

**Environmental Impact Assessment of Quarrying Activity and Aggregate
Production in Dire Dawa Administration, Eastern Ethiopia**



**ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES
SCHOOL OF EARTH SCIENCES**

**Environmental Impact Assessment of Quarrying Activity and
Aggregate production in Dire Dawa Administration, Eastern
Ethiopia**

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By:

Getachew Tamiru Damete

Advisor:

Worash Getaneh (Ph.D.)

Co-Advisor:

Binyam Tesfaw (Ph.D.)

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Author declaration

I declared and confirmed by my signature below this thesis is my work. I followed all ethical and technical principles of research in the preparations, data collection, data analysis, and compilation of this thesis. Any scholarly article which is included in this thesis has been acknowledged through the reference.

Getachew Tamiru

Signature

_____/_____/_____

Date

Abstract

Quarries are open cast excavations from which fairly massive and deep deposits of hard or soft rocks are extracted, usually for the production of aggregates. The destructive nature of quarrying together with poor management of quarry sites has a serious environmental impact leading to a serious threat. This study focuses on the environmental and social impact of quarrying activity and aggregate production. Interviews & focused group discussion, observation, and reconnaissance surveys were utilized to evaluate the overall activity of quarry operation in the study area. Both close and open-ended type concentrated questionnaires were prepared to deal with the impact of quarry on workers and residents. A Focus group dissociation was made with the selected representatives to get information about the impact of the quarry activity. Maximum likelihood classification was applied to map land use/land cover and the transition was evaluated using spatiotemporal data between 2006 and 2021. SPOT-6 data with a 6 m resolution corresponds to 2006, Sentinel-2 data with a 10 m resolution between 2016 and 2021 were used to map the land use land cover. GPS data was used to check the LU/LC classified image into different classes. A field survey was also conducted to gather GPS points to map the change in land use and land cover and precisely validate accuracy assessment based on ground truth as well as to classify the rock mass of the quarry slope stability. The discontinuity of the rock mass was determined with Burton's compass at ten slope section sites. Land use land cover maps for the years considered, as well as the net change between 2006 and 2021 showed that quarrying sites have grown by around 692.68 ha, while Shrubland has shrunk by 2,238.68 ha during the same period. According to the social impact evaluation, numerous issues such as dust, noise, vibration, and flaying rock from quarry sites caused the problem on quarry employees and residents within the immediate vicinity of the quarry sites. The focused group discussion showed that there is a tremendous effect on the environment due to lack of follow-up. Except for site 5 and site 10 the all eight sites were classified as fair rocks whereas sites 5 and 10 were classified as poor rock. Also, according to the land stability review stability of the area ranges from completely unstable (sites 1,3,4, and 7) to partially stable (sites 2,6,8, and 9). According to the study, quarrying activity in the area will continue to cause significant environmental and community harm unless an adequate mitigation approach is followed by all responsible bodies.

Keywords: - Environmental impact, Aggregate, LU/LC, quarry, slope stability, Sentinel-2, SPOT 6.

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<u>Table of Contents</u>	<u>Page</u>
Abstract.....	iii
ACKNOWLEDGEMENT.....	iv
List of Figs	viii
List of Tables	ix
CHAPTER ONE	1
1. Introduction.....	1
1.1. Background.....	1
1.2. Statement of the problem.....	2
1.3. Objective	3
1.3.1. General objective	3
1.3.2. Specific objectives	3
1.4. Research questions.....	3
1.5. Significance of the research.....	4
1.6. Limitation of the study.....	4
CHAPTER TWO	5
2. Literature review	5
2.1. Introduction.....	5
2.2. Aggregate and aggregate production	5
2.3. Quarry excavation.....	5
2.4. Impact of quarrying operation on the environment	5
2.5. Social and economic impacts of stone quarrying	7
2.6. Quarrying impact on the landscape.....	8
2.7. General description of remote sensing and GIS	9
2.8. Application of remote sensing and GIS	9
2.9. Land use and land cover change	11
2.10. Environmental laws and proclamations of the federal democratic republic of Ethiopia	12
CHAPTER THREE	14
3. General description of the study area	14
3.1. Location and accessibility.....	14
3.2. Climate.....	15

3.2.1. Temperature	15
3.2.2. Rainfall.....	16
3.2.3. Wind speed.....	16
3.3. Physiography.....	17
3.4. Regional geology	17
3.4.1. Precambrian basement rocks.....	17
3.4.2. Mesozoic sedimentary rock	18
3.4.3. Adigrat sandstone/ lower sandstone.....	18
3.4.4. Hamaneli limestone	18
3.4.5. Amba aradam sandstone/upper sandstone	18
3.4.6. Tertiary volcanic rocks	18
3.4.7. Quaternary formation.....	19
3.5. Litho-units in the quarry areas	21
CHAPTER FOUR.....	25
4. Materials and methods	25
4.1. Materials and Data	25
4.2. Methods.....	26
4.2.1. Field observation.....	26
4.2.2. Develop and organize a database of quarries in Dire Dawa	26
4.2.3. Land use land covers classification and change detection.....	26
4.2.4. Geotechnical data collection	29
4.2.5. Questionnaire surveying	32
4.2.6. Focused group discussion	32
4.3. Analysis and interpretations.....	32
4.4. The software used for the current study.....	33
CHAPTER FIVE	35
5. Result and Discussion	35
5.1. Land-use/land-cover change in 2006, 2016 and 2021	35
5.1.1. Existing land use land cover	35
5.2. Change detection analysis.....	37
5.2.1. Accuracy assessment	41
5.3. Organized a geodatabase for quarries in Dire Dawa	42

5.4.	Social impact of quarrying activities	45
5.4.1.	Quarrying impact on the community	45
5.4.2.	Quarrying impact on the quarry workers	49
5.5.	Analyzing the Focus group discussion (FGD) Data	58
5.6.	Description of the rock mass.....	62
5.6.1.	The strength of the intact rock material (compressive strength).....	63
5.6.2.	Rock quality designation (RQD)	64
5.6.3.	Discontinuity characteristic	65
5.6.4.	Slope Stability Studies	73
5.6.5.	Slope Stability Classes and Supports	76
CHAPTER SIX	80
6. Conclusion and Recommendation	80
6.1.	Conclusion	80
6.2.	Recommendations.....	81
References	82
ANNEX	87

