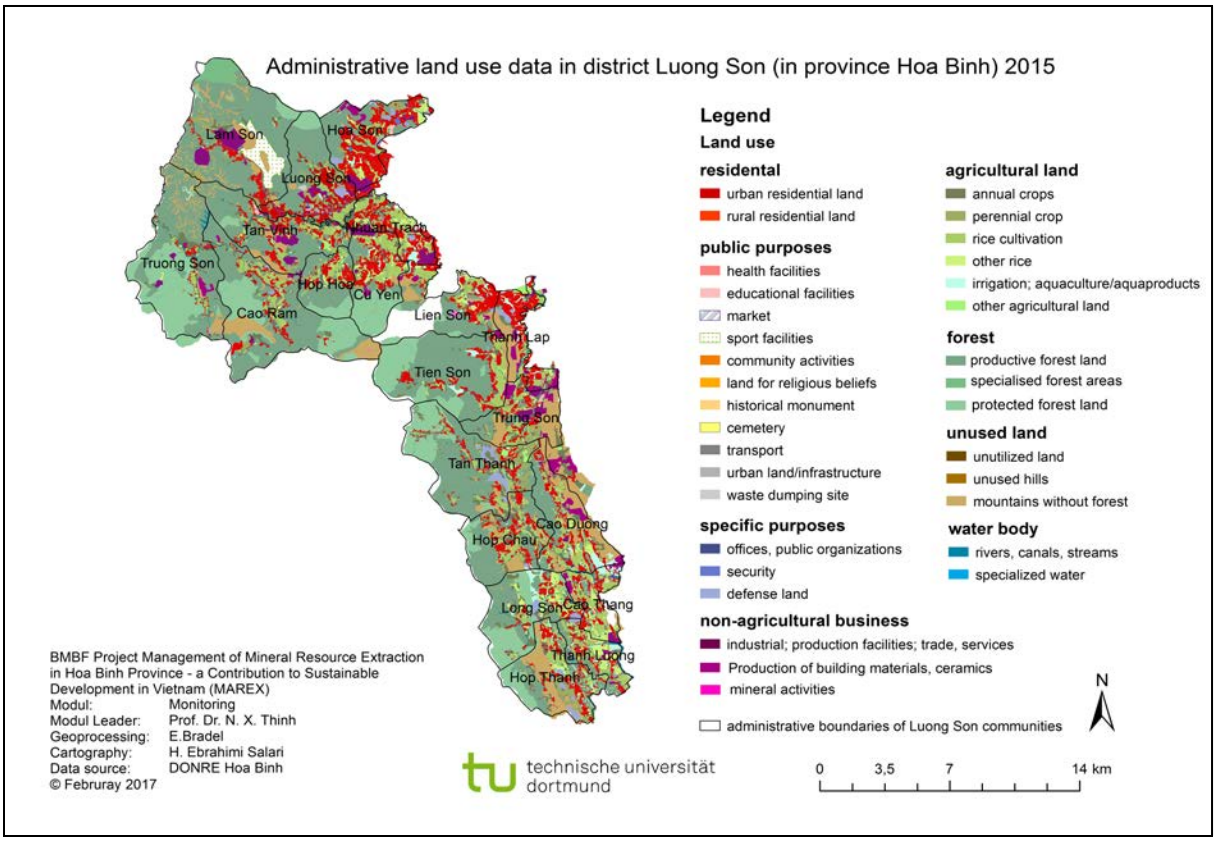


Figure 6: Administrative land use data in district Luong Son (in province Hoa Binh) 2015 (Source: own illustration)

3.5 Legal mining sites in province Hoa Binh

The Department of Natural Resource and Environment (DONRE) provided coordinates of legal open-pit mines in Hoa Binh in word-format. In order to integrate this data in a geo-database, coordinates are imported into GIS and then connected to the associated attribute table.

Possible errors of the coordinates were detected and corrected by comparing the given coordinates with complementary datasets such as google earth, high resolution satellite data and address of the operating site.

3.6 Protected areas banned from mining activities

Information on the protected areas banned from mineral activities are extracted from the mining report Hoa Binh 2013-(Main report) and then imported in GIS. Protected areas in district Luong- Son include productive forest land, protected forest land, specialized forest areas, sport facilities and rice cultivation. In order to monitor the possible conflicts between the issued mining licenses and protected areas, licensed mining sites shapefile from 2015 is overlaid with the protected areas. As a result, four license requests are located in immediate proximity of protected areas. According to the status of mining licenses in year 2017, two of them are already refused and the other two requests for gaining license are still in licensing procedure (see Figure 7).

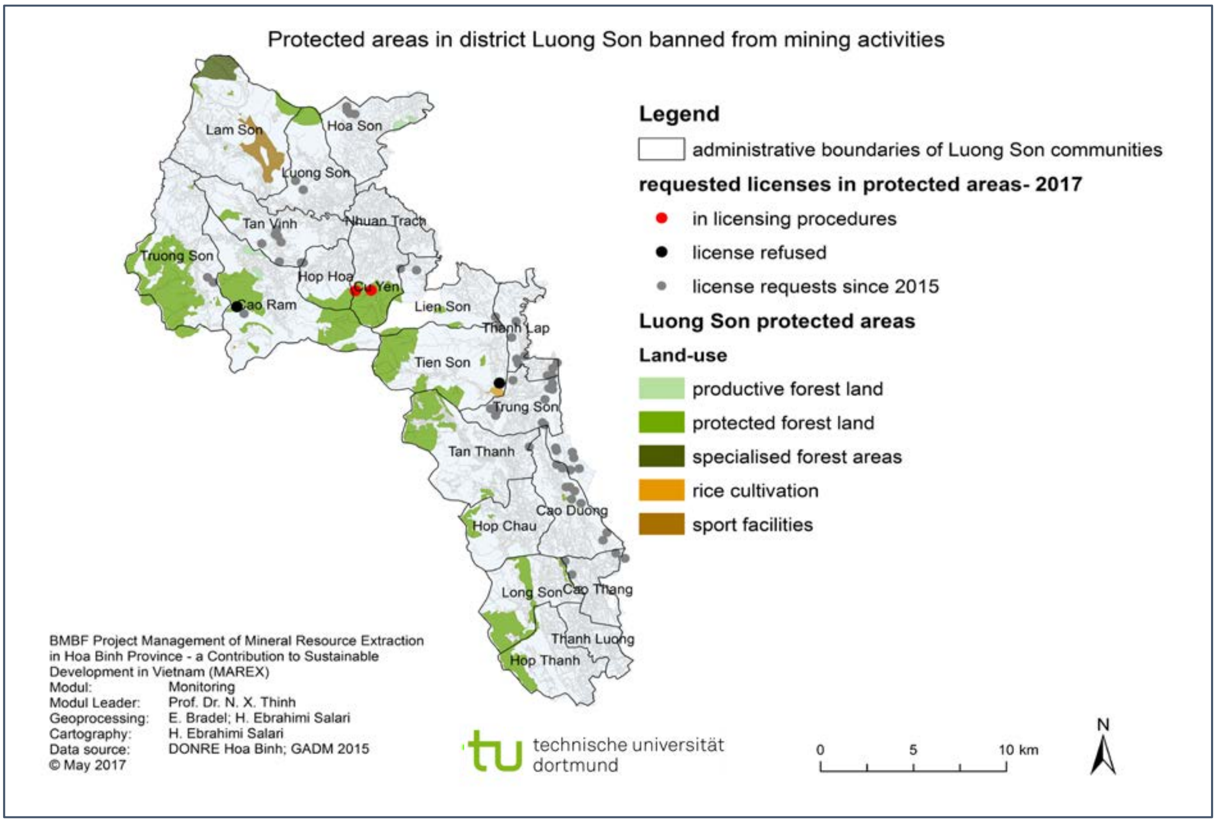


Figure 7: Protected areas in district Luong Son banned from mining activities (Source: own illustration)

3.7 Monitoring data

The Department of Natural Resources and Environment (DoNRE) provided monitoring data for the years 2014 and 2015 for Hoa Binh Province. Further monitoring data is provided by DoNRE and the Institute of Environment and Automation (IEA) for the year 2016 and 2017 for the district Luong Son (see Table 1). The monitoring data includes coordinates of various numbers of monitoring stations and a wide range of measured parameters for air (e.g. TSP, noise, SO_2), soil (e.g. As, Cd, Pb, Zn), groundwater (e.g. NO_2^-, Fe, As, coliform), surface water (e.g. pH, DO, TSS, coliform) and wastewater (e.g. pH, TSS, BOD_5, Pb, coliform). All the monitoring stations are imported into GIS using the given coordinates and joined with the measured data.

- Samples were taken in the field using current standard methods and equipment. For each type (air, soil, groundwater, surface water, wastewater) samples were gathered during two time periods – rainy and dry seasons – for the years 2014, 2015, 2016, 2017. The weather conditions during the sample taking should always be the same, e.g. no rain before and during the sample taking, and the operations at the mining sites take place normally (DoNRE, IEA).
- The chemistry and environmental analysis of the samples were done in the following weeks after the sample being taken at the Research Centre for Environmental Monitoring and Modelling (CEMM) with the available laboratory equipment (DoNRE and IEA 2017).

Table 1: Number of monitoring stations for the years 2014, 2015, 2016, 2017 (Source: DoNRE and IEA 2017)

Monitoring data	**Number of monitoring sites**			
	2014 Hoa Binh Province	**2015 Hoa Binh Province**	**2016 Luong Son district**	**2017 Luong Son district**
Air	75	75	48	48
Soil	13	13	24	24
Groundwater	21	11	24	24
Surface water	57	30	24	24
Wastewater	113	150	24	24

3.8 Remote sensing data

To determine the land cover/land use (LU/LC) change in Hoa Binh Province, Landsat satellite images for the years 2000, 2007, 2009, 2011, 2013 and 2015 with 30 m resolution were classified using remote-sensing techniques. Due to high concentration of mining activities in the district Luong Son, a high-resolution SPOT6 satellite imagery (1.5 m) is analyzed to obtain accurate LC/LU data. Additionally, mining site layer in Luong Son is updated for the year 2017 based on the medium resolution Sentinel-2 satellite image (10-20 m). RIM used the remote-sensing software ENVI to classify the satellite images, to locate different land use types and to determine the changes. The following table gives an overview of the information extracted based on satellite images (see Table 2).

Table 2: Characteristics of the satellite images used for the study (Source: own presentation according to Landsat 8 (L8) Data users Handbook 2018, SPOT 6 | SPOT 7 Imagery User Guide 2013, SENTINEL-2 User Handbook 2015)

Satellite based data	**Resolution**	**Sensor**	**Year**
LU/LC	30	Landsat 7	2000
Mining site	30	Landsat 5	2007
Mining site	30	Landsat 5	2009
Mining site	30	Landsat 5	2011
Mining site	30	Landsat 8	2013
LU/LC	30	Landsat 8	2015
LU/LC	1.5	SPOT 6	2016
LU/LC	10	Sentinel-2	2017

3.9 Legal framework for environmental impact assessment

Vietnam has already set various laws and guidelines on environmental protection, sale and use of chemicals, and mining into effect to balance mining opportunities with protection of the environment (Larkin and Si V 2010). A comprehensive database of Vietnamese technical regulation on the limit values of parameter of surface water, groundwater, wastewater and soil are gathered and processed to be used in the analysis and in the developed tools.

4 The DPSIR-Model

DPSIR (driving force, pressure, state, impact, and response) was developed by the EEA as a framework about the interaction between the environment and socio-economic activities. “In the DPSIR framework, social and economic developments drive (D) changes that exert pressure (P) on the environment. As a consequence, changes occur in the state (S) of the environment, which lead to impacts (I) on human health, ecosystem functioning and the economy. Finally, societal and political responses (R) affect earlier parts of the system, directly or indirectly” (Maguire et al. 2014) (see Figure 8).

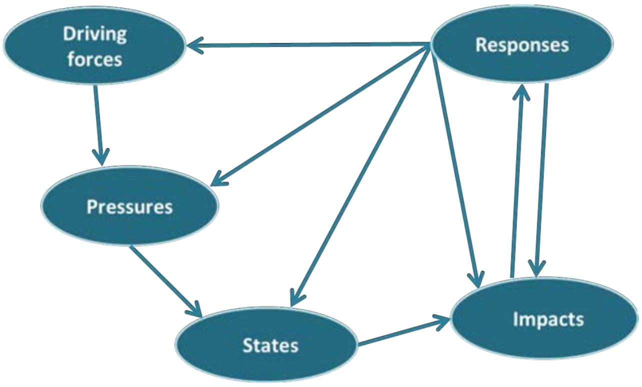


Figure 8: The DPSIR Framework for Reporting on Environmental Issues (Source: own illustration based on Smeets and Weterings, 1999)

The DPSIR is used as a starting point of analysis. Demand for mineral resources is the **driving force**, which imposes **pressure** on the environment by mineral extraction and by various emissions. This leads to some **impacts** on the environment and produces corresponding **state** changes in the environment. Finally, the society **responses** against problem in the form of new regulation, good management practices (including monitoring and remediation) and all measures that influence driving forces, pressures, state and impacts (Jordan and Abdaal 2013). Figure 9 shows the DPSIR framework used for environmental assessment of the mining site within the framework of the MAREX project.

Driving forces	• Economic reform and emphasis on urban areas • Land use • Construction and infrastructure development
Pressures	• Extensive mining activities • Waste production
States	• Land scape change • Uncontrolled land use change
Impacts	• Loss of green cover • Environmental degradation through contamination of recources such as air, water and soil • Land-use conflicts
Responses	• Improvements in the environmental quality • New regulations and guidelines for environmental protection

Figure 9: DPSIR framework used for environmental impact assessment of the mining sites (Source: own illustration based on Jordan and Abdaal 2013)

4.1 Drivers

Mining is considered as one of the drivers of socio-economic well-being in Vietnam at the national level (Nguyen et al. 2017). According to statistics of the year 2015, mining is the fourth biggest contributor to GDP and has high growth rate of 9.61% (General Statistics Office Of Vietnam 2016).

Increasing demand on building materials is one of the key drivers of mining and quarry industry in Vietnam. The massive boom in the building sector is associated with several reasons. At first, Vietnam is experiencing rapid demographic and social change. After years of growth, Vietnam’s population reached about 95 million in 2017 and is expected to increase to 120 million around 2050 (World Bank 2018). Therefore, large amounts of building materials are required to meet the demand of population growth.

Economic reform and thus emphasis on urban development are two other key drivers of the mining sector. “Vietnam’s GDP growth is estimated at 6.8 percent in 2017 – the fastest expansion in the past ten years” (World Bank 2018). Moreover, Vietnam has recently priorities in urban development (Sudmeier-Rieux et al. 2015). By 2020, 45% of Vietnam’s population is forecasted to be residing in cities (Lanjouw and Marra 2018). The emphasis on urban development means more need for construction materials.

Hoa Binh Province is reflecting a similar trend like the whole country. Exploiting and building materials is one of the main priority development industries in Hoa Binh. The Industrial product, mainly diameter, cement, building stones, limestone, clay etc. are produced to meet the needs of industrial development construction (World Bank 2009). Some of the material is consumed locally and the greatest part is delivered to the City of Hanoi (Schneider et al. 2018).

4.2 Pressure

The increasing demand on building material leads to extensive mineral resource exploitation and waste production in province Hoa Binh and specifically in district Luong Son. The analysis of the legal mining licenses confirms the pressures. Spatial distribution of the mining sites, exploitation capacities and operation areas shows that especially Luong Son district is heavily affected by mining operations.

- **Legal mining sites in province Hoa Binh**

According to the status of licenses in 2017, 88 mining licenses are issued in the province Hoa Binh. Figure 10 presents the spatial distribution of the mining licenses according to the status of licenses. 50 of 88 mining licenses are operational and 20 in licensing procedures. 15 of the mining licenses are revocated. Two are in current stop of operation and only 1 license is not operational yet. The map shows that the concentration of mining licenses occurs in district Luong Son, where 52 of the 88 licensed mines of Hoa Binh Province are located (see Figure 10).

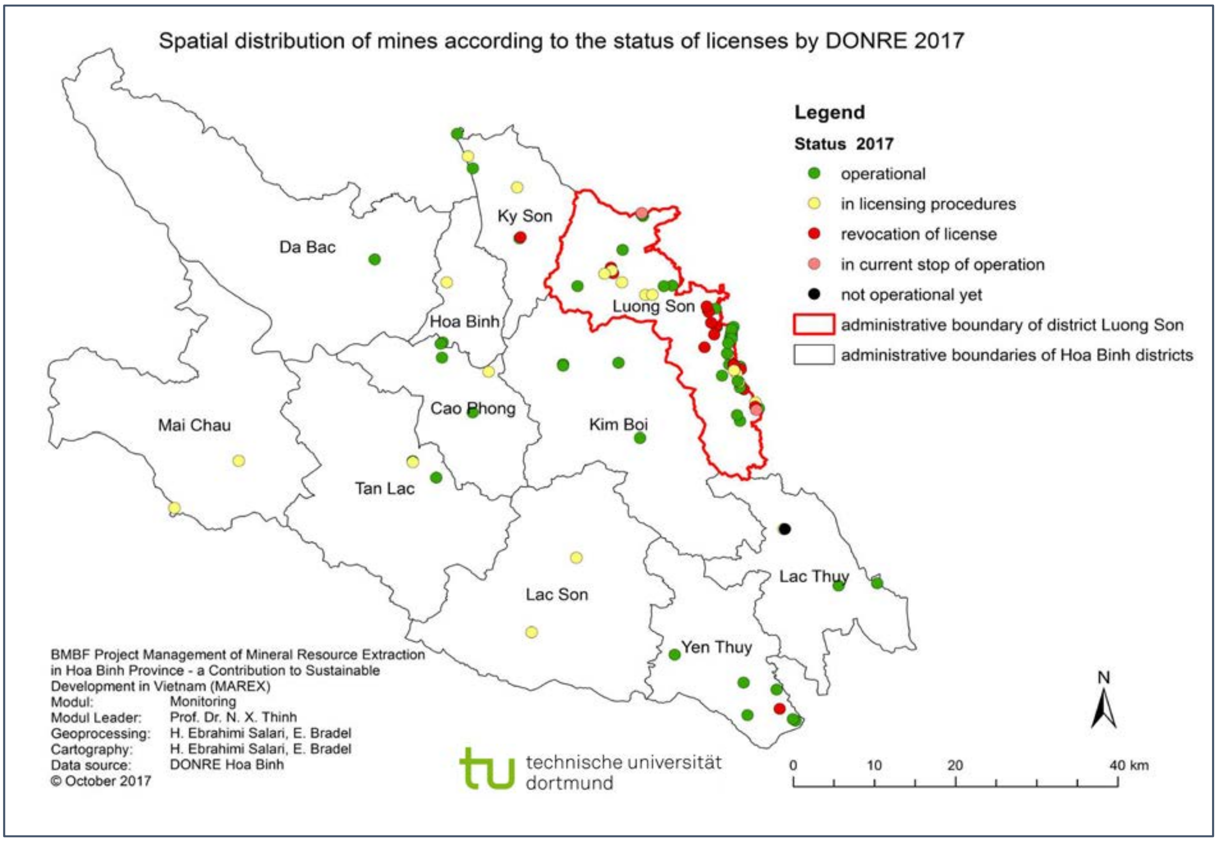


Figure 10: Spatial distribution of mining sites according to status of licenses by DONRE 2017 (Source: own illustration)

The primary products extracted in Hoa Binh include limestone, basalt, sand and clay among which limestone-mining sites have the highest share (see Figure 11). As Figure 12 shows, Luong Son has the largest area of mining sites compared to other districts in 2017 (591 ha of 862 ha).