List of Figs

Figure 1. Location map of the study area.....	14
Figure 2. Temperature data for Dire Dawa (Source – WorldweatherOnline.com).....	15
Figure 3. Rainfall and rainy days data for Dire Dawa (Source – WorldweatherOnline.com).....	16
Figure 4. Maximum wind speed, average gust, and average wind speed for Dire Dawa (Source – WorldweatherOnline.com).....	17
Figure 5. Geological map of the study area simplified, from Geological Survey of Ethiopia (GSE) 1985.	21
Figure 6. A) Photo plate showing massive limestone in quarry site (study area) B) Photo Plate showing brecciated limestone boulder.....	22
Figure 7. Photo plate showing Sandstone in quarry site (study area).....	23
Figure 8. Photo plate showing Rhyolite in quarry site (study area).....	24
Figure 9. Schmidt hammer in the field for compressive strength determination.....	29
Figure 10. 1*1m Volumetric count of an exposed rock face in the study area.....	31
Figure 11. Summarized methodology flow chart.....	34
Figure 12. Land-use/land-cover maps of the study area of the years 2006 (a), 2016 (b), and 2021 (c).....	35
Figure 13. Distributions of land use land cover class on study area from 2006 to 2021	37
Figure 14. A chart showing the LU/LC changes in the study area	39
Figure 15. Map showing in LU/LC from 2006 to 2021.....	40
Figure 16. Flow chart of geo-database components	44
Figure 17. Screenshot of the designed geodatabase and its attribute table	45
Figure 18. quarry problem that adverse the community	47
Figure 19. Series of cracks and collapse in buildings	48
Figure 20. Photo plate while interviewing the quarry workers.....	49
Figure 21. Graph showing the continued supply of safety equipment.....	51
Figure 22. Level of the safety guide	52
Figure 23. The frequency of accidents faced at the quarry site	53
Figure 24. A photo of dust accumulation.....	54
Figure 25. Dust-related problems.....	55
Figure 26. Noise-related problems.....	56
Figure 27. Photo plate showing a man with an ear problem.....	57
Figure 28. Photo plate shows degraded land.....	58
Figure 29. The map showing the Location map of slop sites.	61
Figure 30. photo plate of limestone exposure in the study area.....	63
Figure 31. Preferred orientations of discontinuity planes as observed at different localities in the study area	68
Figure 32. showing different types of failure in graphic form and as real field sites. Planar Failure, Wedge Failure and Toppling Failure.....	75

List of Tables

Table 1. The regional geological succession of the study area (WWDSE, 2004)	20
Table 2. Data source and description.	Error! Bookmark not defined.
Table 3. Land-use and land cover and description of the study area.	27
Table 4. Land-use/land-cover classes and area coverage of 2006, 2016, and 2021 in the Study Area. ha(hectare).....	36
Table 5. Land-use/land-cover distribution and net changes during 2006–2021.	38
Table 6. The changes of the LU/LC between 2006 -20201	41
Table 7. Information of accuracy assessment for the years 2006, 2016, and 2021.....	42
Table 8. Demographic description of respondents in the community.....	46
Table 9. Demographic description of quarry works who participated in the survey	50
Table 10. Location of the slope sites.....	61
Table 11. Name of the quarry, rock type, and precise location.....	62
Table 12. Average UCS values determined at various sites in the study area	64
Table 13. The average value of RQD at various locations in the study area	65
Table 14. Recorded dip direction and dip amount	66
Table 15. Surface Characteristics of the discontinuity planes as observed in the study area	Error! Bookmark not defined.
Table 16. RMR data collected from various locations in the study area	71
Table 17. Input parameter for failure criteria.....	73
Table 18. stability condition of the selected site.....	74
Table 19. Comparison of Bieniawski's RMR method shear strength parameters, cohesion 'C,' and angle of internal friction " with Hoek and Brown failure criteria	76
Table 20. Rating values for different Slope Factors (Romana, 1985).....	77
Table 21. Slope Stability Classes Based on SMR Values.....	78
Table 22. SMR Classes and Suggested Remedial Measures	78

Acronym (Abbreviations)

ESIAs	Environmental and Social Impact Assessment
EMA	Ethiopia Mapping Agency
ESA's	European space agency
GSE	Geological Survey of Ethiopia
GPS	Global Positioning System
GIS	Geographical information system
Ha	Hectare
KA	Kiloampere
LULC	Land Use Land Cover
OGC	Open geospatial consortium
RMR	Rock mass rating
RQD	Rock quality designation
UCS	Uniaxial compressive strength
UTM	Universal Transverse Mercator
USGS	United State Geological Survey

CHAPTER ONE

1. Introduction

1.1. Background

Rock quarrying and stone crushing is a worldwide phenomenon of extracting rock resources (Okafor, 2006). A quarry is a site where dimension stone, rock, construction aggregate, riprap, sand, gravel, or slate has been dug from the earth and it could also refer to an open-pit mine from which minerals are unearthed. According to (Akabzaa *et al.*, 2001) quarrying is open-pit mining out of which any beneficial stone is extracted for the use of building material and engineering.

Aggregate production mainly turns big rocks into small rock fragments and carefully sorts them by size. Quarrying of stone resources generally requires drilling and controlled blasting before the rock is extracted with bulldozers. Sand and gravel deposits are commonly excavated with conventional earth-moving equipment such as bulldozers, front-end loaders, and tractor scrapers from dry grounds or excavated from streams or water-filled pits with draglines or from barges that use hydraulic or ladder dredges (Langer, 2005).

Quarrying activity has both good and bad consequences on the natural and social environments. The positive consequences of quarrying a stone deposit are significant natural resources that can stimulate development in a locality and create work opportunities for the people. The extractive industries contribute immensely to the economic development of a country. However, their operations may result in some adverse effects with regards to the usage of land as well as environmental problems that may need to be addressed to ensure supportable development (Strongman, 1992).

The negative environmental impacts associated with quarrying include noise and vibration, dust pollution, destruction of the environment, and cracks in buildings. From the extraction site, dust is the main concern. The level of pollution depends largely on local microclimate conditions, other dust concentrations in the surroundings, and what the dust is made of. Air pollution from dust has effects on health, in particular for those with respiratory problems (Gauch, 2001).

Noise pollution, particularly if blasting methods are used, following machinery to transport materials as well as possibly processing materials to crush and degrade materials is also another undeniable effect of quarrying. The enormous explosions associated with open pit quarrying have been known to crack foundations of buildings, especially if settlements are around the working

field and the plants of an area are mostly affected. The surface quarrying technique has a serious impact on all landscape components and functions, leading to significant alteration of the original landscape. One of the other negative impacts of quarrying on the environment is the damage to biodiversity (Anand, 1999). Even though habitats are not directly removed by excavation, quarrying indirectly affects and damages the environment, such as changes to groundwater or surface water flow that cause some habitats to dry out and others to become flooded. Like any other man-made activity, quarrying involves the production of a significant amount of waste, whether they are temporary or permanent (Wang, 2007).

Quarry activity has a wide coverage of problems reaching from place to place and to describe the impacts of quarrying at an actual place, appropriate assessment of the causes and effects should be passed out to create proper protective or remedial measures. It is difficult to take a supportable mitigation measure without a detailed study of the impacts. Moreover, many quarries are located within the urban center where there are institutions such as residential houses, hospitals, schools, and offices, which can reinforce and diversify the problem. In this study, we assess the environmental and social impact of quarrying activities in Dire Dawa.

1.2. Statement of the problem

In Dire Dawa, there are extensive housing development projects. These activities are still underway. The area is significantly rich in construction material supply, most of which are extracted around the city. Many quarrying projects belong to cement factories and are also owned by individuals around Dire Dawa city. In those areas, there are quarries used to produce aggregate that contribute to the various types of construction and provides both economic and social benefits. However, environmental impact is affecting the study area in the case of quarry excavation, blasting, and aggregate production. According to Semere Mulat (2013), the environmental focus given by the producers is very small. Although it is not an easy task to evaluate the monetary value of environmental protection activities performed on quarry sites it can be considered as very negligible. Measurements should be always taken to investigate the impact that the operation in the quarry plant has on the surrounding environment and inhabitants. A study conducted on the Augusta quarry site in Addis Ababa revealed that quarrying causes various environmental and social impacts. The operation of land clearing led to loss of vegetation cover, soil removal, spring eye spot extinction, susceptible geomorphology for erosion, land stability problem where the

rockfall on the slope foot can be seen easily creation of deep well and pond, land degradation and social challenges related to the increase in quarrying activities in general include: threats to health and safety, displacement of communities and damage of cultural sites (Enatfenta Melaku, 2007). Therefore, the study area is one of the most potential quarry sites that create large job opportunities and supply different construction materials for building construction. It is observed that various environmental problems, such as the excavated site are abandoned and left as wasteland, resident houses cracked as a result of blasting, the land is degraded. In addition, it leads to pollution like air and sound and also damages property. Therefore, this study seeks to investigate the impacts of quarry excavation, and aggregate production on the environment selected quarry site in the study area.