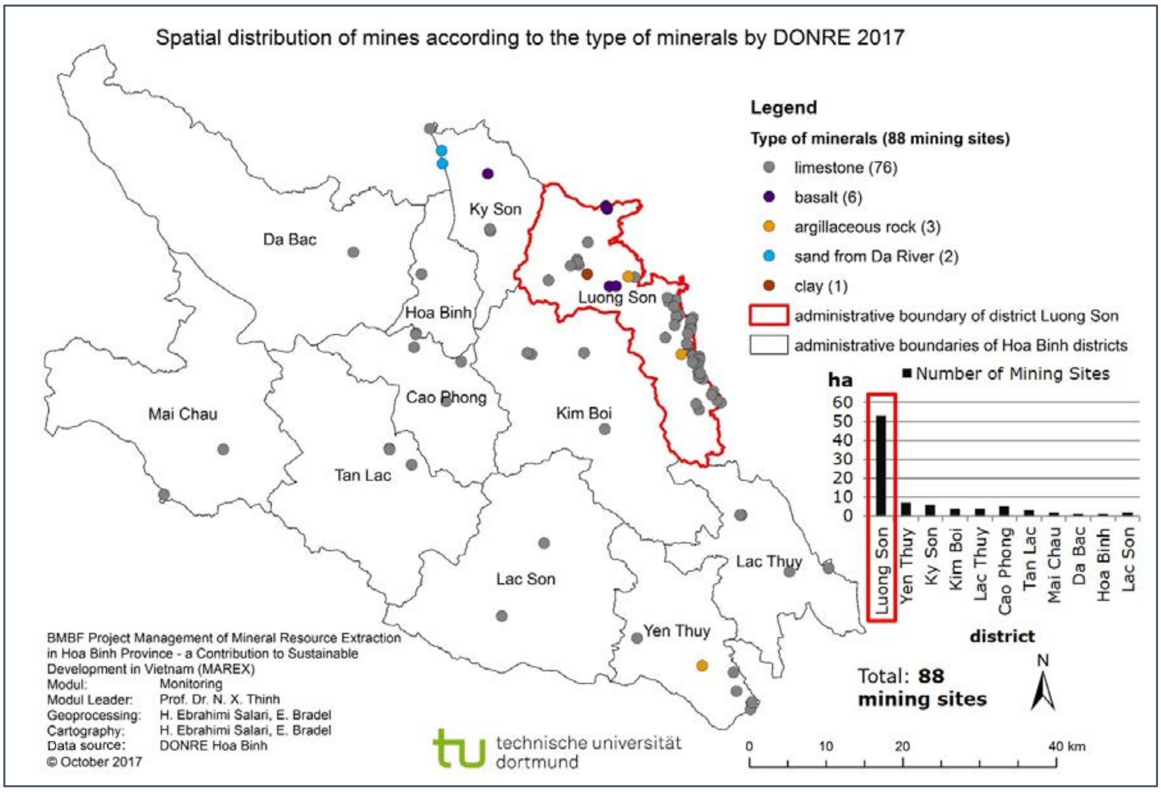


Figure 11: Spatial distribution of mines according to the type of minerals by DONRE 2017 (Source: own illustration)

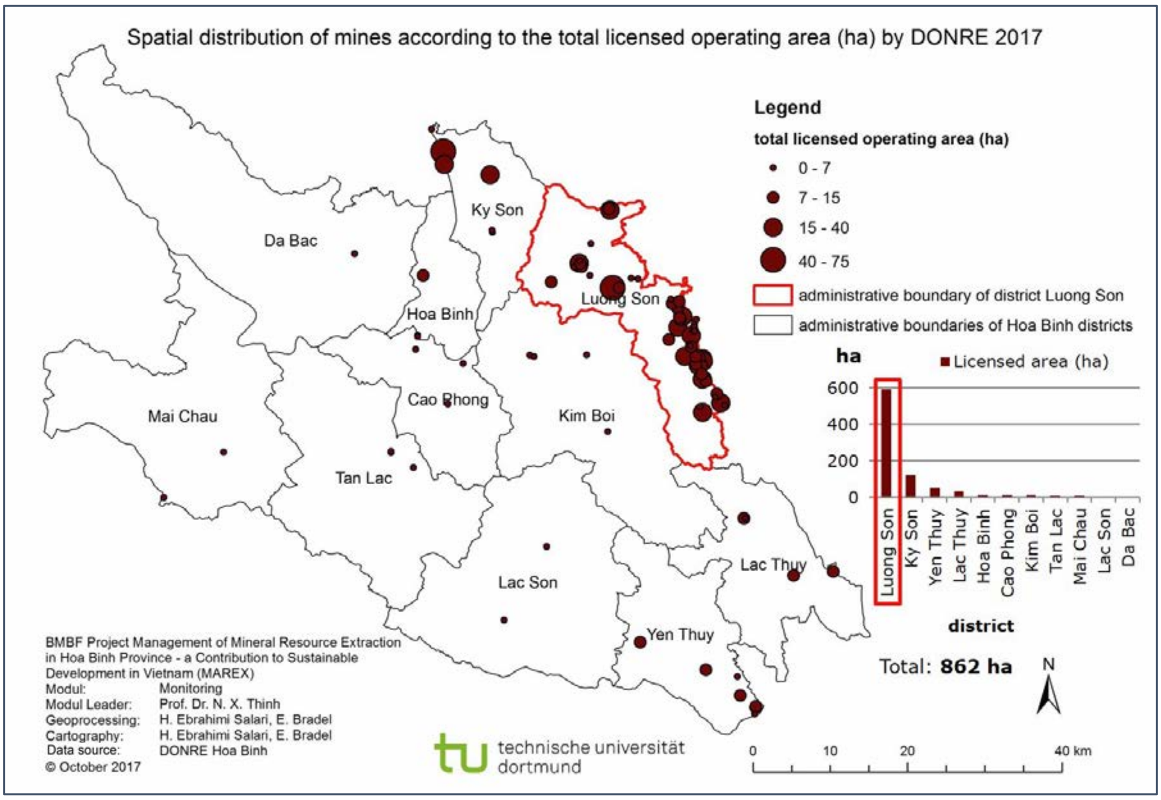


Figure 12: Spatial distribution of mines according to the total licensed operating area by DONRE 2017 (Source: own illustration)

Spatial distribution of mines according to the total licensed extraction capacity (m³) (DONRE 2017) also indicates that Luong Son with 333 Mio m³ of 421 Mio m³ is the district with the highest total licensed extraction capacity in 2017 (see Figure 13).

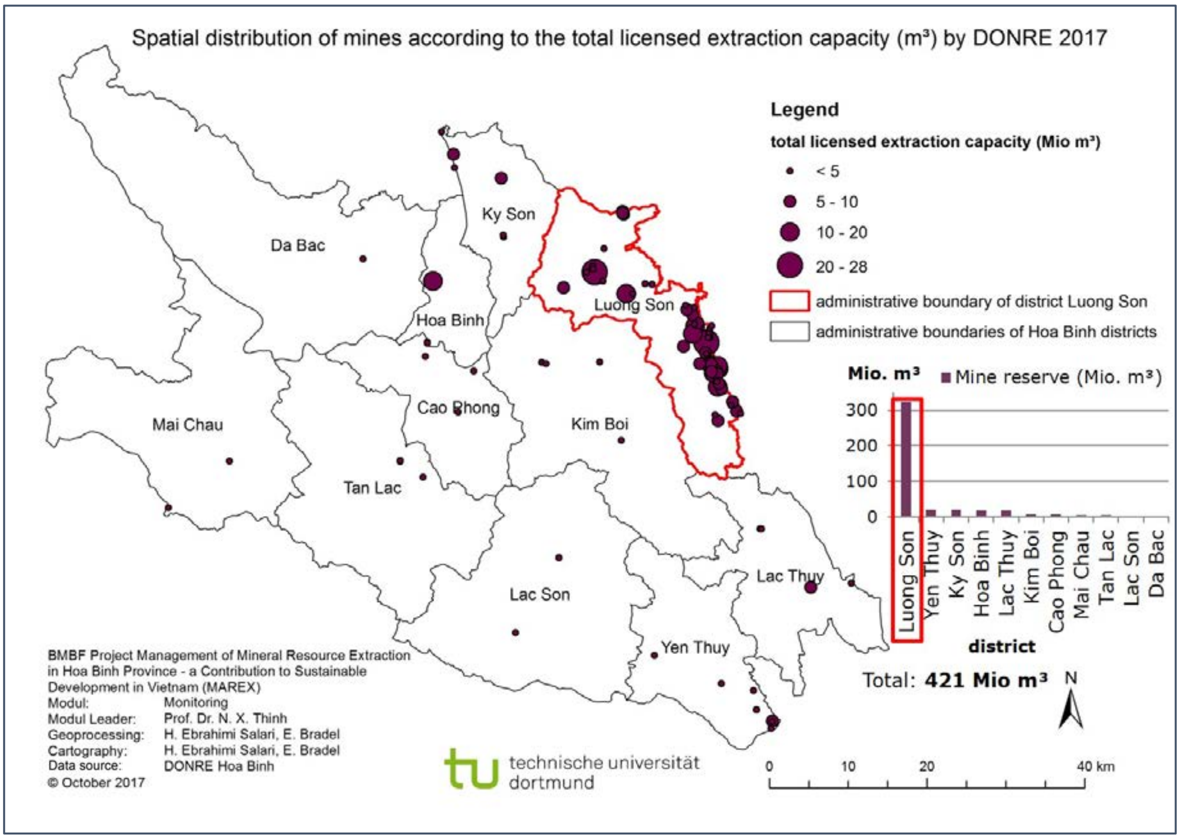


Figure 13: Spatial distribution of mines according to the total licensed extraction capacity (m³) by DONRE 2017 (Source: own illustration)

4.3 State

The state of land use as a result of imposed pressures by mining activities, is a key indicator of the transformation that shows dynamic process through DPSIR scheme. The state of land use and its changes are investigated through an analysis of historic and current satellite images. Landsat series are used for land use change detection and a high resolution SPOT-6 (1.5 m) and a medium resolution Sentinel-2 image (10 m-20 m) are used for the investigation of the current state land use.

4.3.1 Landsat analysis

Monitoring mining activities aims to detect historical mining sites and their development during the time period from the year 2000 to present as well as to identify the exact border of the current mining sites. Mining sites were identified using Landsat images for the dates of 2000, 2007, 2009, 2011, 2013 and 2015. As the classification map of 2000 shows, 70 percent of the total area of Hoa Binh is covered by forest areas whereas mining sites and settlement areas have a very small shares i.e. 0.4% settlement and 0.02% mining site. In 2015, the share of forest has decreased to 60% while settlement and mining site areas have increased (see Figure 14). Figure 15 illustrates the changes of the mining site areas, built-up areas and forest areas. From 2000 to 2015, settlement areas have more than doubled. In 2015, mining areas are thirteen times larger than 2000 while forest areas decreased by 18%.

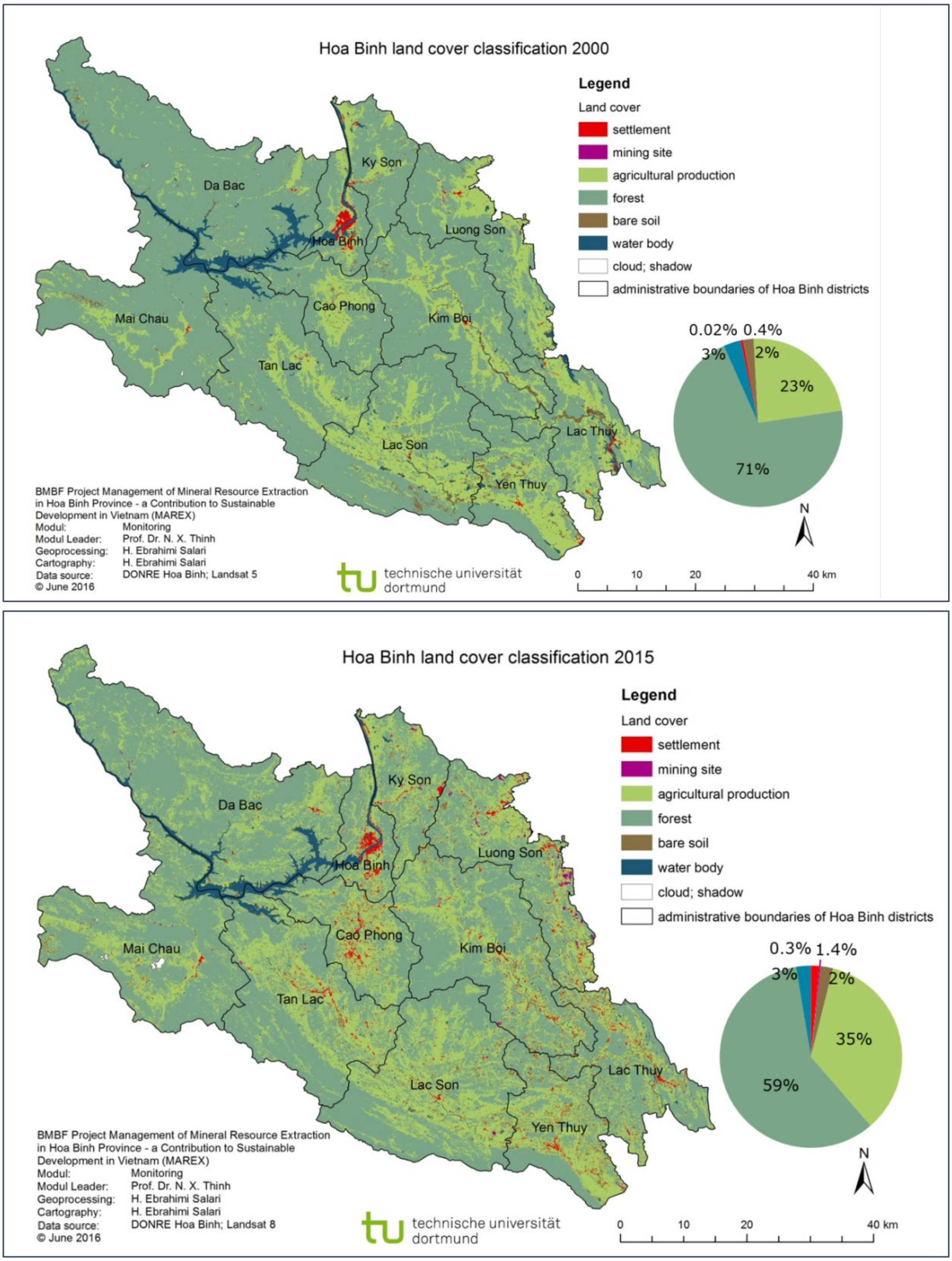


Figure 14: Land cover maps in Hoa Binh Province, 2000 & 2015 (Source: own illustration)

- **Changes in the area of mining sites in Hoa Binh 2000-2015**

Figure 16 presents the development of mining site areas from 2000 to 2015 detected based on Landsat series. The detection and analyzation of the land use as well as geotagging of potential mining sites in the province Hoa Binh for the years 2000, 2007, 2009, 2011, 2013 and 2015, based on Landsat satellite images showed that the landscape in Hoa Binh dramatically changed as a consequence of the intensive and increasing mining activities.

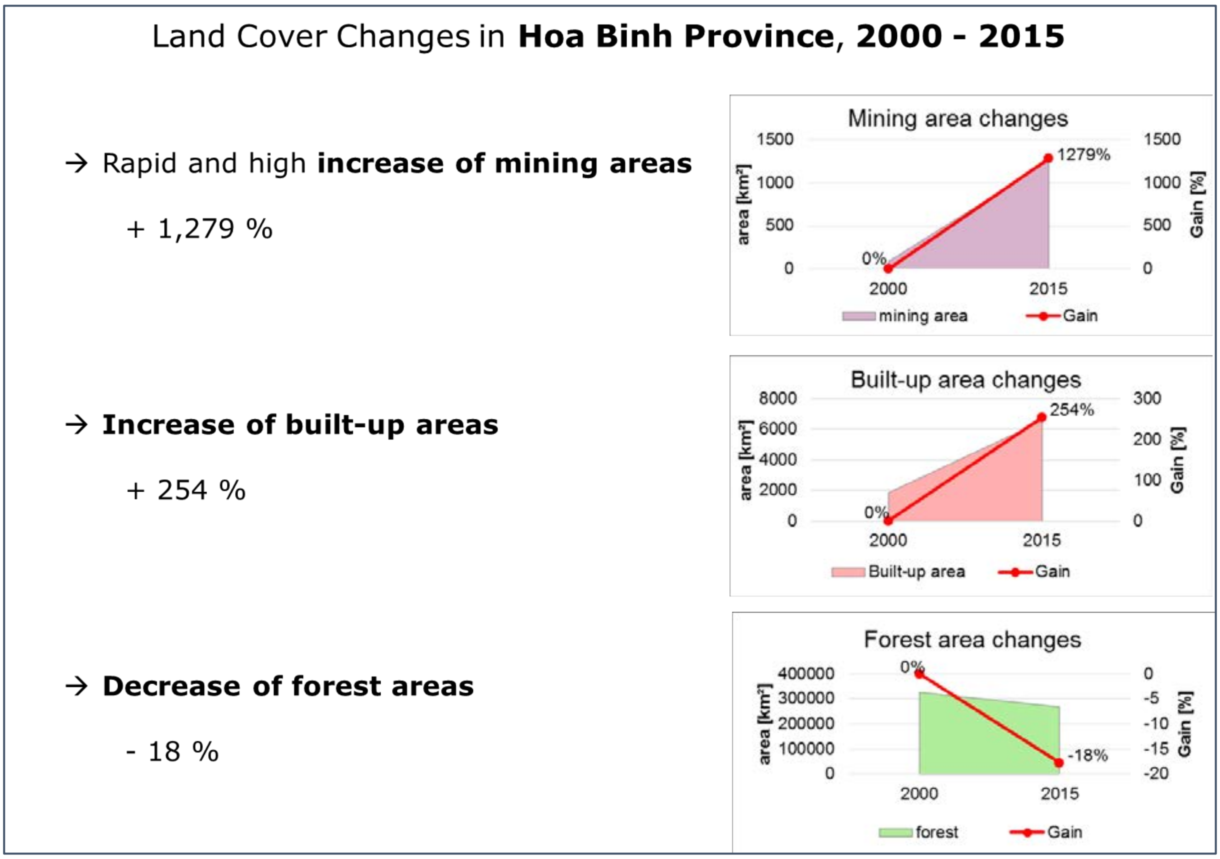


Figure 15: Land cover changes in Hoa Binh Province, 2000-2015 (Source: own illustration)

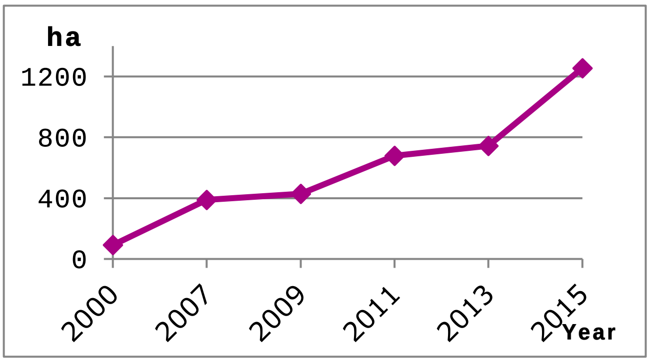


Figure 16: Development of the mining areas 2000-2015 based on satellite analysis (Source: own illustration)

- **Characterization of mining sites in Hoa Binh**

The satellite analysis as well as legal mining sites data reveal that the district Luong Son, which is in the close proximity of Hanoi city, is highly affected by mining activities (see Figure 17).