1.3. Objective

1.3.1. General objective

The main objective of the study is to assess the environmental and social impact of quarrying activity and aggregate production in the Dire Dawa area.

1.3.2. Specific objectives

The specific objectives included in this study are as follows.

- Investigate land-use/ land cover-change between 2006 - 2021 specifically to detect quarrying expansion.
- Develop and organize a database of quarries in the Dire Dawa area.
- Evaluate the impact of quarry activity on quarry workers and nearby communities and evaluate the existing practice of administration and management of quarry operation processes in the study area.
- Conduct Rock Mass Classification of the quarry area and assess the stability of the rocks around quarry slopes.

1.4. Research questions

As stated above, the research aim is centered on assessing the impact of quarrying activity and aggregate production on the environmental condition of the local communities. It will try to answer the following research questions.

1. What is the cause for land use land cover change in the study area?

2. What are the negative impacts of quarrying activity on the natural environment, nearby communities, and quarry workers?
3. How are quarry activity follow-up and management by the administration?

1.5. Significance of the research

Since the research focuses on the environmental impact of quarry activity and aggregate production, it will contribute to the understanding of quarry operation's impact on the natural environment. The study of the land use and land cover will also show the quarry effect on the change in land use and land cover. Besides, it deals with the land stability of the area. The study will also help to create awareness on how a quarry can impact the environment, especially when the quarry is planted in town centers. Thus, planners and decision-makers can use the result for proper planning and management of abandoned quarries and return the quarry site to a safe and secure area. It will also give an important database for the Dire Dawa city administration. Moreover, it will be a good document for quarry companies and other stakeholders to have an overview of the strengths, weaknesses, opportunities, and threats of the current quarry planning and management concerning sustainable resource utilization, social and physical environment protection, and development.

Generally, the collected data about quarrying activities, their impacts, and the perception of the respondents on the quarrying activities in the study area can be useful for all those involved in a quarry operation and further study.

1.6. Limitation of the study

In the study area, the common languages are Oromifa, Af Somali, and Amharic so it was a must to find a translator for the questionnaire to the local language. Additionally, the quarry owners and the governmental concerned bodies find it difficult to contact them and almost all of them aren't available at their workplace and this makes tardiness our work.

CHAPTER TWO

2. Literature review

2.1. Introduction

Stone quarrying is a multiple-stage procedure through which rock is dug from the earth and crushed to generate aggregate that subsequently is divided into portions necessary for direct use, or more uses. According to Akabzaa and Darimani, quarrying is an open-pit out of which any beneficial stone is extracted for use in the fields of building and engineering (Akabzaa et al., 2001).

2.2. Aggregate and aggregate production

Aggregates are materials that can be found as natural resources. We can use them as we found directly or after being modified (ACI.Committee.E1-07, 2007). Aggregates are used for different construction purposes and contain grains or fragments of rock. They can be found through quarrying and are used either in their natural state or after crushing, washing, and sizing. Sand, gravel, and crushed stone are commonly mixed with binding media to form concrete, asphalt. (USEPA, 1995). Rocks for aggregates are quarried through blasting using explosives or mechanical excavation by using machinery. The primary sources of crushed aggregate are the alluvial deposits and various types of rocks such as; basalt, gneiss, dolomite, and limestone (Barakat *et al.*, 2016).

2.3. Quarry excavation

Quarry excavation is a type of surface mining, in which dimensional stone construction aggregate, sand, slate, or gravel excavate from the ground. The depth and length of the excavation matter a lot depending on the market state of the material being excavated. Instead of using those expensive extracts for the benefit of the country in general, the people who live around the area make their houses by those excavated materials (Enatfenta Melaku, 2007). Quarrying is a necessity that provides many materials that help us in finding materials for construction (Danielsen *et al.*, 2015). Despite their economic use, they also have a major challenge for the sustainability of the developing environment, like many other man-made factors (Essalhi *et al.*, 2016).

2.4. Impact of quarrying operation on the environment

Rock quarrying and stone crushing is a global phenomenon, and has been the cause of concern everywhere in the world, including the developed nations (Eshiwani, 2014). The highest

environmental impacts that are caused due to quarries are generated through blasting (Langer, 2001). There was a study done by Samrawit Yimame on the environmental impact assessment of quarrying activities on the downstream section of the Big Akaki Catchment (Addis Ababa, Ethiopia). The author reported that the communities near the quarry are facing different problems. The houses developed different degrees of fractures by the blast and the heavy vibrations. Besides, the communities nearby are suffering from different health-related issues such as repeated common colds, sinus allergies, and asthma caused by the dust. Further, the community argues that blasting can generate vibrations, perceptible noise, fly rock, and dust which are disastrous to lives within the environment of quarrying and they are always scared of the fly rocks that fall to the top of the roof of their house (Samrawit Yimame, 2020).

Research on quarrying in India reported that the uncaring removal of solid waste quarries causes extreme damage to agricultural zones. The researcher more detects that legal guidelines and rules on the environment are ignored and quarry outcomes in the devastation of habitations. The important rebuilding, recovery, and restoration of the quarry, as necessitated by way of the laws of India, are commonly unnoticed or averted (Weyzig *et al.*, 2006). Researchers are also concerned about the environmental consequences of quarrying processes, which are associated with health risks and issues. Solid substances in the form of dust and vapor formed in the direction of quarrying operations are generally up in the air for a long time, according to UNEP (1991b). It is also possible to transport particulate matter in the air from the point of origin to other places (Last, 1998). In terms of waste management, it is thought that the quarrying industry in general, and stone companies in particular, have yet to learn how to deal with air, water, and noise pollution. Quarry waste, like industrial waste, contains overburden. Clipping the slabs' edges produces a significant amount of waste. In the quarrying and processing units, fragments, uneven, and abnormally formed blocks are distributed. For example, Madhavan and Raj (2005) found that in most foreign locations, quarrying waste on lands that have not been legitimately acquired and without permission often destroys the site's natural vegetation and ecology (Madhavan *et al.*, 2005).

The impact of air pollution on human health and the environment is an increasing source of concern around the world. Drilling, blasting, and loading rocks into haul trucks all produce dust associated with rock quarrying. There is also a rise in car emissions, which would degrade air quality in the

local area, adversely impacting residents' health and well-being. Materials for manufacturing (Roundtable, 1987).

Quarrying produces noise and emissions through practices such as drilling, screening, blasting, sand conveyance, sandstone production, and open-cast quarrying, and it poses a danger to the health and safety of workers and residents by creating operational impacts such as noise and vibration. Aside from that, the quarry site would be able to collect rainwater, making it ideal for use (Yacoub, 2012). The impact of quarrying especially relates to loss of habitat, loss of wetland, woodland, or vegetated lands, in affiliation with instruction and development of the new road. In this manner dwelling hoods lose their habitat and the natural world will be lost (Eberhard, 1990). Accordingly, the effects of stone quarrying are not independent of the environment it operates from. The activity applies several adversative effects on the environment which may need attention for mitigation to decrease its adverse effects to the barest minimum.

2.5. Social and economic impacts of stone quarrying

Quarrying operations have a variety of economic and social consequences for both staff and residents of the surrounding communities. It can affect people who aren't directly interested in it. In light of this, this sub-section aims to investigate the various scenarios in which stone quarrying affects the lives of residents in host communities.

Quarrying operations generate employment and contribute to a country's GDP by producing goods for local consumption and export. The improving job situation in quarrying areas is aided by the rising demand for quarrying products. Rajasthan, India's sandstone capital, is a fine example of this. The sandstone mines of Finland, according to Finnish studies, almost two million people are employed by the state, with over a hundred thousand workings in Jodhpur alone. The sandstone industry is the largest industrial sector in Western Rajasthan, in terms of the number of people employed (Health, 2002) and also According to Weyzig (2006), India's marble industry accounts for 95% of the country's total marble output. Around twelve thousand to fifteen thousand people work in marble quarrying in Rajasthan's Nagaur district, which covers around a hundred square kilometers.

Auty's (1995) theory is correct in the sense that, despite the negative consequences of quarrying, the practice still creates job opportunities for residents. Quarrying is a job that both men and women do for a living. Mines are dominated by men, while crushers are dominated by women.

Women typically bring head loads of baskets from the mine site to the crusher site in short-distance transportation.

One of the most notable results of quarrying is the provision of both direct and indirect jobs for the people living in the surrounding area. Additionally, the operation breeds ancillary projects such as food vending, which also include the local population and thus raise their standard of living. Quarrying is most common in rural areas, where agriculture is the primary source of income for the majority of the population. Quarrying activity transforms cultivable fields into uncultivable, so continuous quarrying will reduce farmland. This was brought up by Adams (2001) when he argued that quarrying is one of the occupations that have serious degrading effects on land. When out of control, it defeats the objectives of land management (Adams, 2001).

On the other hand, the quarry sites are given to the workers by government regulatory agencies or local authorities without excuse negotiation with the communities (Candessus, 2001). Over here, attention is not given to the livelihood of the rural societies in that, about 80% of them on agriculture-dependent for that matter depend on the land for their existence. The only relief for the rural societies may be the compensation that is paid to them based on the crops they lose to the quarry operation, but the question is for how long they can survive with the compensation given as compared to their cultivable land that has been degraded. Compensation is mostly not satisfactory and it is woeful for those victims or whose land is taken over by the quarry firms (Delbridge *et al.*, 1998).

2.6. Quarrying impact on the landscape

The quarrying technique has a serious impact on landscape components and functions which in turn bring a permanent change on the original landscape, which in turn disrupts the ecosystem and the complex relationship among ecosystem components. Quarrying can also intensely disturb hydrogeological and hydrological regimens (Abate Zelalem, 2016).

According to (Yayesh Mihiritie, 2017) potential extensive impacts of the quarry activity are landscape changes, erosion, loss of habitats and the system in it, and stability problems. Landscape change is a highly visible effect but it does not bring a direct impact on the people. Landscape change affects the farmland and also causes difficulty to move from one place to another place. The nature of the land surface is also affected and changed due to excavation and the extraction of the earth's material. This landscape change may have various kinds of problems, slope instability,

and landslides, rockfall, and erosion. The slope will fail and become unstructured which results in a sliding plane, and wedge mode of failures (OECD, 1999). The quarry excavation may cause land conversion of previous land use and possibly lead to environmental degradation if quarrying is not well planned and managed (Ming'ate, 2016).

2.7. General description of remote sensing and GIS

Remote Sensing is “the science and technology by which the characteristics of objects of interest can be identified, measured or analyzed without direct contact”. Usually, remote sensing is the measurement of the energy that is emanated from the Earth’s surface. If the source of the measured energy is the sun, then it is called passive remote sensing, and the result of this measurement can be a digital image. If the measured energy is not emitted by the Sun but from the sensor platform then it is defined as active remote sensing, such as radar sensors that work in the microwave range (Richards *et al.*, 2006).

There are several definitions of Geographic Information Systems (GIS), which is not simply a program. In general, GIS are systems that allow for the use of geographic information (data have spatial coordinates). In particular, GIS allows for the view, query, calculation, and analysis of spatial data, which are mainly distinguished in raster or vector data structures. Vector is made of objects that can be points, lines, or polygons, and each object can have one or more attribute values; a raster is an image where each cell has an attribute value (Unwin *et al.*, 2005). Several GIS applications use raster images that are derived from remote sensing.

2.8. Application of remote sensing and GIS

Remote sensing is not easy to cover all possible applications. However, remote sensing has a wide range of use in land use/land cover mapping, geologic and soil mapping, agriculture, forestry, rangeland, water resources, snow and ice mapping, urban and regional planning, wetland mapping, wildlife ecology, archaeology, environmental assessment, disaster assessment, and landform identification and evaluation (Lillesand *et al.*, 2015).

According to Lillesand *et al.* (2015) remote sensing has application for geologic mapping and the identification of landforms, rock types, and rock structures and the portrayal of geologic units and structures on a map or other display in their correct spatial relationship with one another. Mineral resource exploration is an important type of geologic mapping activity. Because most of the surface and near-surface mineral deposits in inaccessible regions of the earth have been found, the

current emphasis is on the location of deposits far below the earth's surface or in inaccessible regions. Geophysical methods that provide deep penetration into the earth are generally needed to locate potential deposits, and drill holes are required to confirm their existence. However, much information about potential areas for mineral exploration can be provided by the interpretation of surface features on aerial photographs and satellite images. One important role of remotely sensed imagery in this field is as a logistical aid to field-based geologic mapping projects, especially in remote regions. Aerial and satellite imagery provides an efficient, comparatively low-cost means of targeting key areas for the much more expensive ground-based field surveys. Images are used to locate areas where rocks are exposed at the surface and are thus accessible to the geologist for study and to trace key geologic units across the landscape. Images also allow the geologist to make important distinctions.

GIS determines what is happening or what features are located inside a specific area/region. Finding what is nearby We can find out what is happening within a set distance of a feature or event by mapping what is nearby using geoprocessing tools, we can map the change in a specific geographic area to anticipate future conditions, decide on a course of action, or to evaluate the results of an action or policy. The use and Importance of GIS for scientific research are not countable. It can be used as a tool in both problems solving and decision-making processes, as well as for the visualization of data in a spatial environment. Geospatial data can be analyzed to determine

1. The location of features and relationships to other features
2. Where the most and/or least of some feature exists
3. The density of features in a given space
4. What is happening inside an area of interest?
5. What is happening nearby some feature or phenomenon?
6. And how a specific area has changed over time (and in what way).

According to Macleod and Cogalton (1998), the following four LU/LCs change detection (aspects of change detection), which are important when monitoring natural resources:

- Distinguishing the nature of the change

- Detection/finding of the changes that have occurred
- Measuring the area extent of the change
- Assessing and investigating a spatial pattern of the change

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values, which can be remotely sensed (Macleod *et al.*, 1998).