According to the classification map of 2015, 42% of the mining area in province Hoa Binh (525 ha of 1,255 ha) are located in district Luong Son (see Figure 17).

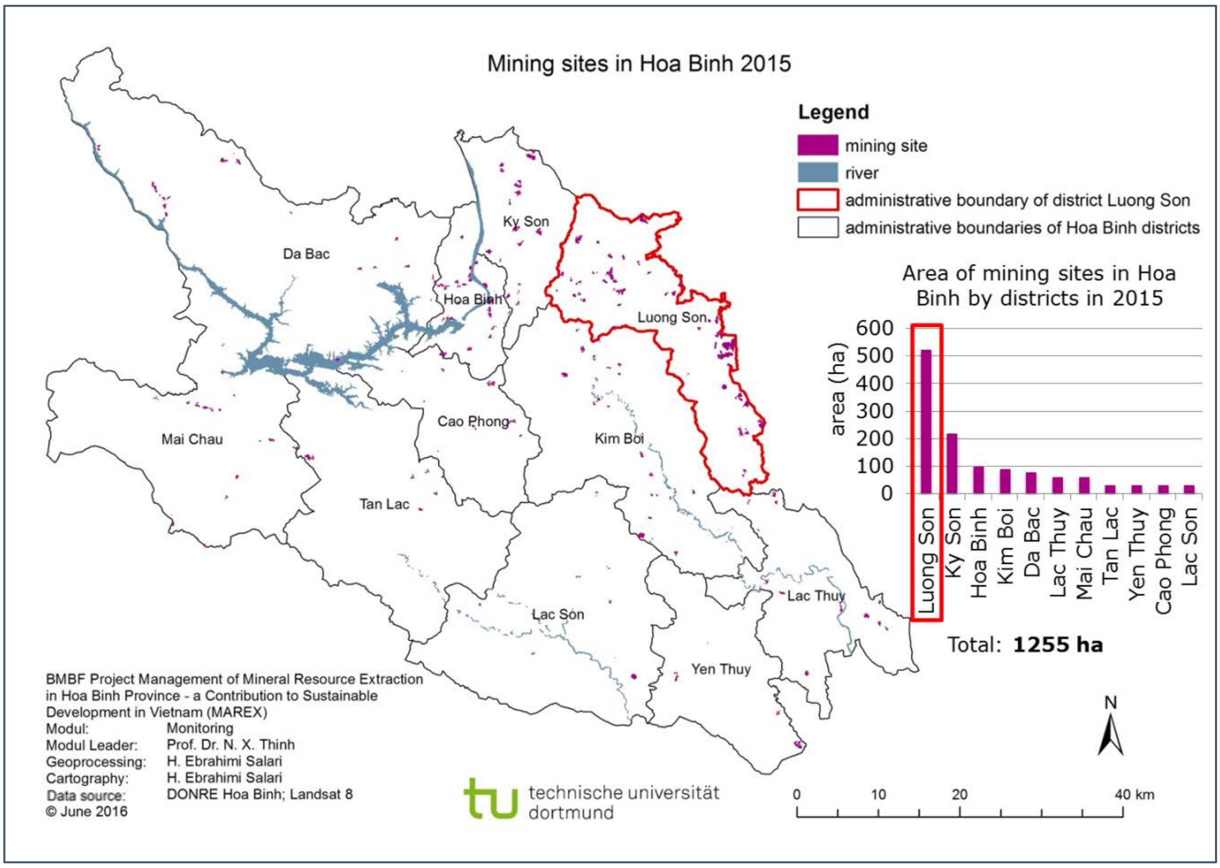


Figure 17: Mining sites in Hoa Binh 2015 (Source: own illustration)

4.3.2 Land cover in Luong Son based on SPOT-6 (2016)

According to the analysis and data collection on mining sites in Hoa Binh, it can be concluded that in district Luong Son there are intensified mining activities causing negative environmental impact. Due to the close transportation distance, Hanoi is currently the main customer of raw building material extracted in Luong Son. Likewise, it is expected that Hoa Binh and in particular district Luong Son will be constantly involved in mining activities due to the increasing demand for constructions and related services in future development of Hanoi. Therefore, a detailed investigation of environmental impacts of mining sites in district Luong Son is of great importance in order to effectively manage the environmental impacts. Therefore, TUDO/RIM achieved SPOT-6 satellite data with 1.5m resolution to be able to detect small settlement areas that would be affected by mining activities using the remote-sensing software ENVI. Figure 18 shows the classification map of district Luong Son. Land cover data is classified as follows:

Settlement (6%), Mining Site (1.3%), Bare soil (6%), Agricultural production (20%), Forest (54%), other vegetation (12%), Water (2%) and Shadow.

Land cover data achieved based on SPOT imagery is compared to the administrative land use data. The comparison of both datasets shows no significant differences between the share of mining site, agricultural production, forest and water area. The share of settlement (17%) by the administrative data is almost three times the share of settlement detected by remote sensing analysis (6%). One of the reasons for this is that administrative settlement data includes both house and green structures. However, remote sensing based settlement data includes only the areas of houses and the green areas between the houses are classified under the category “other vegetation”. Nevertheless, the total area of the settlement (6%) and other vegetation group (12%) from satellite-based data is almost the same as the share of residential area in the administrative dataset (see Figure 19).

The results of the comparison validate the high accuracy of the LU/LC data produced by satellite imagery.

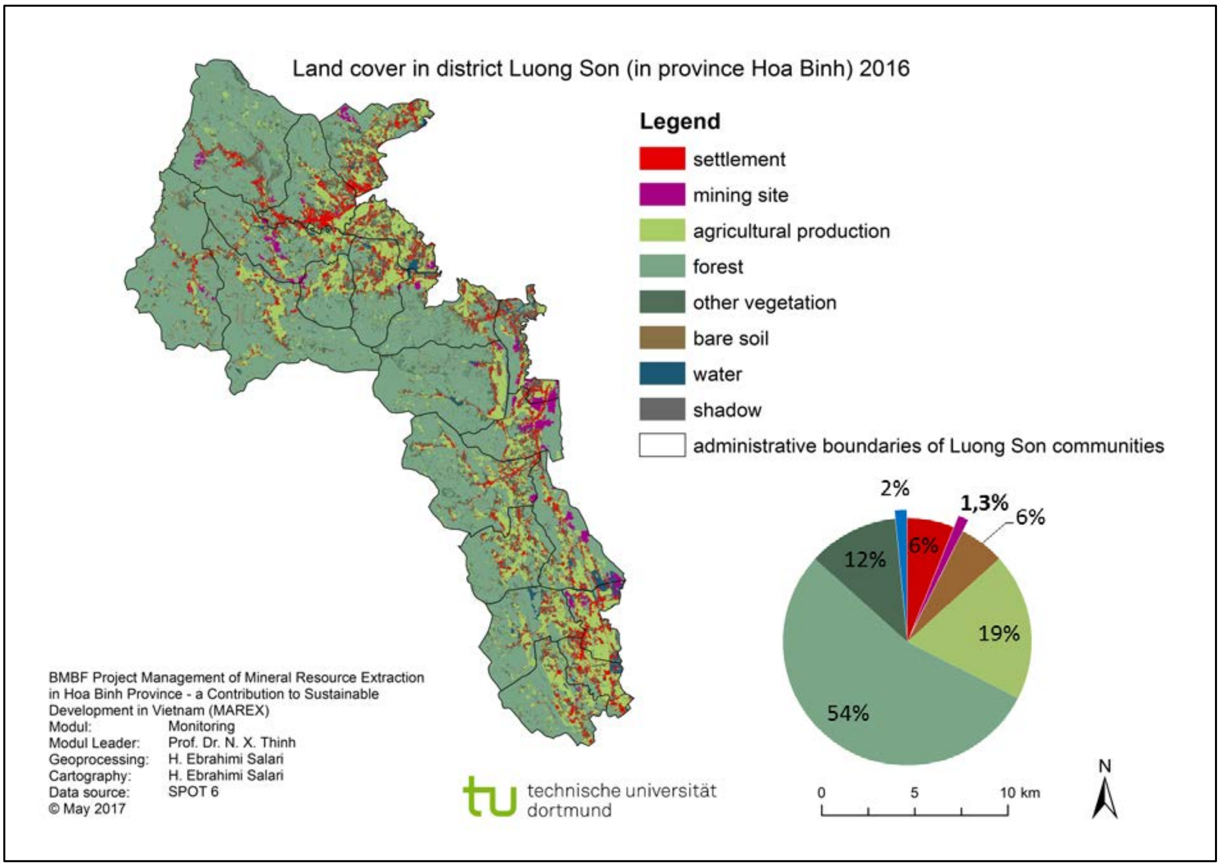


Figure 18: Land cover classification in district Luong Son based on SPOT 6 (Source: own illustration)

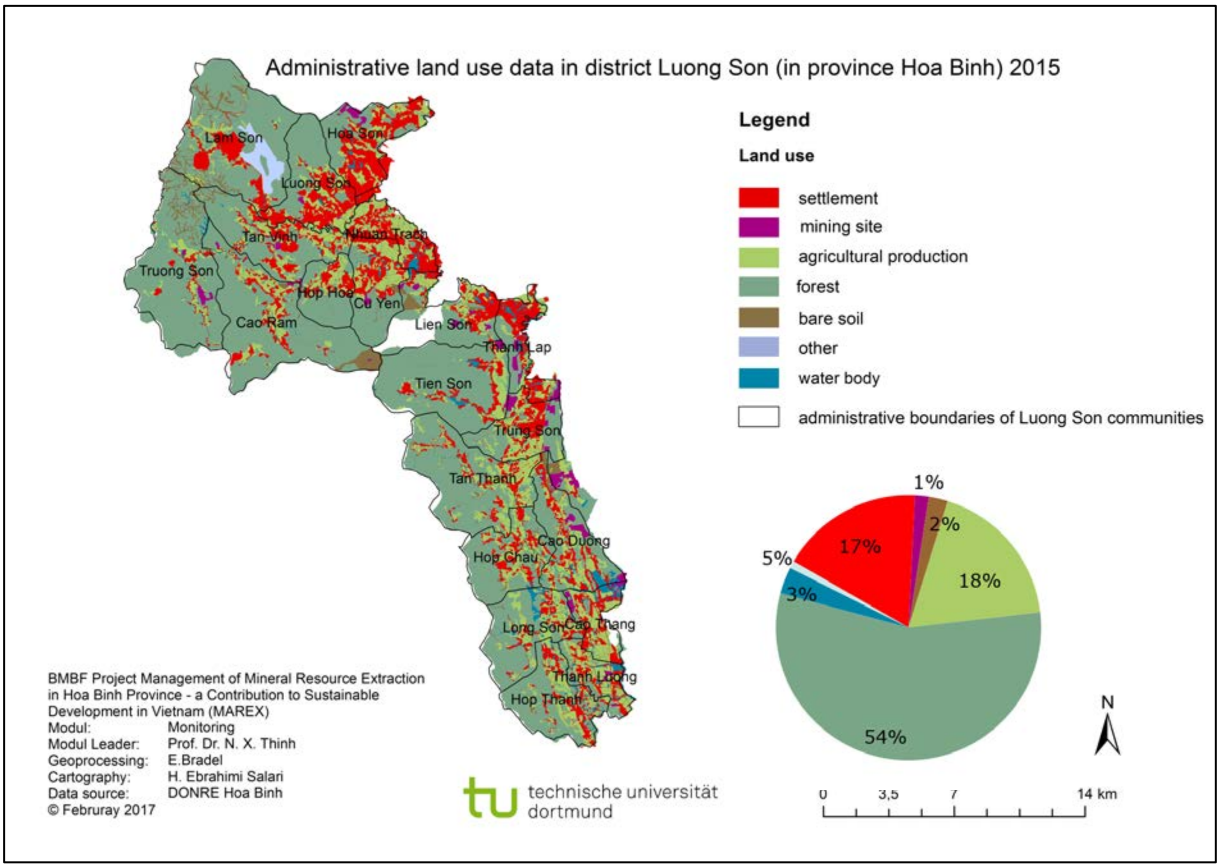


Figure 19: Administrative land use data in district Luong Son 2015 (Source: own illustration)

4.3.3 Mining site identification based on medium resolution Sentinel-2 (2017)

Sentinel-2 satellite image (10 m) for the year 2017 is classified to update the current status of mining site area. The analysis shows that the mining site area has increased from 477 ha in 2016 to 544 ha in 2017. Trung Son is the commune with the highest area of mining sites (see Figure 20)

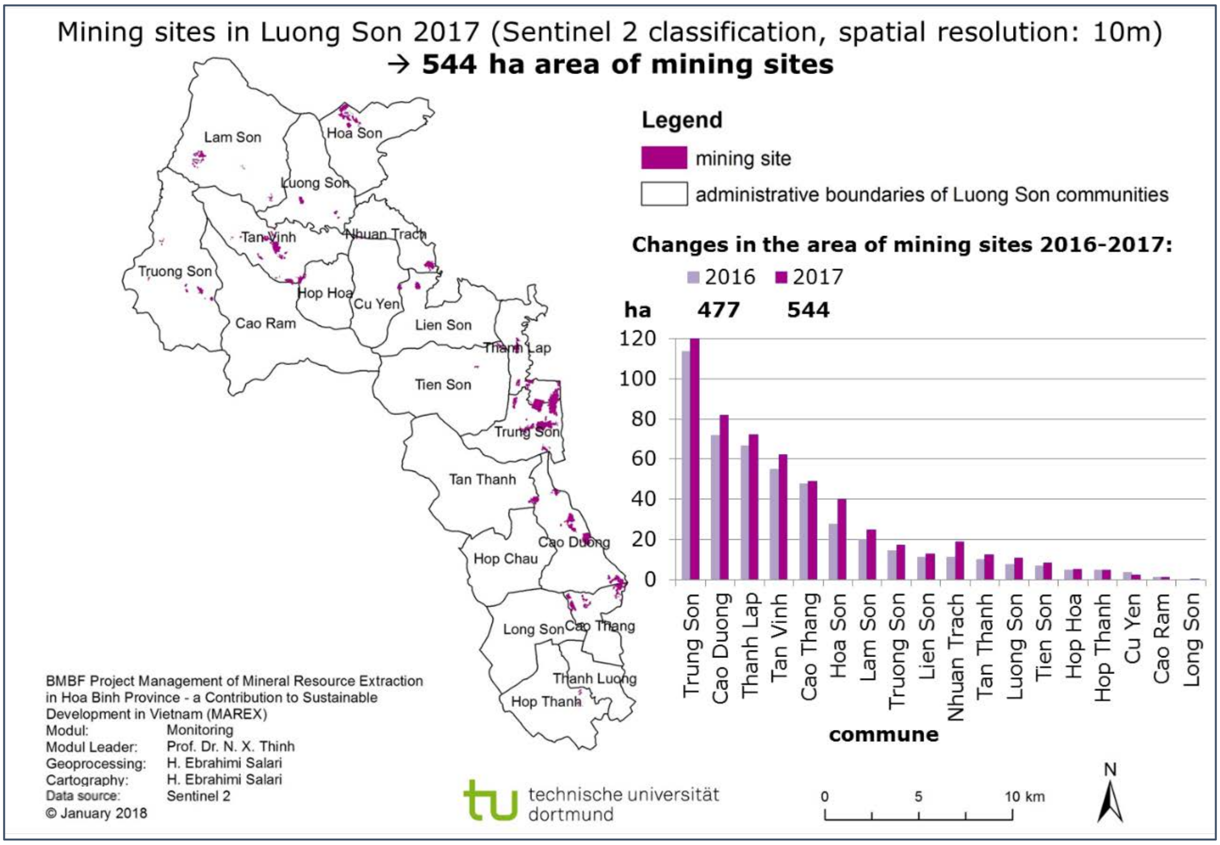


Figure 20: Mining sites in Luong Son 2017 (Source: own illustration)

4.4 Impacts

The environmental impacts of mining activities are investigated by evaluating environmental indicators reflected by monitoring stations. Furthermore, the environmental impacts of mining sites are modeled based on the selected environmental quality parameters.

In addition, post mining landscape is modeled in order to visualize the impact of mining sites on the future landscape of Luong Son. Finally, a land use conflicts analysis reflects the impacts of mining activities on society due to land use change.

4.4.1 Environmental impacts of mining activities reflected by monitoring stations

Monitoring and understanding the potential impacts that mining projects might have on the environment is crucial for environmental protection (Castilla-Gómez and Herrera-Herbert 2015). Environmental impact of mining operations is assessed by comparing the measured environmental indicators with standard values based on the environmental guidelines of Vietnam. The environmental impact assessment includes evaluating several parameters measured for air, surface water, groundwater, wastewater and soil from 2014 to 2017. In this part, several of the environmental indicators with significant negative impacts are presented.

4.4.1.1 Air monitoring stations

Evaluating air environmental indicators reveals that average noise, Sulfur dioxide (SO_2) and total suspended particles (TSP) have elevated levels of contamination in monitoring stations.

Noise and vibration: Blasting operations produce noise which obviously affect the nature. Environmental effects of noise due to blasting may arise from the blast itself and from the explosion wave. It can damage building structures of neighboring residents by inducing dynamic stresses that exceed the strength of building materials or rock materials. Therefore it is necessary to monitor and control the extreme vibration caused by blasting operations to have an environmentally friendly mining activities (Afeni and Osasan 2009). The evaluation of the average noise level in 2016 and 2017 reveals that explosions at mining sites in district Luong Son generate noise levels which exceed the standard values (see Figure 21).