GIS and remote sensing have use for the research as my title is environmental impact assessment of quarry activity and aggregate production. by using remote sensing and GIs I study the land use land cover change that happens by the quarry activity. Mapping of LULC and change detection using remote sensing and GIS techniques is a cost-effective method of obtaining a clear understanding of the land cover alteration processes due to land-use change and their consequences. To understand how LULC change affects and interacts with global earth systems, information is needed on what changes occur, where and when they occur, the rate at which they occur, and the social and physical forces that drive those changes (Lambin, 1997). The information needed for such synthesis is diverse. Remote sensing has an important contribution to making and documenting the actual change in land use/land cover on regional and global scales.

2.9. Land use and land cover change

The earth's surface has been changed noticeably in the past years by humans as a result human-made factors of deforestation, agricultural activities, expansion of housing, and excavating lands to get raw material for construction. Land is the final resource of the biosphere and the explanation of LU/LC has been used as the same meaning in various research. However, these two terms describe two different issues and have different meanings. Land cover refers to the observed biophysical cover on the earth's surface, including water bodies, vegetation, soil, and hard surfaces. Land use is the exploitation/utilization of the land by human activities for settlements, agriculture, forestry, and by pasture altering land surface processes including biogeochemistry, hydrology, and biodiversity (Gregrio *et al.*, 2000). Human actions have a significant impact on the ecosystem's shape and use. The way we use the land will reveal information about the factors that have caused the land cover to shift. Economic factors, demographic factors, housing preferences, social dimensions, transportation, and regulatory structures are all factors that drive urban

expansion (Asok *et al.*, 2016). Because of the increasing demand for building materials to promote housing, quarrying activity in and around urban centers increased, and different land uses were converted to residential and industrial uses (Yayesh Mihiritie, 2017).

2.10. Environmental laws and proclamations of the federal democratic republic of Ethiopia

In the federal Democratic Republic of Ethiopia, there are different policies and legislations in different aspects. For this study, we need to consider the policies that relate to our topic, which is about environmental impact assessment, pollution control, and mining Proclamation In the constitution of Ethiopia any type of projects that harm the environment for example planting manufactures, excavation of natural resources, quarry for aggregates, etc., the legislation requires that activities should be performed by avoiding and minimizing negative impacts on the environment.

Proclamation No. 299/2002 Environmental Impact Assessment Proclamation

Proclamation No. 299/2002 Makes ESIA (Environmental and Social Impact Assessment) mandatory for implementation of major development projects programs and plans the proclamation is a tool for coordinating and adding environmental, economic, cultural, and social considerations into decision-making processes to promote sustainable development. The proclamation clearly defines the reason why there is a need to prepare ESIA, what procedure is to be followed to implement ESIA, the depth of environmental impact studies, which projects require full ESIA reports, which projects need partial or no ESIA report, and to whom the report must be submitted. Generally proclamation no. 299/2002 indicated that every project should prepare an environmental impact assessment, a proponent shall undertake an environmental impact assessment, identify the likely adverse impacts of his project, incorporating the means of their prevention, and submit to the authority or the relevant regional environmental agency the environmental impact study report together with the documents determined as necessary by the Authority or the relevant regional environmental agency.

Proclamation No. 52/1993 mining proclamation

All mineral resources are public property that has a significant contribution to the economic development of the country and that the state shall ensure the conservation and development of the resources for the benefit of the people. The Government may designate any area of mineral as reserved or excluded for particular mining operations and exclude any area from mining operations particularly as regards sites of historical, cultural, or religious interest and public buildings, infrastructure, and other installations.

This legislation specified about prospecting, exploration, and exploitation of mineral resources should be carried out under appropriate technology and sound principles of resource conservation and develop national expertise in the mining industry; Give employees the training and education necessary for mining operations and company with appropriate training programs.

Proclamation No. 300/2002 Environmental Pollution Control

According to this proclamation any pollutants discharged from different developmental activities can be controlled by the governmental organization and also the owner of the project could be taken responsibility and it must avoid any pollutants which can be hazardous to surrounding life and environment because the protection of the environment and safeguarding of human health and well beings as well as the maintaining of biota, is the responsibility of all. This article aims to improve environmental quality; manage pollutants discharged into water, air, and land, to mitigate harmful chemicals and radioactive element emissions. Generally, the above-listed legislation plays a great role to protect the environment from various impacts according to the strengths and weaknesses of an executive organization.

CHAPTER THREE

3. General description of the study area

3.1. Location and accessibility

Dire Dawa Administrative Council is found at the margin of the eastern part of the Ethiopian Rift Valley and it covers 1500 Km². Geographically, it is located between 79,500,0 m – 84,500,0 m East and 10,452,00 m – 1080000 m North (Fig 1). Dire Dawa is accessed by Addis Ababa through the Djibouti Railway, which is located 10 km northwest of the city center close to the town of Melka Jebdu. In addition, the city is served by the Ethio-Djibouti Railways with its western terminus located in the city center. The Dire Dawa Airport offers flights to and from the city. Additionally, the bus provides an inter-city bus service.