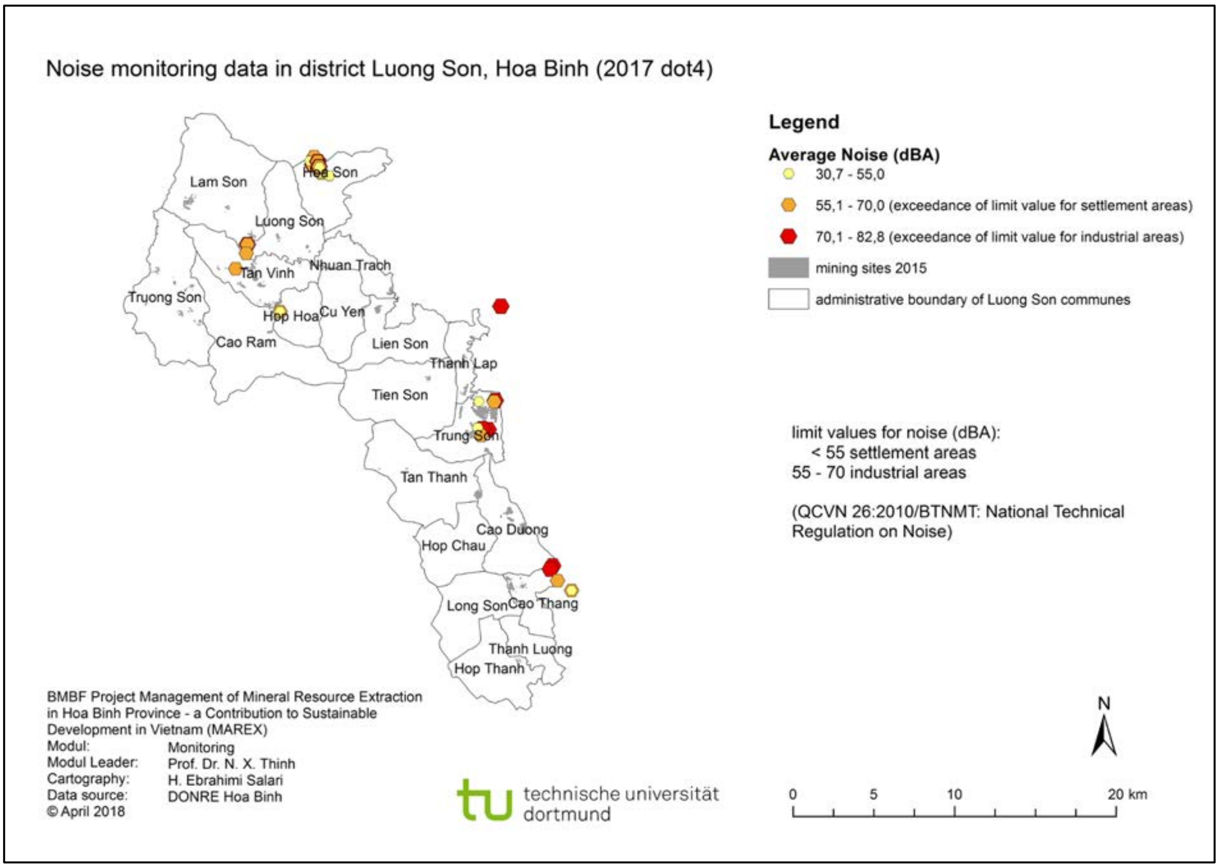


Figure 21: Noise monitoring data in Luong Son 2017.4 (Source: own illustration)

4.4.1.2 Surface water monitoring stations

Water quality analysis gives an idea about the health of the water bodies. According to the analysis of water samples taken in four dates during 2016 and 2017, water quality parameters including Ammonium (NH_4^+), Cadmium (Cd), Chemical oxygen demand (COD) Grease, Iron (Fe), Mercury (Hg) and total suspended solids (TSS) show exceedance of limit values.

Total Suspended Solids (TSS): The TSS concentration in almost all the monitoring stations is extremely higher than the standard limit value of 30mg/l which is set for the domestic water supply and 50mg/l which is for irrigation and similar purposes (see Figure 22).

4.4.1.3 Groundwater samples

Mining operations can directly disrupt groundwater flow (e.g. (Booth 2002)) and contaminate surface waters that are in hydraulic continuity with the affected groundwater system (Younger and Wolkersdorfer 2004). Groundwater samples evaluations show that Fe, Hg and Manganese (Mn) are above the standard limit values in almost all of the monitoring stations in both 2016 and 2017.

Manganese: Manganese released through mining activities into the environment causes contamination in water such as neurotoxicity, low hemoglobin levels and gastrointestinal accumulation (Fadel et al. 2017). Figure 23 shows the evaluation of the Mn values in stage 4 of 2017. In all monitoring stations manganese values exceed the limit value.

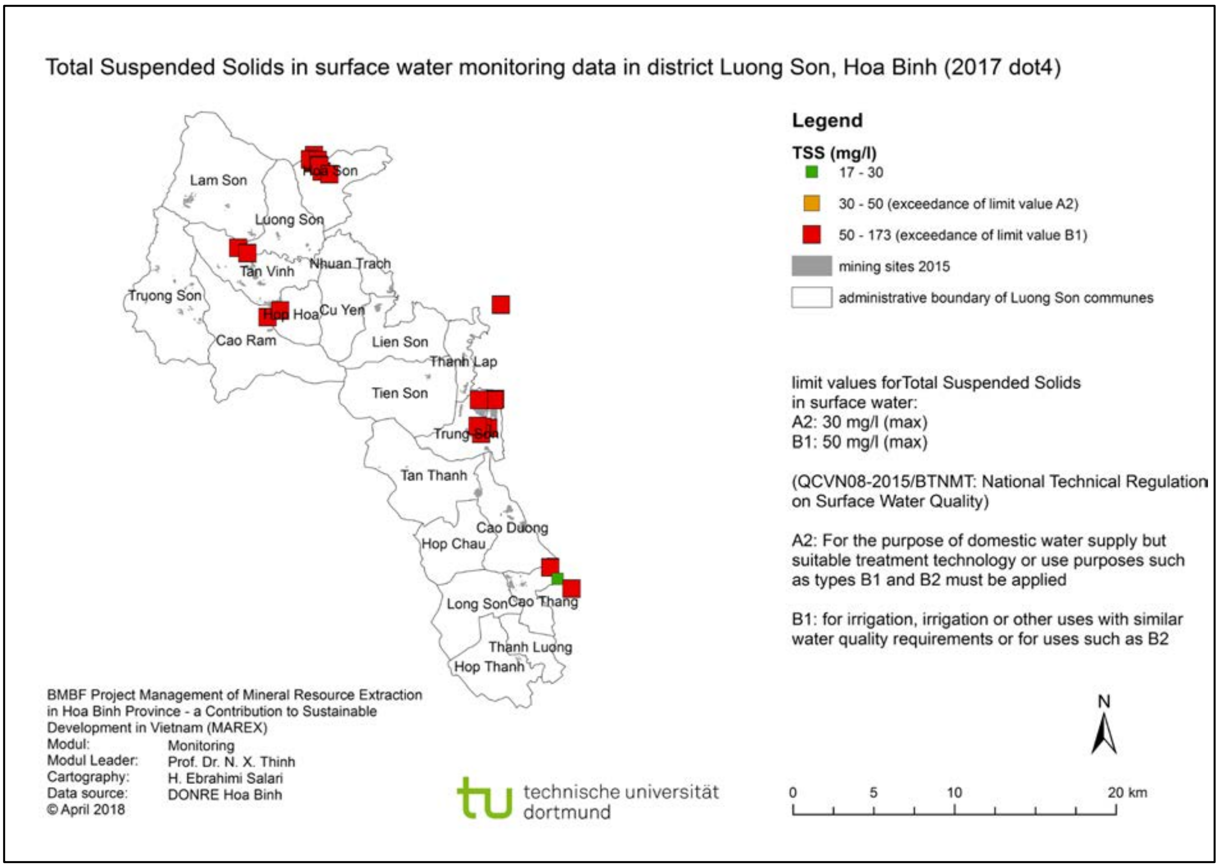


Figure 22: Total suspended solids in surface water monitoring data in Luong Son 2017.4 (Source: own illustration)

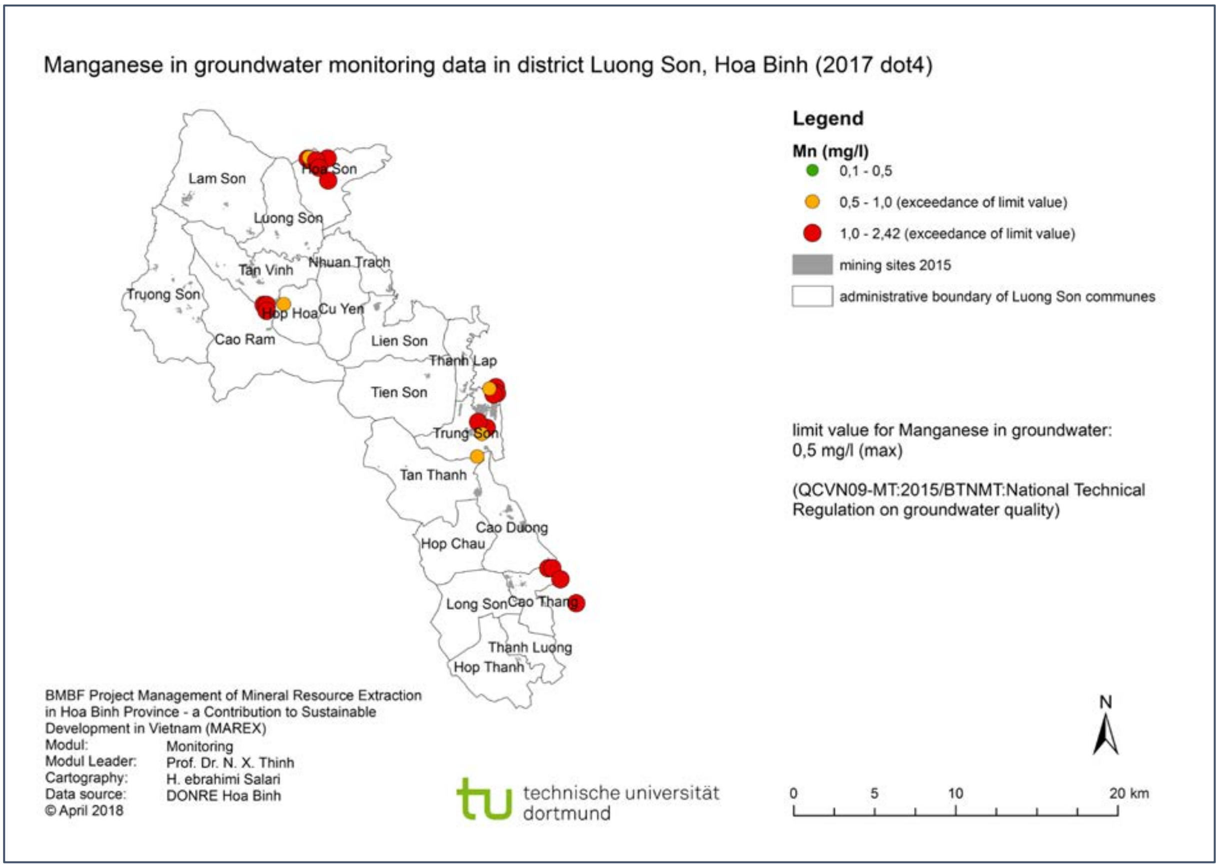


Figure 23: Manganese in groundwater monitoring data in Luong Son 2017.4 (Source: own illustration)

4.4.1.4 Wastewater

According to the wastewater sample evaluation, NH4+, 5-day Biochemical oxygen demand (BOD5), COD, Grease, Hg, PH, total nitrogen (TN), TSS are exceeding the standard values.

TSS: TSS is a major pollutant that affects waterways (Verma et al. 2013). It contributes to the deterioration of water quality leading to higher costs for water treatment, decreases in fish resources, and the general aesthetics of the water (Bilotta and Brazier 2008). High contents of TSS occur in mining areas in the all four sampling times and stations in 2016 and 2017 (see Figure 24).

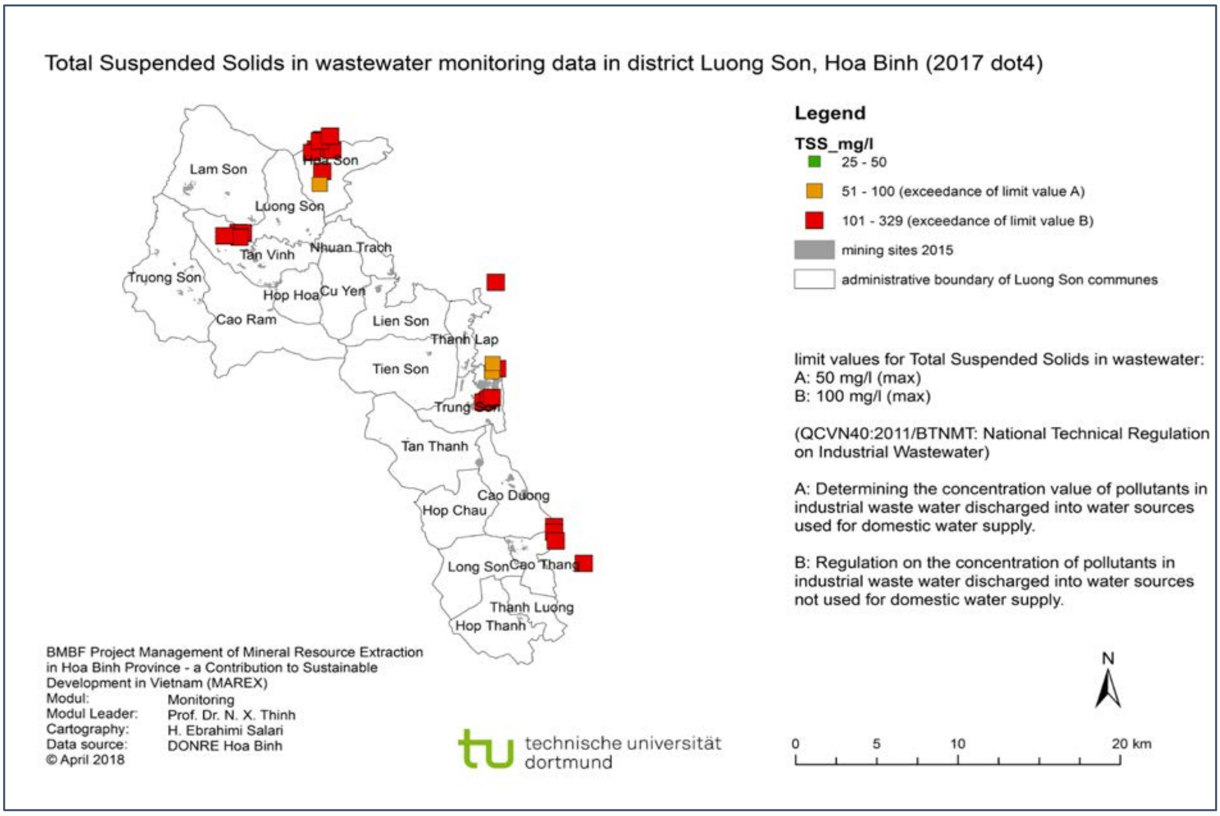


Figure 24: Total suspended solids in wastewater monitoring data in Luong Son 2017.4 (Source: own illustration)

4.4.2 Typology of environmental impacts of mining sites reflected by monitoring stations

Cluster analysis (CA) is an unsupervised pattern recognition technique that groups the objects (cases) into classes (clusters) based on their similarities within a class and dissimilarities between different classes. The results of CA help to interpret the data and indicate patterns (Hajigholizadeh and Melesse 2017). Using clustering methods, monitoring stations of air, surface water, groundwater and wastewater are grouped into three clusters. The three clusters correspond to three statistically significant clusters including low pollution, moderate pollution, and high pollution clusters. The quality parameters are selected based on the exceedance of limit values. In the following maps (Figure 25 to Figure 28) monitoring stations of the high contamination group are shown in red and other monitoring stations in yellow.

4.4.2.1 Air environmental indicators

The air monitoring stations are modeled for each of the sampling time on the basis of selected parameters, including TSP, particulate matter10 (PM10), particulate matter2.5 (PM2.5), maximum noise level (dBA), average noise (dBA), radiation, hydrocarbons (HC), SO_2, Nitrogen Dioxide (NO), Ozone (O_3) and Carbon Monoxide (CO). The models show that the air monitoring stations in the getting area and the production area of the mining sites in the commune of Cao Thang in 2016 (Phase 1 and Phase 2) and in 2017 (Phase 4) belong to the heavily contaminated cluster. In addition, the monitoring stations in the affected residential area of this site in 2016 (Phase 1) belong to the heavily polluted cluster (see Figure 25).

Comparing the four models of air quality indicators, it can be concluded that the air pollution level at different measurement times is generally higher in the mining sites of the commune Cao Thang than that of other stations.

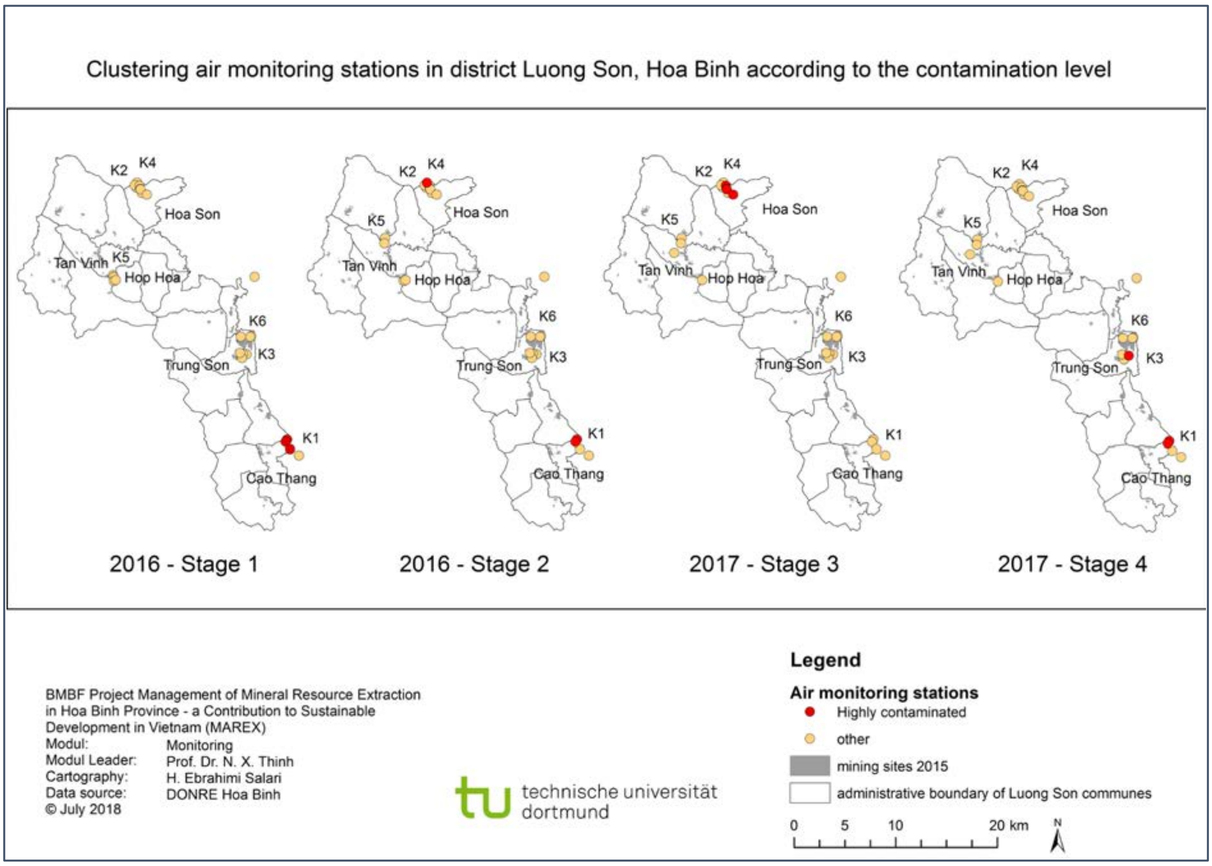


Figure 25: Clustering air monitoring stations in Luong Son according to the contamination level (Source: own illustration)

4.4.2.2 Surface water environmental indicators

Surface water monitoring stations of each sampling time are modeled based on selected parameters including NH_4^+, Dissolved Oxygen (DO), Grease, COD, Cd, Iron (Fe), Mercury (Hg) and Total Suspended Solids (TSS).

The comparison of the models shows that highest contamination in the surface water happens in the mining area of the commune Cao Thang namely in the production area in 2016 (stage 1 and stage 2) and 2017 (stage 4). In addition, the monitoring station in 2016 (stage 2) belongs to the heavily polluted group. Moreover, the monitoring station in the getting area of this mining site (2017, phase 3) belongs to the highly polluted group (see Figure 26).

Therefore similar to the air monitoring, the surface water samples taken at the mining sites of the Cao Thang commune are generally of higher contamination than that of other stations.

4.4.2.3 Groundwater environmental indicators

Groundwater monitoring stations of each sampling time are shaped based on selected parameter including Iron (Fe), Manganese (Mn), Mercury (Hg), Sulfate (SO_4^{2-}), Total suspended solids (TSS), NH_4^+, Nitrate (NO_3^{1-}), Nitrite (NO_2^-), Cd, Fluoride (F^-) and Arsenic (As).

The comparison of the models shows high pollution of the groundwater samples taken at the mining sites in the commune Cao Thang in the affected residential areas in 2016 (Phase 1), in the getting area and in the production area in 2017 (Phase 3 & Phase 4) and are thus classified as the high contaminated cluster.

The same as air and surface water, the groundwater samples taken at the mining site in commune Cao Thang are generally of higher contamination than that of other stations (see Figure 27).

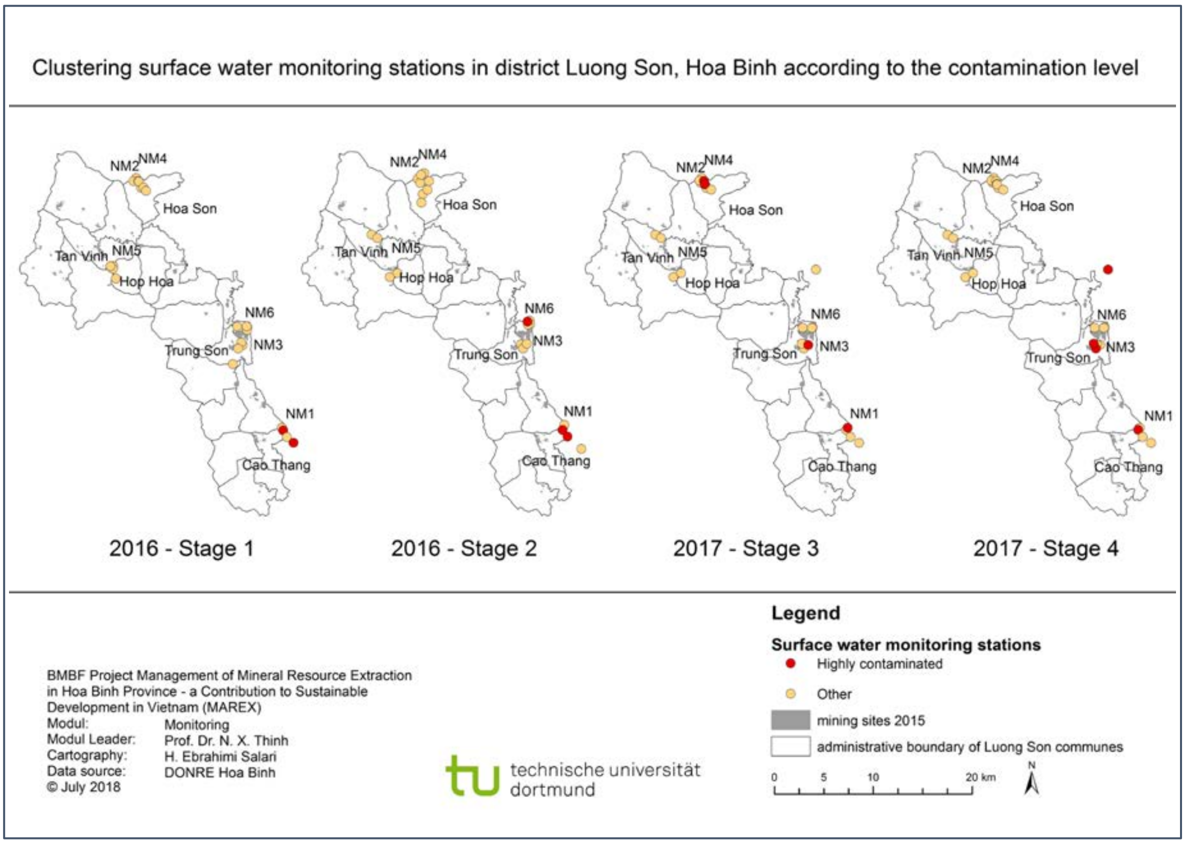


Figure 26: Clustering surface water monitoring stations in Luong Son according to the contamination level (Source: own illustration)

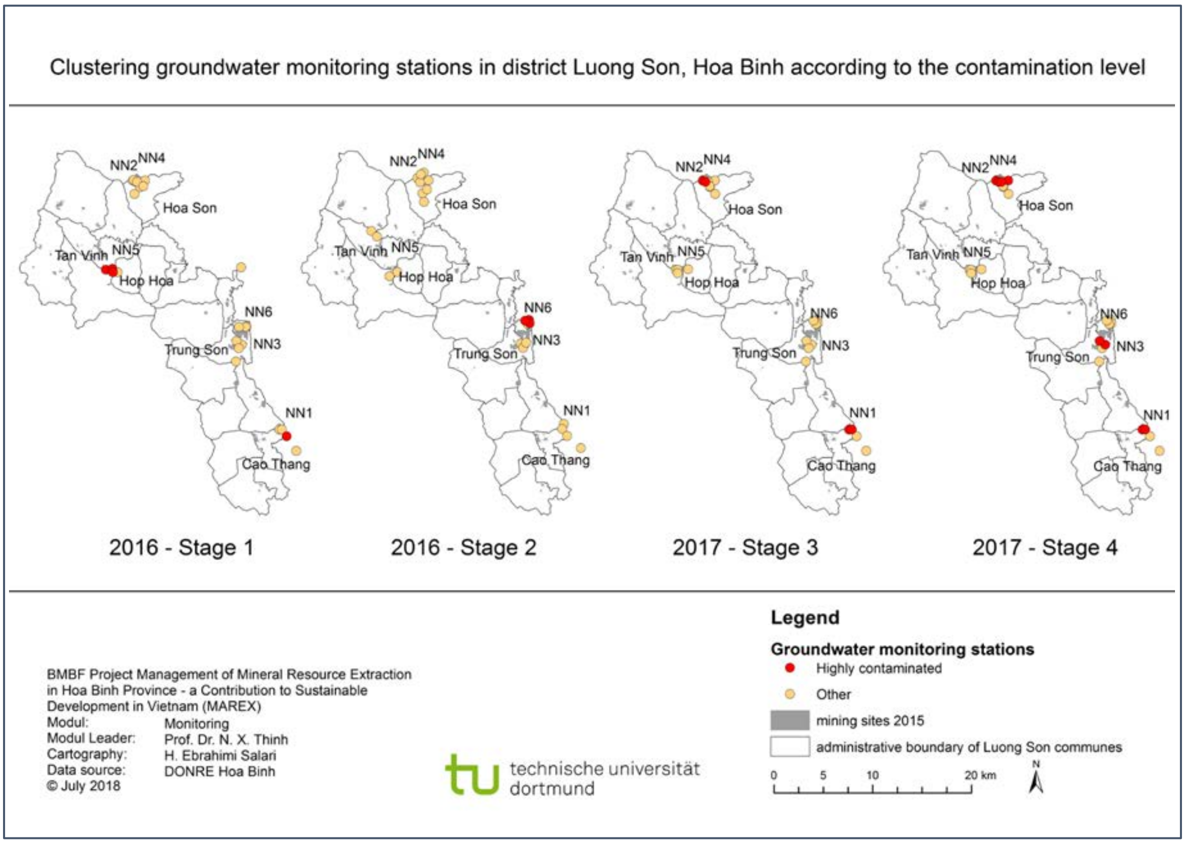


Figure 27: Clustering groundwater monitoring stations in Luong Son according to the contamination level (Source: own illustration)

4.4.2.4 Wastewater environmental indicators

Wastewater monitoring stations are located for measurements on the basis of selected parameters such as NH_4^+, BDO_5, COD, grease, Hg, pH, TN, total phosphorus (TP) and TSS.

According to the analysis, the monitoring stations for wastewater in the production area and getting area of the mining site in commune Tan Vinh show a high degree of contamination compared to other stations in stages 2, 3, 4 (see Figure 28). In contrast to other environmental indicators (air, surface water, groundwater) the wastewater samples taken at the mining site in commune Tan Vinh are generally of higher contamination than that of other stations.

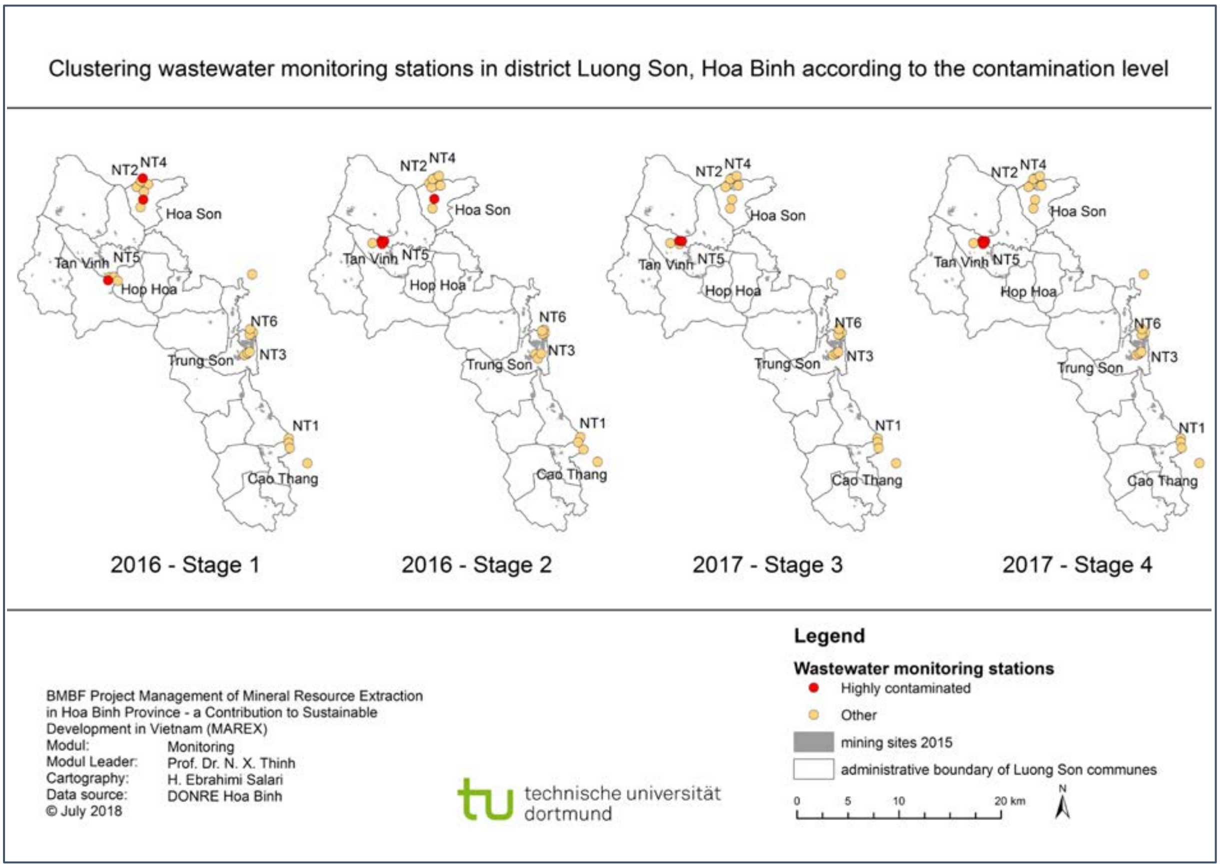


Figure 28: Clustering wastewater monitoring stations in Luong Son according to the contamination level (Source: Own illustration)

4.4.3 Modelling the post mining landscape in district Luong Son

Landscape destruction is one of the common environmental damage of mining sites (Lei et al. 2016). The most important land use change imposed by mining activities is the clearing of forest. In Hoa Binh massive forest areas are removed to access the underlying ore which has caused alteration in landscape and thus various environmental problems such as forest fragmentation.

Therefore, it is necessary to mitigate the impacts and to restore the post-mining landscape and all its functions after the ending of mining activities (Svobodova et al. 2012).

Under the assumption that the legal mining sites maintain with the same number and areas in district Luong Son, still almost 103 ha of forest areas are to be mined by the year 2042 (last expiration date of the issued license). In other words, in the period from 2016 to 2042, there will be almost 1% decrease in the forest areas. Although it is a small value, it can greatly affect the landscape.

The post mining landscape for mining sites is modeled according to the scenario that no changes will occur in the area and the number of mining sites until 2042. The model is developed using a spatial analysis tool in GIS by considering the former shape of expansions of mining sites from 2000 to 2017. In addition, land use types except forest areas are regarded as ban area expansion for mining (see Figure 29).

To provide a better insight of the landscape change, a 3D visualization of the expansion model is provided which presents special characteristics of environmental change in a compelling manner.

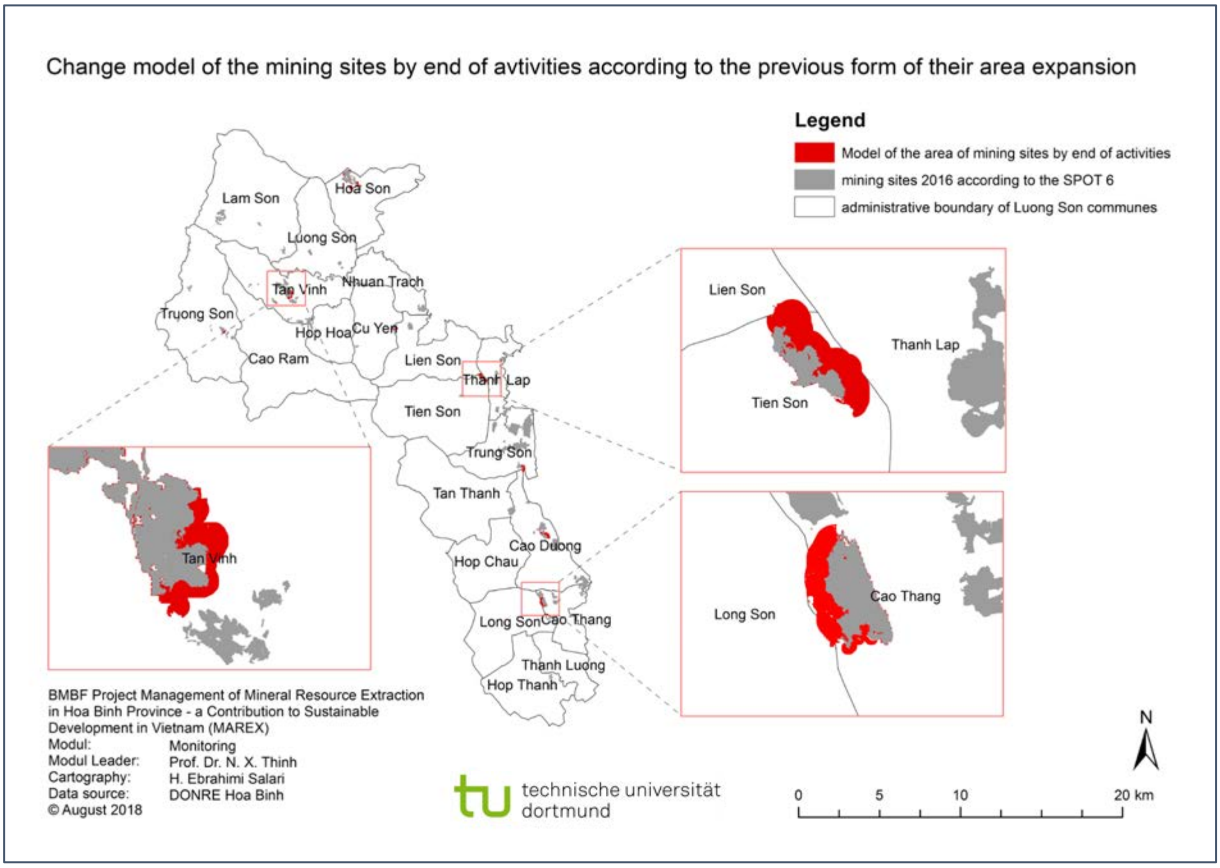


Figure 29: Change model of the mining sites by end of activities according to the previous form of their area expansion (Source: own illustration)

The 3D visualization is created using ArcScene. GIS datasets, including topography (DEM) and polygon features of the area. The expansion model of the mining sites are combined with high resolution SPOT satellite imagery to provide a *geo-specific* texture (see Figure 30).

Figure 30: Example of 3D Model of the expansion of mining site area by end of the mining project (Source: own illustration)

4.4.4 Analysis of the land use conflict

One of the negative Impacts by mining activities are land use conflicts. It is a big challenge for mines, which need a significant amount of area for exploitation, to coexist with the local people of surrounding communities who depend largely on the land for their livelihoods. The analysis is helpful for mine management to ensure that land use conflicts are effectively prevented and resolved (Hilson 2002).

4.4.4.1 Analysis of impacts of mining activities on affected communities

Figure 31 shows the settlement affected by mining activities in district Luong Son 2016. According to the analysis, in Luong Son 183 ha settlement area is located in the 200 m distance from mining sites in the year 2016. This leads to conflicts between the mining sector and inhabitants especially due to air pollutants like TSP and noise which can cause serious health problems for humans (Patra et al. 2016; Li et al. 2016; Parker et al. 2017).

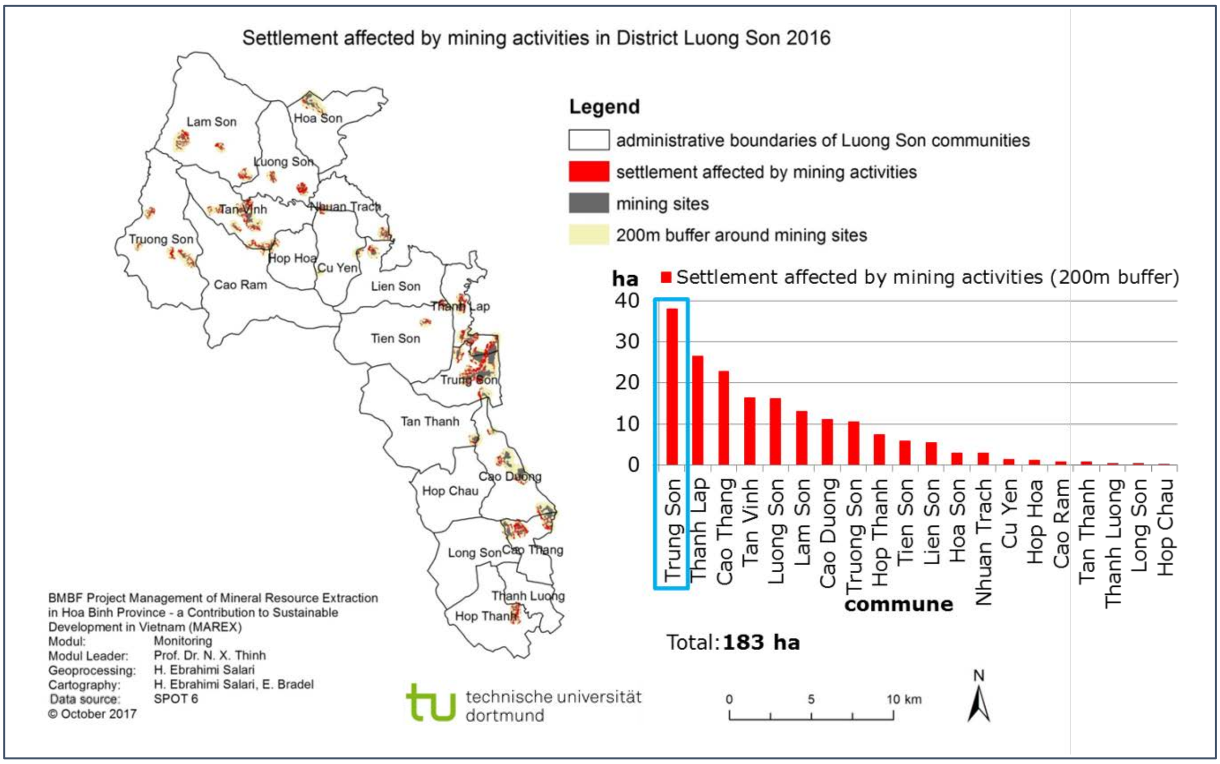


Figure 31: Settlements affected by mining activities in district Luong Son 2016 (Source: own illustration)

4.4.4.2 Contamination of agricultural activities near mining site

The contamination of soils used to for agricultural purposes is one of the major environmental damage caused by mining activities. Chemical leakage, Acid Mine Drainage (AMD), and breaches in waste storage facilities can contaminate surrounding soils, and endanger local fisheries and agricultural activities. In addition, waste tailings from mines threaten the surrounding agricultural land and pose a major threat to human health (Hilson 2002). Spatial analysis is performed to identify farmland areas affected by mining sites. Consequently, 509 ha of farmland was situated in the 200 m area around mining sites in district Luong Son in the year 2016 (see Figure 32). Thanh Lap is the commune with the highest amount of affected farmland (85 ha).