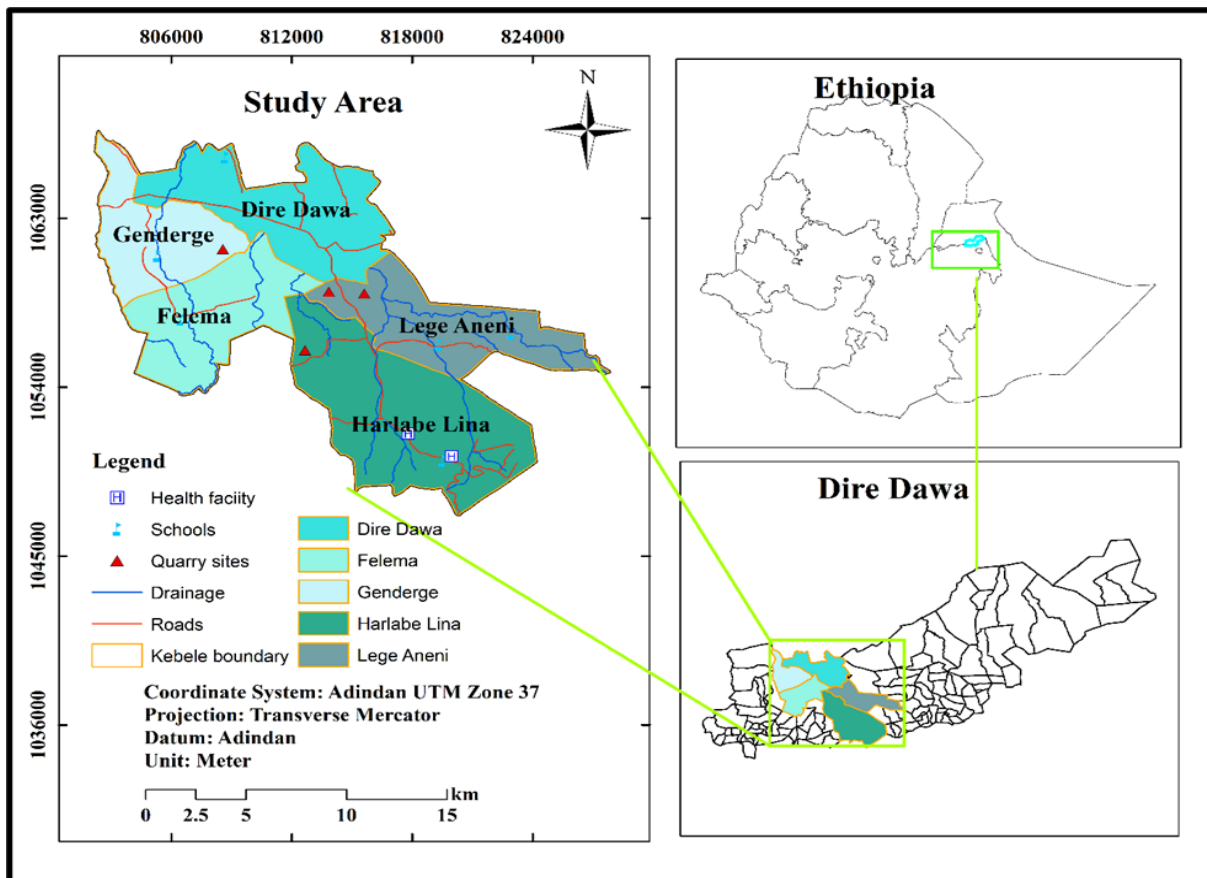


Figure 1. Location map of the study area

3.2. Climate

Dire Dawa has generally semi-arid (Kola) climatic conditions. The climate is classified as a hot semi-arid climate (type “Bush”) as per the Köppen-Geiger climate classification system. The temperature is hot throughout the year with minor seasonal variations. November, December, and January are the coldest months while June and July are the hottest months of the year. The average annual temperature is about 26 °C. The mean minimum and maximum temperatures during the year are about 18 °C and 31°C respectively.

The area receives bimodal rainfall. The rainfall occurs mainly in the summer season (June, July, August) with some rainfall during the spring season (September, October, November). The average annual rainfall in the area is about 600 to 650 mm. The potential evapotranspiration exceeds precipitation in all months.

3.2.1. Temperature

The temperature data for Dire Dawa from January 2009 to January 2021 is depicted in Fig2 (WorldweatherOnline.com, 2021).

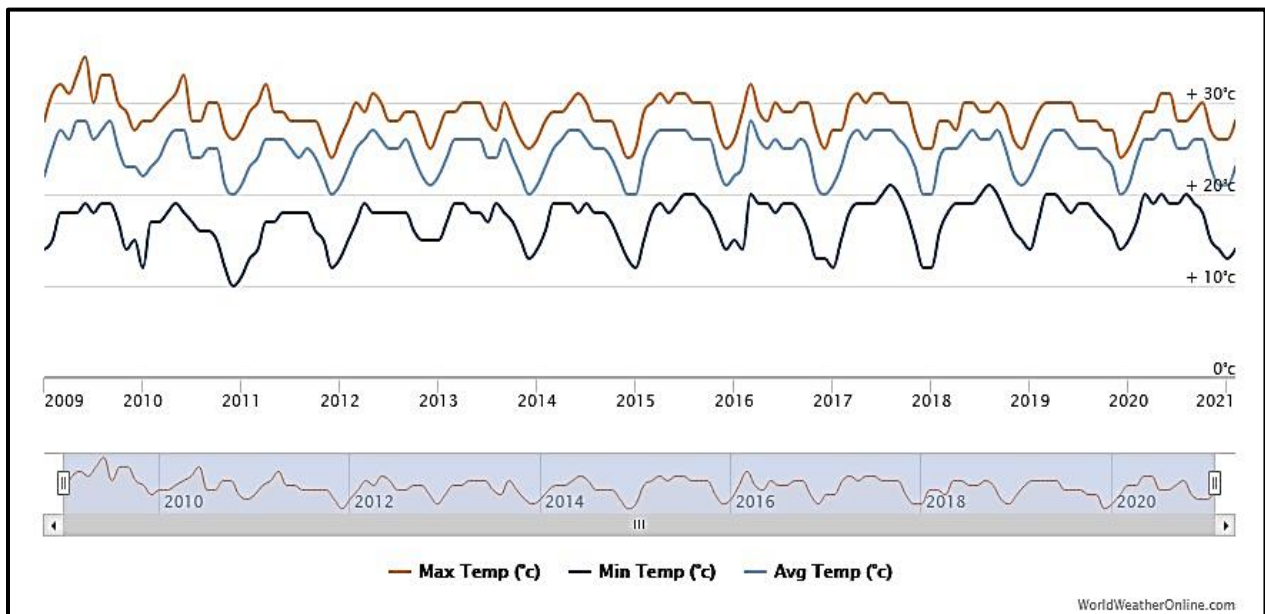


Figure 2. Temperature data for Dire Dawa (Source – WorldweatherOnline.com)

3.2.2. Rainfall

The rainfall and number of rainy days data for Dire Dawa from January 2009 to January 2021 are depicted in Fig 3 (WorldweatherOnline.com, 2021).

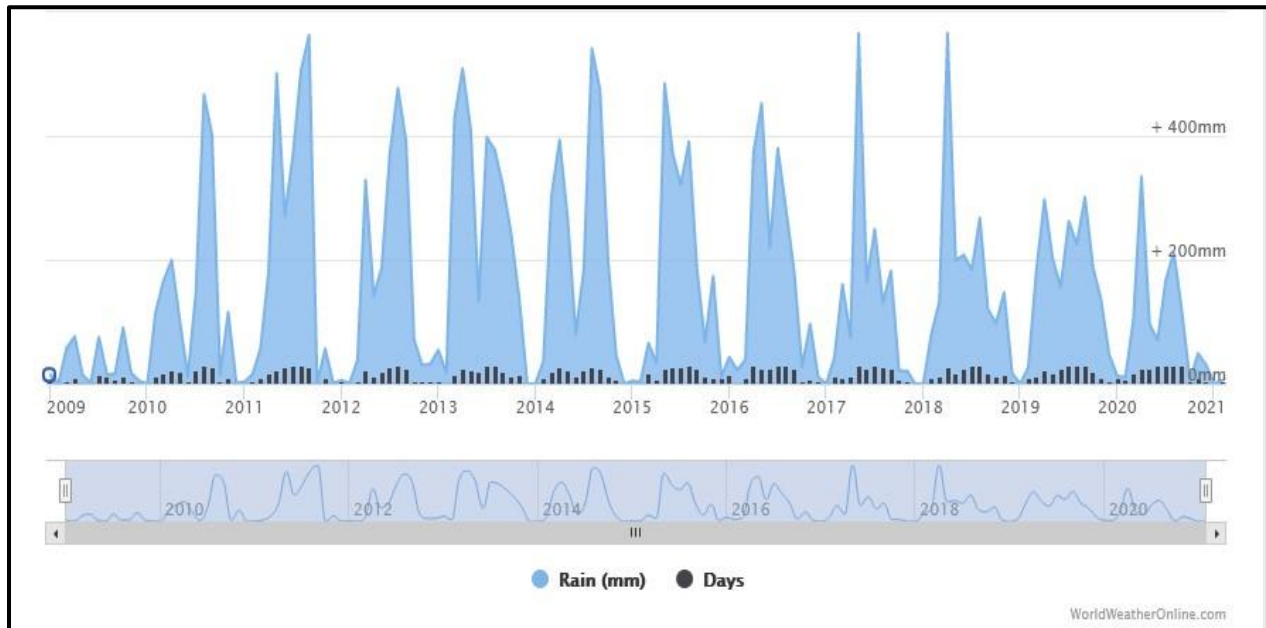


Figure 3. Rainfall and rainy days data for Dire Dawa (Source – WorldweatherOnline.com) About 31% of the total annual rainfall occurs from March to May and 50% of the total annual rainfall occurs from July to September in a year.