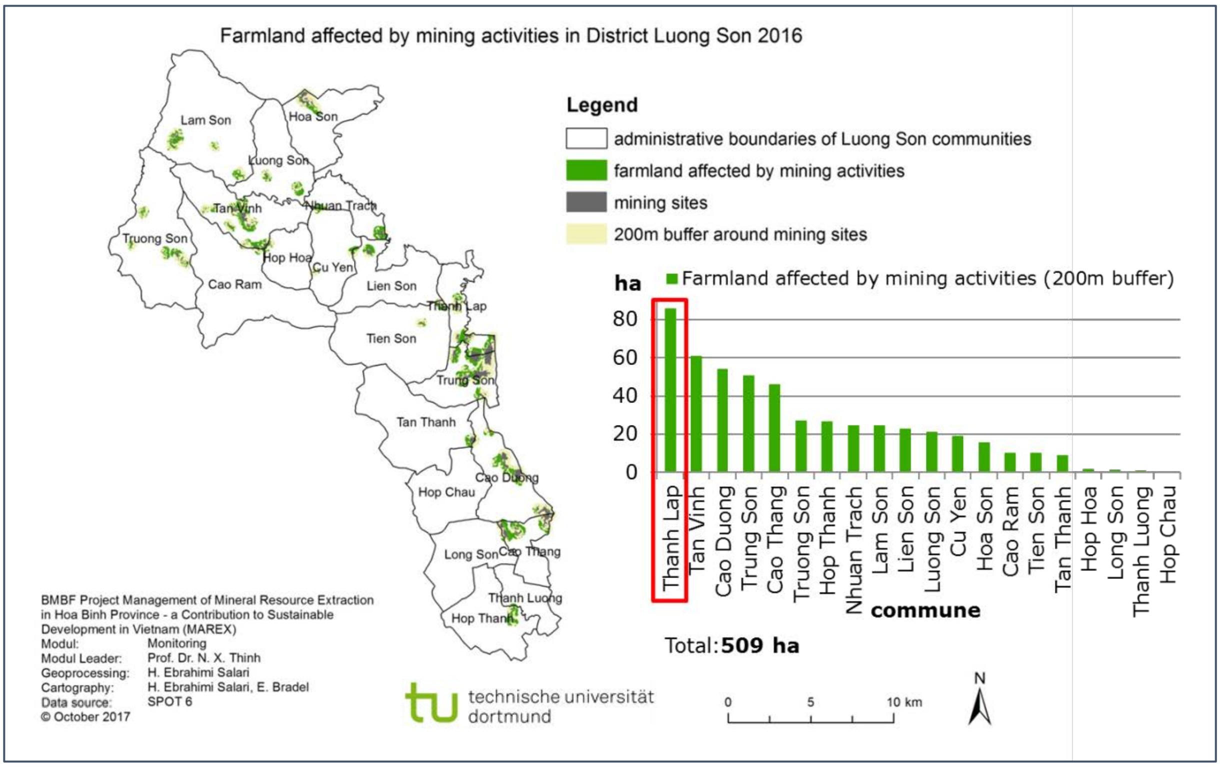


Figure 32: Farmland affected by mining activities in Luong Son 2016 (Source: own illustration)

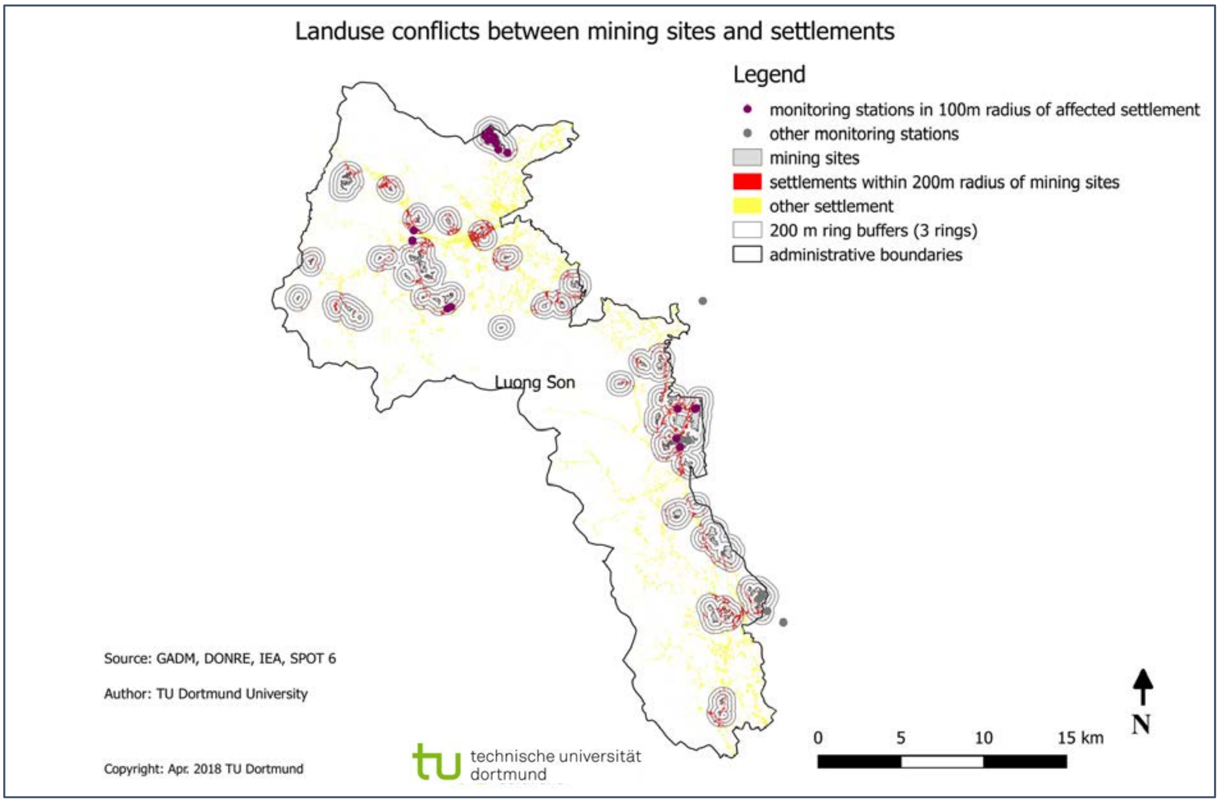


Figure 33: Output Land use Evaluation Tool (Source: own illustration)

4.4.5 Analysis of monitoring stations in affected settlements

The analysis of monitoring data from the surrounding areas of six mines in the district Luong Son for the year 2016 showed that there are exceedances of limit values of different parameters. At air monitoring stations, the comparison samples for TSP are below the limit values, but residential areas are affected by TSP at two mining sites (DoNRE and IEA 2017). In Luong Son, 183ha settlement area (8% of total settlement area in Luong Son) is in the 200m distance from mining sites in 2016 (see Figure 33). As regulated, the safe distance between a quarry and a residential area must be 200 meters or more. The mine's expansion across residential area can affect the lives of residents and pose safety risks (Patra et al. 2016; Parker et al. 2017; Li et al. 2016).

Especially due to air pollutants such as total suspended particulate (TSP) and extreme noise impact which may cause serious health problems.

According to the result of this analysis, the average of the TSP among monitoring stations in 100 m radius of affected settlement is about 0.27 mg/m^3 (see Figure 34) which is almost reaching the limit value of TSP (0.3 mg/m^3) according to the Vietnamese Technical Regulation on air quality (QCVN05:2013/BTNMT). Figure 34 shows the presentation of statistical data (exceeding stations, critical stations for evaluated parameter).

Statistic	TSP_mg_m3 value		
Minimum	0.058		
Maximum	1.57		
Average	0.275		
Standard deviation	0.302		
First quartile	0.111		
Median	0.1615		
Third quartile	0.2735		
Total Number	34		
list of monitoring stations in search area	K21C	K21S	K22C
TSP_mg_m3 value	0.912	1.57	0.24
Commune	Hoa Son	Hoa Son	Hoa Son

Figure 34: Output statistics (Source: own illustration)

4.5 Responses

Reducing the environmental impact of mining requires government response. The National Environmental Protection Strategy direction from 2010 to 2020 adopted by the Prime Minister in 2003 sets out the principles of environmental protection. It defines 5 basic tasks, 8 executive solutions and 36 programs, projects and operations.

Vietnam is currently drafting a national strategy for environmental protection by 2020 and a vision for 2030 to contextualize the new perspective and review past work on environmental protection. Based on this strategy, positions, goals, content, tasks and solutions for the future are derived in conformity with the new context of the world and Vietnam. According to this strategy, the current Vietnamese environmental protection act will be upgraded to environmental law, focusing on the objective of environmental governance and supervision. This generates a legal framework for environmental protection and sustainable development when addressing socio-economic development policies and implementing socio-economic development actions. Environmental protection has therefore evolved from a policy and legal content to actions carried out by all public authorities and people's organizations with constant awareness and action by the people. It is a step forward that deserves recognition (Vietnam ministry of planning and investment 2012).

5 Development of GIS-tools

Programming language python is used by RIM to establish GIS-based tools for processing data. The self-established GIS-Tool can be used in QGIS as a plugin (see Figure 35). Easy understanding of the tools is conceivable by provided Help function in HTML-format. The HTML help is tool-oriented and allows to search for the keywords.

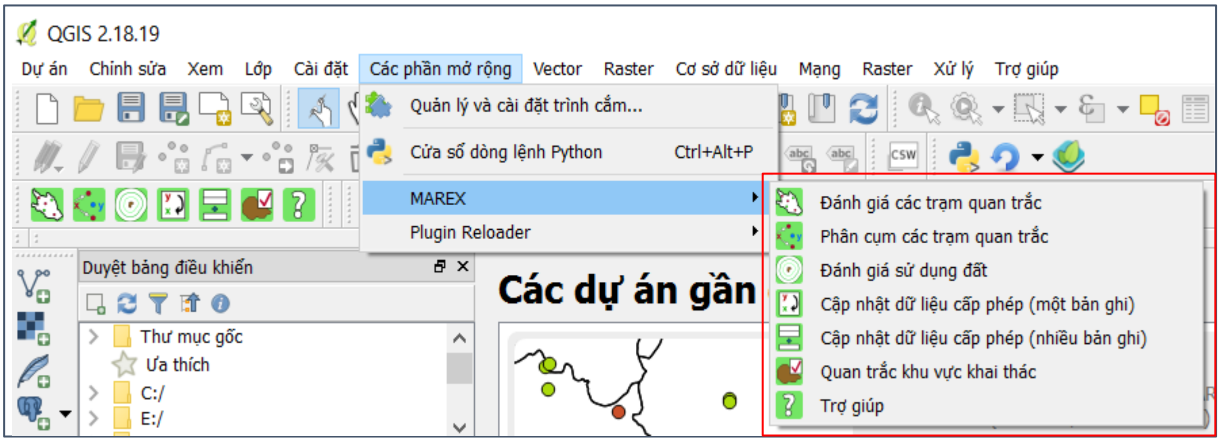


Figure 35: MAREX Plugin for QGIS (Source: own illustration)

The GIS-Tools offer the three main functions of maintaining tool, query tool, analysis tool.

5.1 Maintaining tools

An efficient data storage during *data* collection and data preservation afterwards are important steps to build an effective monitoring system. The developed maintaining tools offer data storage automation and management to facilitate the process of environmental impact monitoring.

Two functions of single-entry and multiple-entry are figured out for data update and storage. The single-entry function is designed to update the data one by one, whereas the multiple-entry tool allows the user to update and store several data using an excel table. These tools also produce spatial representation of the data on a geographical map.

The tool is of great importance for minimizing errors by data entries thus improving data efficiency. This tool deals with data of mining licenses and provides ability to control, search and update existing information as well as to add new data to the geo-database.

Using the tool, the status of mining site licenses from 2015 was updated with a table of legal mining site licenses from 2017. Figure 36 presents the spatial distribution of the mining licenses in province Hoa Binh categorized according to the status of licenses in 2017. In total, 106 mining records of mining licenses exist in both tables of 2015 and 2017. 50 of 106 mining licenses are operational. 20 of 106 licenses are still in licensing procedures. 11 licenses are refused and 7 licenses are expired. Only 1 given license is not operational yet.

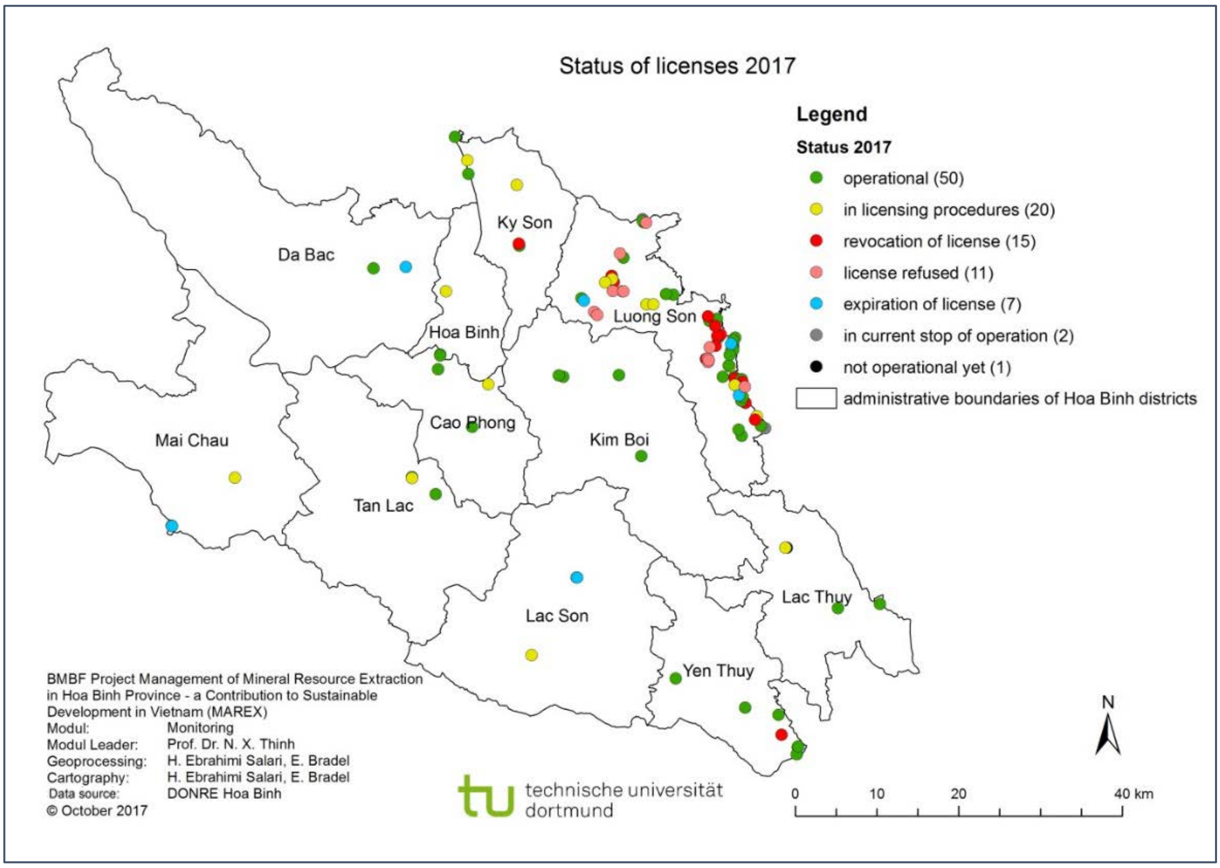


Figure 36: Status of licenses in 2017 (Source: own illustration)

5.2 Querying and reporting tools

The querying and reporting tool enables user to retrieve data or information from a database according to a search parameter. A basic query tool is developed to determine the over-explored mining areas by comparing the total licensed operational area and current explored area for mining activities. The tool also produces a shapefile, a map and a table of the analysis results.

Figure 37 shows the result of the tool in form of a map. Red points show the mining sites which exceed the licensed areas for exploration, while mining sites which do not exceed the licensed area are given in green. The analysis revels that there are several over-explored mining sites in several districts namely Cao Thang, Cao Duong, Trung-Son, Thanh Lap, Lien Son and Luong Son. This tool provides fast supervision of operating area of mining sites to control the operations.

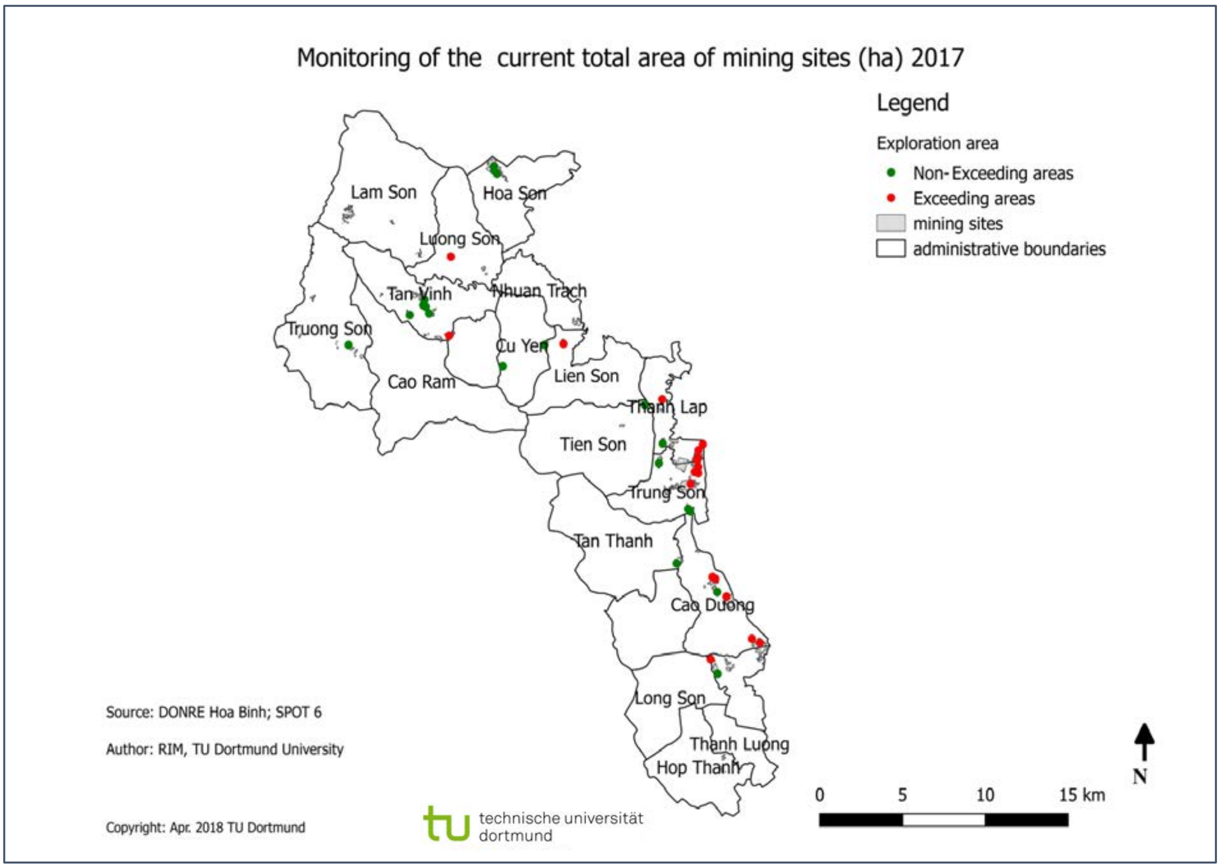


Figure 37: Monitoring of the current total area of mining sites (ha) 2017 (Source: own illustration)

The tool also generates an Excel-table with the information about the differences between licensed operational areas and the current operational areas (see Figure 38).

Site_location	licensed Operating area	Current operational area	Difference of areas
Trung Sơn	13.17	6.64	-6.53
Hòa Sơn	38.1	27.51	-10.59
Thành Lập	20	4.52	-15.48
Trường Sơn	12	9.93	-2.07
Cao Dương			11.00
Trung Sơn			57.93
Tân Vinh			5.35
Thành Lập			57.93
Trung Sơn	25.33	83.2	57.93
Tiến Sơn	14.76	4.74	-10.02
Thành Lập	25.33	83.26	57.93
Cao Dương	19.2	8.55	-10.65
Tân Vinh	48.31	38.23	-10.08

Differences between current areas of mining sites and licensed operation areas

Figure 38: Example of Excel application – Monitoring of the current total area of mining sites (Source: own illustration)

5.3 Analysis tools

The analysis tools are developed to perform specific GIS analysis for environmental impact assessment of the mining activities. The analysis toolset is composed of three main tools:

- Evaluating monitoring stations to detect limit value exceedance of environmental thresholds
- Evaluating land use around mining sites to detect the existing land use conflicts
- Clustering of monitoring stations to determine the level of environmental contamination

5.3.1 Evaluation of monitoring stations

A GIS-based monitoring system for the analysis of environmental impacts of mining activities is established. This tool offers standard limit values for parameters and the user can set a self-defined critical value. Any analysis area can be chosen (commune, district, province) and the layout style can be defined. The GIS-tool uses Excel-tables of monitoring data as an input together with a base map to produce a map (see Figure 39), diagram (see Figure 40) as well as statistics (see Figure 41) about user-defined parameters. The output is based on the chosen parameter and presents the monitoring stations with exceedances of limit values and critical high values. A comprehensive database of Vietnamese technical regulation on the standards of contamination of surface water, groundwater, wastewater and soil limit values were also prepared for this analysis tool.

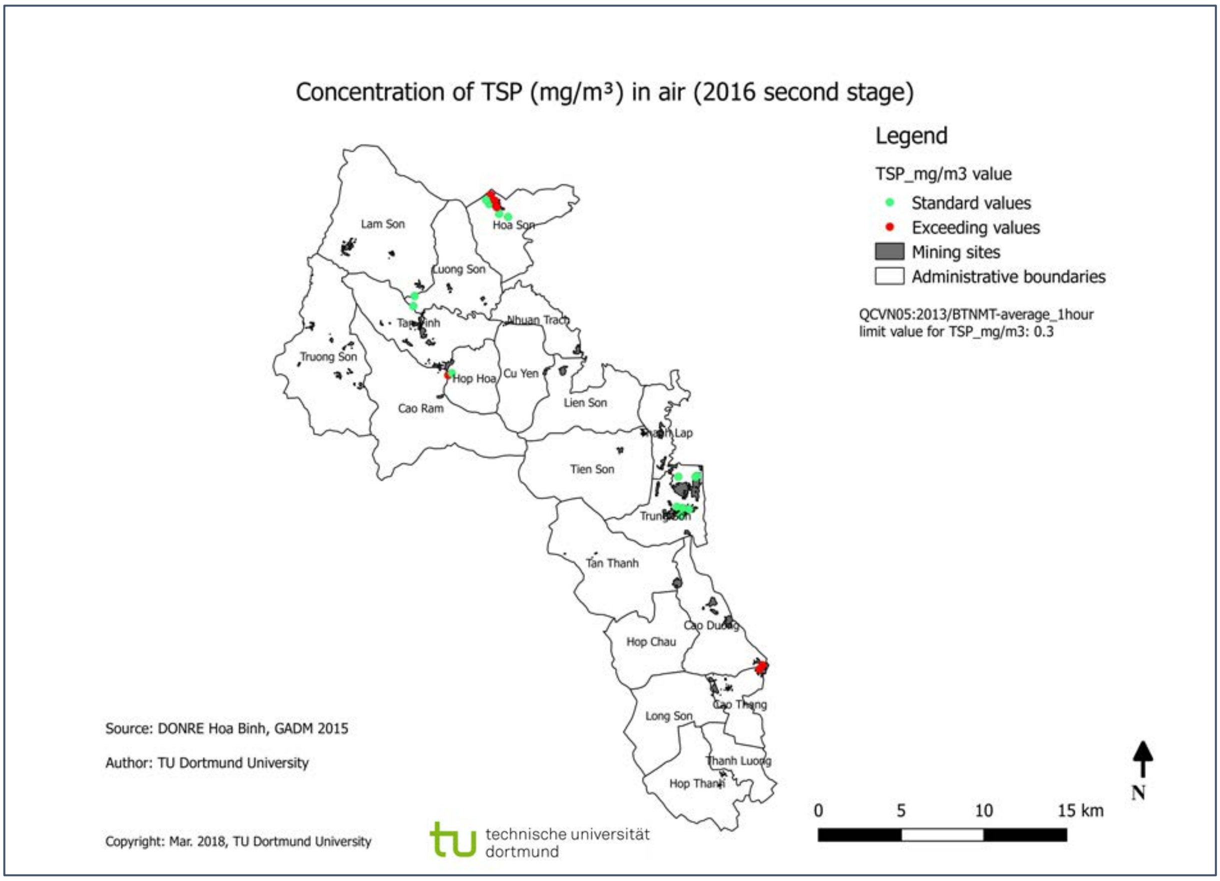


Figure 39: Concentration of TSP (mg/m³) in air in Luong Son (2016 Second stage) (Source: own illustration)

The following information is offered in the Excel-table (see Figure 41):

- Basic statistics based on the selected parameter (Total number, Min, Max, Average…)
- Total number of standard and exceedance monitoring stations regarding selected parameter
- List of exact exceeding and critical monitoring stations
- Values of selected parameter in exceeding and critical monitoring stations
- Location of exceeding and critical stations

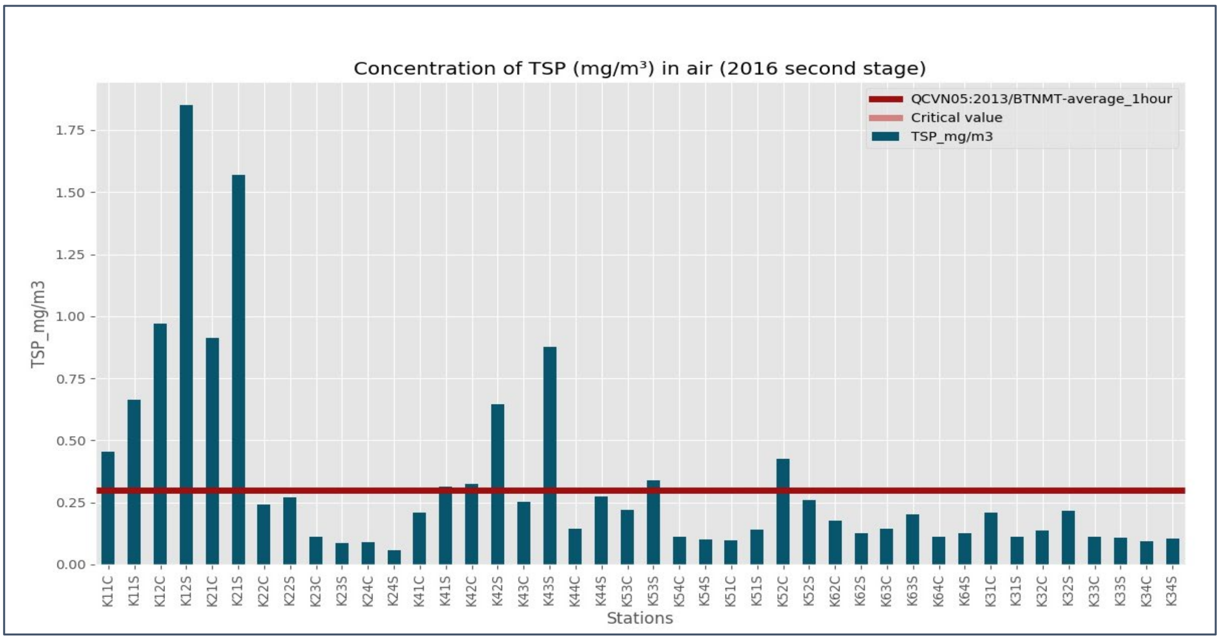


Figure 40: Output diagram of the concentration of TSP in air in Luong Son (2016. Stage 2) (Source: own illustration)

This is a helpful tool for authorities as it offers the possibility to prematurely intervene when measured parameters at mining sites are critically high or exceed the limit values. This can help to detect and prevent negative environmental impacts of mining activities.

	Statistics			
Minimum	0.058			
Maximum	1.852			
Average	0.333214285714			
Standard deviation	0.383335147142			
First quartile	0.112			
Median	0.2045			
Third quartile	0.32325			
Total Number	42.0			
No. of standard stations	30.0			
No. of exceeding stations	12.0			
Exceeding stations	K42C	K12C	K11C	K52C
Exceeding stations location	Hoa Son	Cao Thang	Cao Duong	Tan Vinh
Exceeding stations TSP_mg/m3 value	0.326	0.969	0.456	0.426

Basic statistics

Exceeding stations

Values and location of exceeding stations

Figure 41: Output statistics (Source: own illustration)

5.3.2 Evaluating land use around mining sites

Another plugin of the GIS-tool makes it possible to put the monitoring data into context with the existing land use to demonstrate the impacts of the mining activities on different land uses.

Using this tool, users can identify land use types in a defined distance of mining sites. Moreover, the tool allows the investigation of a selected environmental indicator in or around affected areas also with a user defined search radius.

The tool is used to evaluate the environmental impact of mining sites in the affected settlements by considering manganese value in the groundwater in commune Trung Son since it is the commune with the biggest area of mining sites. Firstly, the settlement areas within the 200 m buffer-zone around mining sites are identified. Then, the monitoring stations which are in 100 m distance of the affected area are examined. Two monitoring stations are found within the specified distance (100 m). Both of them show exceedance of limit value of manganese (0.52mg/l) regulated by QCVN09-MT: 2015/BTNMT (see Figure 42 & Figure 43). The monitoring station with the highest value is highlighted in red in the generated chart (see Figure 44).

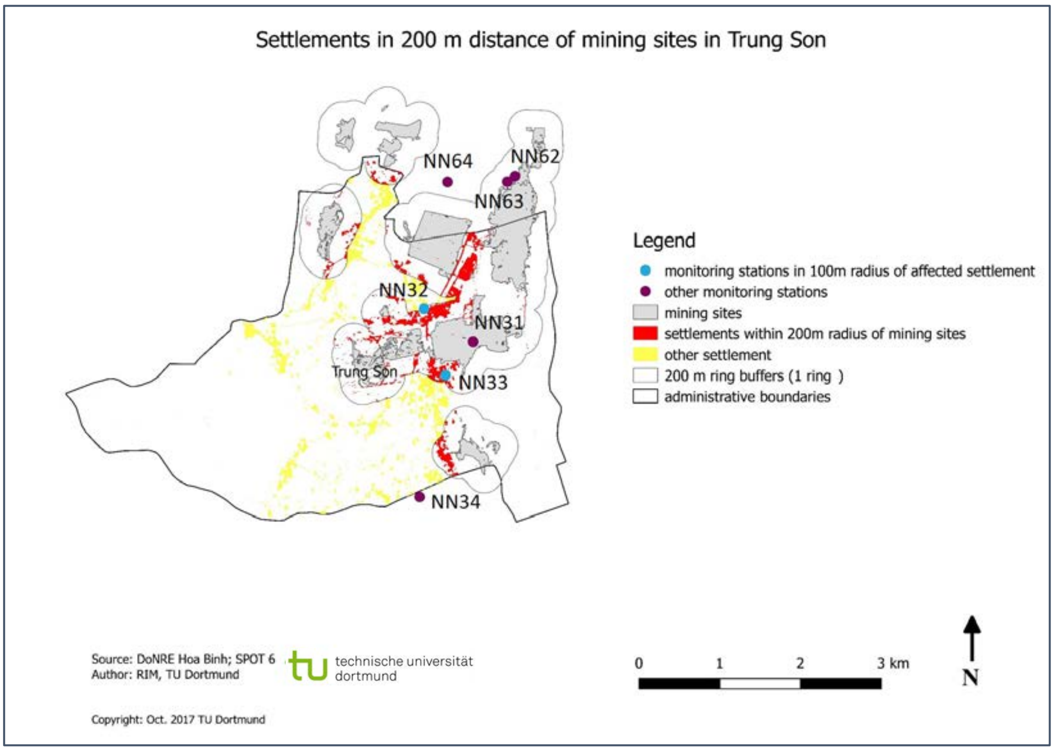
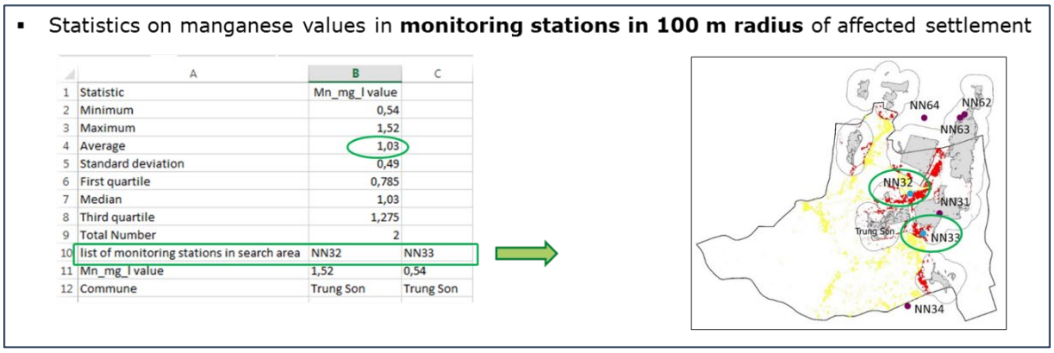


Figure 42: Output Land use Evaluation Tool for Trung Son (Source: own illustration)



	A	B	C
1	Statistic	Mn_mg_l value	
2	Minimum	0,54	
3	Maximum	1,52	
4	Average	1,03	
5	Standard deviation	0,49	
6	First quartile	0,785	
7	Median	1,03	
8	Third quartile	1,275	
9	Total Number	2	
10	list of monitoring stations in search area	NN32	NN33
11	Mn_mg_l value	1,52	0,54
12	Commune	Trung Son	Trung Son

Figure 43: Output statistics in CSV format (Source: RIM 2018)

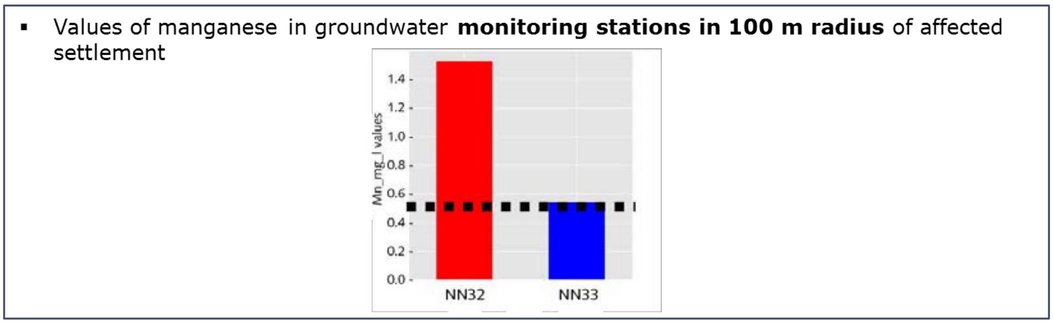


Figure 44: Output chart in JPEG format (Source: own illustration)

5.3.3 Cluster analysis tool

Cluster analysis is a categorization technique to divide data into classes or clusters. The aim of the analysis is to place similar observations into a number of clusters based on the observed values of several variables for each individual (Peterson et al. 2010).

The cluster analysis tool accepts the excel table or the shapefile of the monitoring stations as input data and classifies monitoring stations according to the values of selected environmental parameters into different groups. The user has to choose environmental indicators to be employed in the cluster analysis through a drop-down menu on the user interface. The initial result of the analysis is a table in which each monitoring station has been assigned to a cluster.

Figure 45 shows the final result of the cluster analysis using 9 environmental indicators (contamination indicators for air: Temperature (°C), Equivalent Continuous Sound Level (dBA), Maximum Noise Level Lmax (dBA), Noise L50 (dBA), CO (mg/m³), NO_2 (mg/m³), SO_2 (mg/m³), O_3 (mg/m³), TSP (mg/m³) in air) in province Hoa Binh. 75 air monitoring stations are used as the input data and are divided into 3 clusters of low, medium and high contamination. According to the result, 7 monitoring stations are in high contamination cluster, of which 5 belong to air mining monitoring stations (see Table 3). This shows the intensity of air contamination in mining areas comparing to other areas.