3.2.3. Wind speed

The wind speed and average gust for Dire Dawa from January 2009 to January 2021 are depicted in Fig 4 (WorldweatherOnline.com, 2021). The wind speed is maximum during July and August in a year. The average wind speed measured at Dire Dawa is 4.5 m/s during the year with a maximum of 5.6 m/s in July and a minimum of 3.6 m/s in December. The most prevailing wind direction in the area during the year is from South-Southeast to North-Northwest

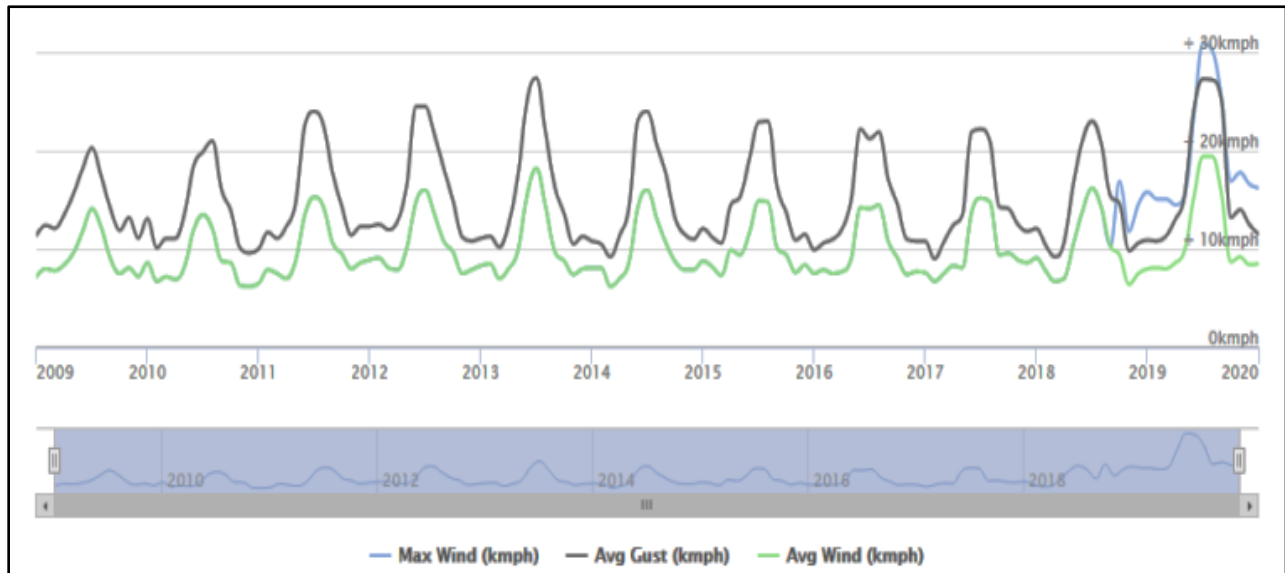


Figure 4. Maximum wind speed, average gust, and average wind speed for Dire Dawa (Source – WorldweatherOnline.com)

3.3. Physiography

The physiography of the area is mainly controlled by volcano-tectonic-related activities. The area is characterized by successive short-running East-West oriented step faults forming half-graben and horsts. The aggregated throw of the fault made the area drop its elevation from more than 2200 m at Dhangago to below 1000 m at the north part of Shinile town. The geomorphology of the study area can be classified into three major features: the escarpment, the transitional region, and the alluvial plains (WWDSE, 2004).

3.4. Regional geology

According to (Tamiru Alemayehu, 2006) concerning their surface exposure, the main lithologic units of the country have been grouped into Precambrian metamorphic basement rocks, Mesozoic sedimentary rock, Tertiary volcanic rocks, and Quaternary formations (Fig 5).

3.4.1. Precambrian basement rocks

Precambrian basement rocks are exposed in the northern, western, southern, and eastern parts of the country. In the eastern part of the country, the basement rocks consist of crystalline acidic migmatites, gneisses, and granites. The main components of this formation are magmatic quartz-rich gneisses and the intrusive pegmatite-feldspathic granite (Tamiru Alemayehu, 2006). The Precambrian metamorphic rocks of the study area belong to the Archean complex of the Alge

group and are mainly composed of high-grade quartz-feldspar-biotite gneiss, biotite-hornblende gneiss, and pegmatite.

3.4.2. Mesozoic sedimentary rock

Mesozoic sedimentary rocks of the study area which are the effect of transgression and regression events are grouped into three formations known as Adigrat sandstone, Hamaneli limestone, and Amba Aradam sandstone. Sandstone was deposited on the aged land surface, followed by the deposition of shale and limestone as the depth of groundwater was raised. In the west of the country, sedimentation ended up with the deposition of clay, silt, sand, and conglomerate during the Jurassic.

3.4.3. Adigrat sandstone/ lower sandstone

This formation is unconformably overlying the basement complex and is exposed mainly in the southern parts of the area underlying the Hamaneli limestone. Triassic to lower Jurassic in age, this sandstone is medium to coarse-grained and its color is red to brown. The thickness of the Adigrat sandstone in the Dire Dawa area does not go beyond 50 m and the maximum thickness of 800 m is evident in Ethiopia (Kazmin, 1972).

3.4.4. Hamaneli limestone

The Hamaneli limestone conformably overlies the Adigrat sandstone and is the dominant form in the study area. It is exposed in the southern part of the area forming different steep ridges extended in the east-west direction and declining topographic elevation from south to the north. In the absence of the Adigrat sandstone, it unconformably overlies the Precambrian basement rocks. Hamaneli limestone is composed of alternating layers of shale at the lower part and brown to gray color limestone at the upper part. The overall thickness is not known although (Greitzer, 1970) predicted it to reach 175m for the upper limestone.

3.4.5. Amba Aradam sandstone/upper sandstone

This upper Jurassic to lower cretaceous formation is unconformably overlying the Hamaneli limestone and is exposed mainly in the west, central, north, and northeastern parts of the area. This unit is estimated to have a thickness of about 200 m (Tesfamichael Keleta, 1974).

3.4.6. Tertiary volcanic rocks

The tertiary volcanic rocks mapped in the study area are Alaje basalts and the steroid basalt of the Afar series (Seife Berhe, 1985). The Alaje basalt is exposed largely in the northwest, central, and

northeastern parts of the study area. This unit mainly consists of phyric flood basalts associated with rhyolites and minor trachyte and ranges in age between 36-13 Ma (Kazmin, 1972). The steroid basalt exposed in the study area is the upper part of the Afar series and is represented by the transitional type basalt (Seife Berhe, 1985). This rock unit is cropped out in the northwest and northeast of the study area forming an east-west trending continuous ridge, which is most likely fissure eruptions and serves as a barrier for the surface runoff in the Dire Dawa area.

3.4.7. Quaternary formation

The quaternary sediments of the area consist of alluvial sediments, lacustrine deposit (travertine), and river sand deposit.