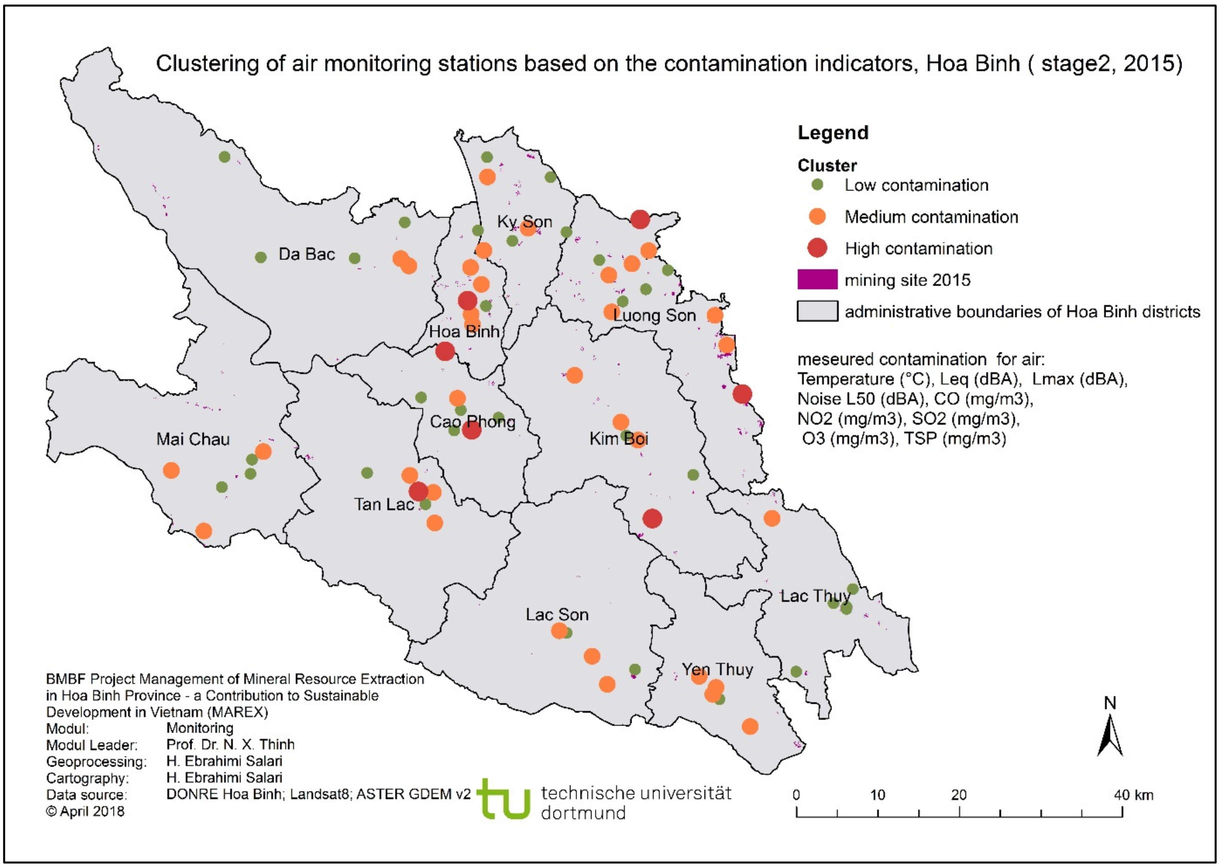


Figure 45: Clustering of air monitoring stations based on air contamination indicators, Hoa Binh (stage 2, 2015) (Source: own illustration)

Table 3: Number of monitoring stations in high, medium and low contamination clusters (Source: own illustration)

Cluster	All air monitoring stations	Air mining monitoring stations
High contamination	7	5
Medium contamination	33	6
Low contamination	35	3
Total number of monitoring stations	75	14

6 Discussion and conclusion

The DPSIR model is effectively used to structuralize the monitoring of the environmental impact of the mining sites in Hoa Binh district. Using the DPSIR model, five factors of Driving forces, Pressures, State, Impact and responses associated with mining activities are studied.

The detection and analyzation of the land use as well as the geotagging of potential mining sites in the province Hoa Binh for the years 2000, 2007, 2009, 2011, 2013 and 2015, based on Landsat satellite images showed that the landscape in Hoa Binh dramatically changed as a consequence of the intensive and increasing mining activities. In the same time period, the forest area decreased about 18 %. A large amount of settlement areas is highly affected by mining activities which leads to health issues for the inhabitants occurring especially from the exceedances of standard limit values for air pollution and noise.

The rapid increase of the mining industry in Hoa Binh during the past 15 years due to higher demand for building materials has led to increasing damages to landscape, environment, humans, health, … as a result of the large interventions in the nature.

Additionally, the evaluation and cartographic visualization of the monitoring data of several air, soil, surface water, groundwater and wastewater monitoring stations for the years 2014-2017 pointed out the exceedances of limit values in Hoa Binh, especially for air parameters close to mining sites. Furthermore, land use conflicts arise due to the unregulated development of mining area in Hoa Binh.

Luong Son district, which contains 52 of the 88 licensed mines of the province Hoa Binh, is highly affected by mining activities. Therefore, further research with SPOT 6 high-resolution satellite data together with additional monitoring data for the year 2016 and 2017 was conducted for this district. Identified LU/LC data based on SPOT 6 enables detailed analysis on land use conflicts due to mining activities. It is demonstrated that 183ha settlement area which is 8% of total settlement area in Luong Son are in close proximity of mining sites. A Sentinel-2 satellite image of 2017 is also classified in order to investigate the current changes in the area of mining sites from 2016 to 2017. This analysis proves that the mining sites are growing rapidly (477 ha in 2016 to 544 in 2017).

Various analysis performed by this study reveal that the province Hoa Binh and in particular the district Luong Son are highly affected by mining activities. Moreover, the evaluation of the monitoring data also implies the exceedance of limit values for several environmental indicators such as TSP. On the other hand, land use analysis shows that some settlements are located in close proximity of mining sites, so they can be severely affected by negative environmental impacts of mining activities.

Environmental impacts of mining sites are successfully modeled to help local authorities to develop mitigation measures for severely contaminated areas. According to the developed models of environmental quality indicators, the mining site in the commune Cao Thang has the worst situation in terms of air, surface water and groundwater, while the mining site in commune Tan Vinh has the worst situation in wastewater contamination.

Post mining landscape is modeled considering the previous development trend of mining areas. The representation of the post mining landscape provides local authorities with better insight for landscape management. Landscape management is of great importance for Hoa Binh, as the province priorities calling for investment in tourism projects in several districts including Luong Son district (World Bank 2009).

Due to intensive impact of mining activities, there is an urgent need to develop instruments which support local authorities in monitoring mining activities and developing mitigation measures. For this end, a GIS-based analysis tool is developed. It is a powerful option for monitoring the environmental impacts and management of mining activities. Monitoring and management of mining activities require provision of necessary data, information and tools for real time analysis. The established open-source GIS tools increase the effectiveness of data storage and management. It also offers standard monitoring and evaluation methods. The user-friendly analysis tools help local authorities and decision makers to assess the negative environmental impacts of mining activities to take mitigation measures in timely manner.

The GIS software tool makes it possible to gain an overview of the status of the mining activities and their effects on the environment by generating comparable outputs such as statistical data, diagrams and maps. It features three key functionalities:

(1) Storage automation and management, including single- and multiple-entry functions and spatial representation of the data on geographical maps;

(2) Querying and reporting functions, which enable users to retrieve data or information from a database according to search parameters and to access the results in a shapefile, map and/or table; and

(3) Analysis functions, which evaluate monitoring stations to detect when limiting values have been exceeded, evaluate land use around mining sites to detect land use conflicts, and cluster monitor stations to determine the level of environmental contamination.

The comparable outputs of the GIS-tools such as statistical data, diagrams and maps provide an easier understanding of the analysis results and can help to build an effective monitoring system of the environmental impacts of mining sites. Providing web map of the different datasets and analysis results in the geodatabase also enables easy share of results with other users without knowledge of GIS.

The development of the python-based GIS tool as a plugin in QGIS, an open source geographic information system, is of vital importance. Not only is the free availability of the tool guaranteed since it is based on open source software, but also a help function in HTML format is available for a better understanding of the tool. Moreover, the developed open source tool is applicable for the establishment of a database on natural resources and environmental monitoring in other provinces in Vietnam. It supports local authorities in monitoring mining activities and developing mitigation measures by improving the effectiveness of data storage and management as well as enabling real time analysis.

7 Publication bibliography

Afeni, Thomas B.; Osasan, Stephen K. (2009): Assessment of noise and ground vibration induced during blasting operations in an open pit mine — A case study on Ewekoro limestone quarry, Nigeria. In Mining Science and Technology (China) 19 (4), pp. 420–424. DOI: 10.1016/S1674-5264(09)60078-8.

Bilotta, G. S.; Brazier, R. E. (2008): Understanding the influence of suspended solids on water quality and aquatic biota. In Water research 42 (12), pp. 2849–2861. DOI: 10.1016/j.watres.2008.03.018.

Booth, Colin J. (2002): The effects of longwall coal mining on overlying aquifers. In Geological Society, London, Special Publications 198 (1), pp. 17–45. DOI: 10.1144/GSL.SP.2002.198.01.02.

Castilla-Gómez, Jorge; Herrera-Herbert, Juan (2015): Environmental analysis of mining operations: Dynamic tools for impact assessment. In Minerals Engineering 76, pp. 87–96. DOI: 10.1016/j.mineng.2014.10.024.

DoNRE; IEA (2017): Report of Phase I. Tasks: “Investigation, survey and analysis of environmental quality in mining sites in Luong Son district, Hoa Binh Province”.

Fadel, M.; Hassanein, Naziha M.; Elshafei, Maha M.; Mostafa, Amr H.; Ahmed, Marwy A.; Khater, Hend M. (2017): Biosorption of manganese from groundwater by biomass of Saccharomyces cerevisiae. In HBRC Journal 13 (1), pp. 106–113. DOI: 10.1016/j.hbrcj.2014.12.006.

GENERAL STATISTICS OFFICE of VIET NAM (2016): Statistical Yearbook of Vietnam 2015. Hà Nội: Thống kê.

General Statistics Office Of Vietnam (2016): statistical yearbook of vietnam 2016. Available online at https://www.gso.gov.vn/default_en.aspx?tabid=774, checked on 8/1/2018.

Hajigholizadeh, Mohammad; Melesse, Assefa M. (2017): Assortment and spatiotemporal analysis of surface water quality using cluster and discriminant analyses. In CATENA 151, pp. 247–258. DOI: 10.1016/j.catena.2016.12.018.

Hilson, Gavin (2002): An overview of land use conflicts in mining communities. In Land Use Policy 19 (1), pp. 65–73. DOI: 10.1016/S0264-8377(01)00043-6.

Jordan, Gyozo; Abdaal, Ahmed (2013): Decision support methods for the environmental assessment of contamination at mining sites. In Environmental monitoring and assessment 185 (9), pp. 7809–7832. DOI: 10.1007/s10661-013-3137-z.

Lanjouw, P.; Marra, M. R. (2018): Urban poverty across the spectrum of Vietnam’s towns and cities. In World Development 110, pp. 295–306. DOI: 10.1016/j.worlddev.2018.06.011.

Larkin, Alex Thomas; Si V, Tran (2010): Balancing mining opportunities with protection of the environment. Edited by Vietnam Law and Legal Forum magazine, Vietnam News Agency. Available online at http://vietnamlawmagazine.vn/balancing-mining-opportunities-with-protection-of-the-environment-3719.html, updated on 8/28/2018, checked on 8/28/2018.

Lei, Kai; Pan, Huiyun; Lin, Chunye (2016): A landscape approach towards ecological restoration and sustainable development of mining areas. In Ecological Engineering 90, pp. 320–325. DOI: 10.1016/j.ecoleng.2016.01.080.

Li, Xiaodong; Song, Ziyang; Wang, Tao; Zheng, Yu; Ning, Xin (2016): Health impacts of construction noise on workers: A quantitative assessment model based on exposure measurement. In Journal of Cleaner Production 135, pp. 721–731. DOI: 10.1016/j.jclepro.2016.06.100.

Maguire, Cathy; Hoogeveen, Ybele; Martin, Jock; Petersen, Jan-Erik; Panja, Gabriela; Pignatelli, Roberta et al. (2014): Digest of EEA indicators 2014. Luxembourg: Publications Office (EEA Technical report, 8/2014).

Mancini, Lucia; Sala, Serenella (2018): Social impact assessment in the mining sector: Review and comparison of indicators frameworks. In Resources Policy 57, pp. 98–111. DOI: 10.1016/j.resourpol.2018.02.002.

METI; NASA (2017): ASTER GDEM v2. The Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA) jointly announced the release of the ASTER Global DEM Version 2 (GDEM V2). Available online at https://www.arcgis.com/home/item.html?id=93545c023ec44b109be1b3425edc72e1, updated on 7/18/2018, checked on 9/12/2018.

Ness, Barry; Anderberg, Stefan; Olsson, Lennart (2010): Structuring problems in sustainability science: The multi-level DPSIR framework. In Geoforum 41 (3), pp. 479–488. DOI: 10.1016/j.geoforum.2009.12.005.

Nguyen, Nhi Ba; Boruff, Bryan; Tonts, Matthew (2017): Mining, development and well-being in Vietnam: A comparative analysis. In The Extractive Industries and Society 4 (3), pp. 564–575. DOI: 10.1016/j.exis.2017.05.009.

Notesco, Gila; Kopačková, Veronika; Rojík, Petr; Schwartz, Guy; Livne, Ido; Dor, Eyal (2014): Mineral Classification of Land Surface Using Multispectral LWIR and Hyperspectral SWIR Remote-Sensing Data. A Case Study over the Sokolov Lignite Open-Pit Mines, the Czech Republic. In Remote Sensing 6 (8), pp. 7005–7025. DOI: 10.3390/rs6087005.

Parker, Anthony W.; Tones, Megan J.; Ritchie, Gabrielle E. (2017): Development of a multilevel health and safety climate survey tool within a mining setting. In Journal of safety research 62, pp. 173–180. DOI: 10.1016/j.jsr.2017.06.007.

Patra, Aditya Kumar; Gautam, Sneha; Kumar, Prashant (2016): Emissions and human health impact of particulate matter from surface mining operation—A review. In Environmental Technology & Innovation 5, pp. 233–249. DOI: 10.1016/j.eti.2016.04.002.

Schneider, Petra; Oswald, Klaus-Dieter; Riedel, Wolfgang; Meyer, Andreas; Schiller, Georg; Bimesmeier, Tamara et al. (2018): Engineering Perspectives and Environmental Life Cycle Optimization to Enhance Aggregate Mining in Vietnam. In Sustainability 10 (2), p. 525. DOI: 10.3390/su10020525.

Sudmeier-Rieux, K.; Fra.Paleo, U.; Garschagen, M.; Estrella, M.; Renaud, F. G.; Jaboyedoff, M. (2015): Opportunities, incentives and challenges to risk sensitive land use planning: Lessons from Nepal, Spain and Vietnam. In International Journal of Disaster Risk Reduction 14, pp. 205–224. DOI: 10.1016/j.ijdrr.2014.09.009.

Svobodova, Kamila; Sklenicka, Petr; Molnarova, Kristina; Salek, Miroslav (2012): Visual preferences for physical attributes of mining and post-mining landscapes with respect to the socio-demographic characteristics of respondents. In Ecological Engineering 43, pp. 34–44. DOI: 10.1016/j.ecoleng.2011.08.007.

Tien Bui, Dieu; Pradhan, Biswajeet; Lofman, Owe; Revhaug, Inge; Dick, Oystein B. (2012): Landslide susceptibility assessment in the Hoa Binh Province of Vietnam: A comparison of the Levenberg–Marquardt and Bayesian regularized neural networks. In Geomorphology 171-172, pp. 12–29. DOI: 10.1016/j.geomorph.2012.04.023.

Verma, Anoop; Wei, Xiupeng; Kusiak, Andrew (2013): Predicting the total suspended solids in wastewater: A data-mining approach. In Engineering Applications of Artificial Intelligence 26 (4), pp. 1366–1372. DOI: 10.1016/j.engappai.2012.08.015.

Vietnam Ministry of Planning and Investment (2012): Implementation of sustainable development. National Report at the United Nations conference on sustainable development (RIO +20). Hanoi.

World Bank (2009): Vietnam - Additional financing for Second Rural Energy Project: environmental assessment (Vol. 26): Environmental impact assessment for Hoa Binh Province (English) | The World Bank. Available online at http://documents.worldbank.org/curated/en/859391468141592290/Environmental-impact-assessment-for-Hoa-Binh-Province, checked on 8/21/2018.

World Bank (2018): The World Bank In Vietnam-Overview. Available online at http://www.worldbank.org/en/country/vietnam/overview, checked on 8/28/2018.

Younger, Paul L.; Wolkersdorfer, Christian (2004): Mining Impacts on the Fresh Water Environment: Technical and Managerial Guidelines for Catchment Scale Management. In Mine Water and the Environment 23 (S1), s2-s80. DOI: 10.1007/s10230-004-0028-0.

MAREX Publication Series

– The final results of the project –

Issue 1: **Management of mineral resource extraction in Hoa Binh Province, Vietnam**
Seven recommendations for responsible construction aggregates mining and contributions to sustainable urban and regional development
Bernhard Müller, Georg Schiller, Peter Wirth, Tamara Bimesmeier, Anh Minh Vu, Nguyen Xuan Thinh, Haniyeh Ebrahimi-Salari, Paulina Schiappacasse, Klaus-Dieter Oswald, Wolfgang Riedel, Petra Schneider

Issue 2: **Monitoring of mineral resource extraction and analyzing its impacts on the environment and land cover/land use in Hoa Binh Province**
Nguyen Xuan Thinh, Haniyeh Ebrahimi-Salari

Issue 3: **Technical solutions for mining and processing of aggregates and the mining sites after-use**
A Cleaner Production Guideline for Vietnam
Klaus-Dieter Oswald, Petra Schneider, Wolfgang Riedel

Issue 4: **Cleaner production, mining optimizing approaches and material flow analysis**
MAREX Workshop, Hoa Binh, Vietnam, November 2017
Tamara Bimesmeier, Pham Thi Viet Anh, Klaus Dieter Oswald, Wolfgang Riedel, Georg Schiller, Petra Schneider

Issue 5: **Regional material flow analysis**
A concept for balancing supply and demand of construction minerals for regions using the example of Hanoi and the hinterland province Hoa Binh
Georg Schiller, Tamara Bimesmeier

Issue 6: **The economic impacts of construction aggregate mining on regional development**
The case of Hoa Binh Region, Vietnam
Paulina Schiappacasse, Bernhard Müller, Peter Wirth

Issue 7: **Planning for the responsible extraction of natural aggregates**
The case of the Hanoi Metropolitan Area
Bernhard Müller, Paulina Schiappacasse

Issue 8: **Legal framework for aggregates mining in Vietnam from the perspective of environmental protection**
Anh Minh Vu, Juliane Albrecht, Denise Füssel

Issue 9: **The MAREX Alliance**
A Business-Policy Interface for the responsible management of mineral aggregates in Hoa Binh Province, Vietnam
Bernhard Müller, Paulina Schiappacasse, Peter Wirth, Anh Minh Vu

All results and information: www.marex-project.de

This booklet is a result of MAREX project:
Management of Mineral Ressource Extraction in Hoa Binh Province –
A Contribution to Sustainable Development in Vietnam

MAREX Partners in Germany

Leibniz Institute of
Ecological Urban and
Regional Development

TECHNISCHE
UNIVERSITÄT
DRESDEN

technische universität
dortmund

C&E · Consulting und
Engineering GmbH

SPONSORED BY THE

Federal Ministry
of Education
and Research

MAREX Partners in Vietnam

The Institute of
Environment and
Automation

VNU University of Science,
Vietnam National
University

SPONSORED BY THE

Ministry
of Science and
Technology

SUPPORTED BY THE

People's Committee
of Hoa Binh Province,
Vietnam

ISBN 978-3-933053-43-5