A. Alluvial sediments

The alluvial deposit, which is the weathering product of the existing rocks in the area, is mainly covering the lowermost elevation of the study area. These deposits consist of boulders, gravel, sand, silt to clay sizes of the rock units of metamorphic rocks, sandstone, limestone, and basalts. The alluvial sediment is mainly deposited over the Tertiary basalts and has a variable thickness.

B. Travertine

Lacustrine deposit (travertine) is exposed in the Dire Dawa and Melka Jebdu area. The rock is contained within the alluvial sediments. In both areas, the travertine is used for the construction of houses and fences.

C. Recent alluvial deposits

These are the most recent sediments in the study area. It is deposited in the flood plains of the main streams of the area. Important deposits are associated with Goro, Dechatu, and Lega Hare, which are intermittent streams crossing the Dire Dawa town. The sand deposit is the weathering product of the rocks within the watershed of the main streams and their tributaries. The deposit is composed of fragments of metamorphic, sedimentary, and volcanic rocks of the area.

As it is generally stated in the above section, the regional geology of the study area is the part of the south-eastern part of the rift valley and the flank of the rift system. The regional geological constituents are those sedimentary and volcanic complexes composed of Mesozoic limestone and early to late Mesozoic limestone to marl with minor basaltic deposits, with the Pliocene and quaternary alluvial sediments being very much dominant. The regional geological succession of the study area is presented in Table 1.

Table 1. The regional geological succession of the study area (WWDSE, 2004)

Litho-stratigraphy	Age	Lithologic Description
Adigrat sandstone	Upper Triassic - Liassic	Fine to medium-grained, sorted or unsorted at place cross-bedded, yellow, reddish-brown to white sandstone
Lower limestone (Hamanlei formation)	Lower to middle Liassic	Densely cemented, bottom part fossiliferous fine-grained, grey to dark grey limestone
Amba Aradam Formation (Ka) (upper sandstone)	Albian - Cenomanian	Greyish brown, yellow-brown, and massive to thickly bedded.
Alaji basalts (P3N1a)	Oligocene	Transitional basalt. It forms smoothly gentle topography, which is dissected by gully's and streams. It is also exposed in plain lands forming smaller hills.
Stratoid basalt of Afar (lower parts) (N2ab)- N1- 2gg)	Upper Miocene - Pliocene	Transitional basalts and peralkaline rhyolitic and trachytic domes and flows.
Undifferentiated alluvium (Qa)	Pleistocene	Composition varies from silty to sandy mud to sandy silty-conglomerates.
Travertine (Qtr)	Lower Pleistocene	Quaternary travertine crops out along the river flood plains and springs.
Recent alluvium (Qha)	Holocene	This alluvium is exposed along with valley floors of recent age. They are confined to river channel beds. They are compositionally variable from coarse sand, gravels, which are none stratified and at places mixed with cobbles and boulders.

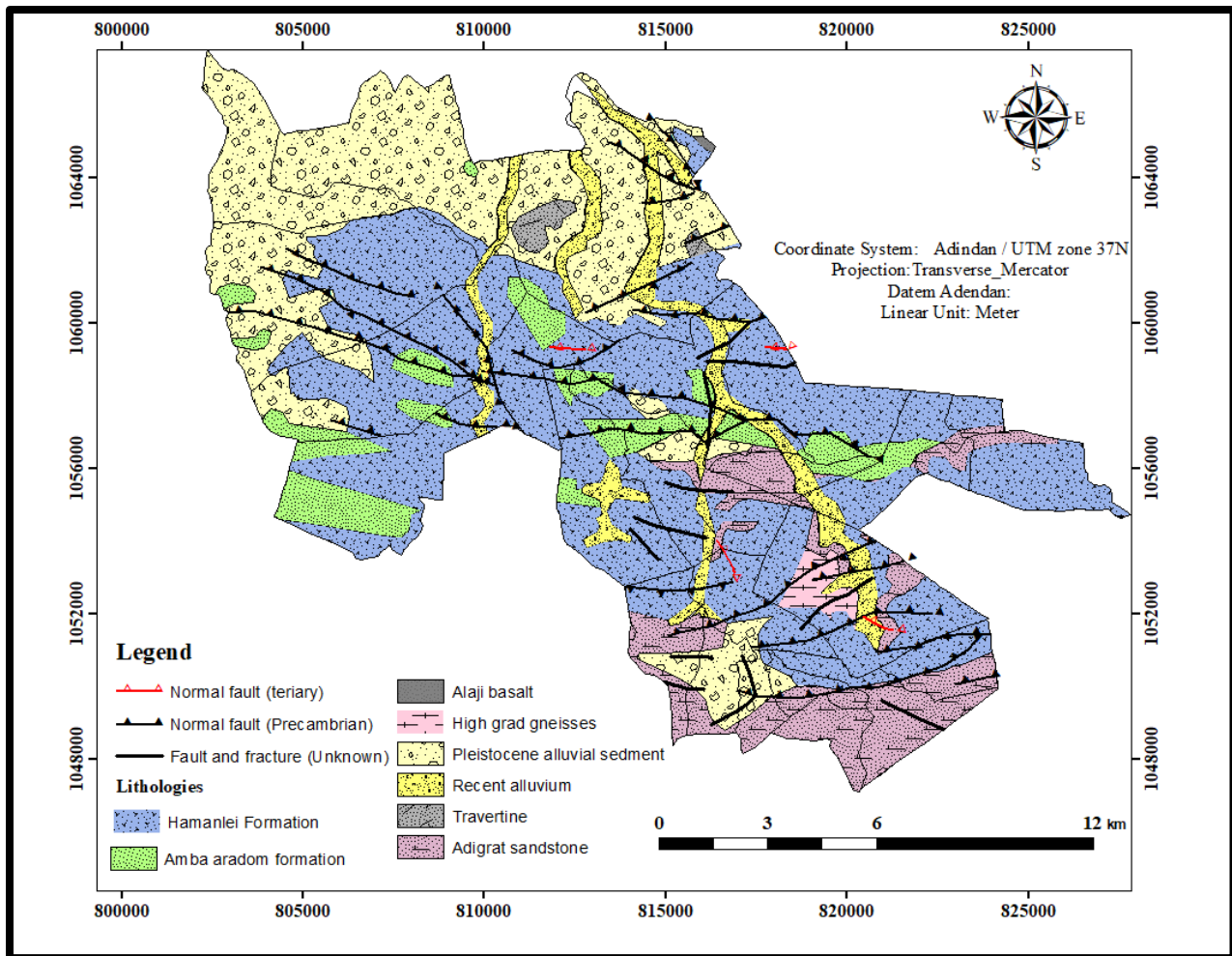


Figure 5. Geological map of the study area simplified, from Geological Survey of Ethiopia (GSE) 1985.

3.5. Litho-units in the quarry areas

Based on a study carried out in the area, the litho-units within the quarry areas represent the Hamanlei formation and Amba Aradom formation of Triassic to Cretaceous age and comprises limestone and sandstone.

Limestone

The limestone of the area is light to dark grey and sometimes black with inter-beds of light brown limestone. The surface of the limestone is commonly sculpted into hollows by weathering but no true karst type form exists. The limestone of the area is massive, fine-grained, hard, and compact (Fig 6). The limestone is also seen brecciated at places in quarry sites as well as boreholes drilled in the area.

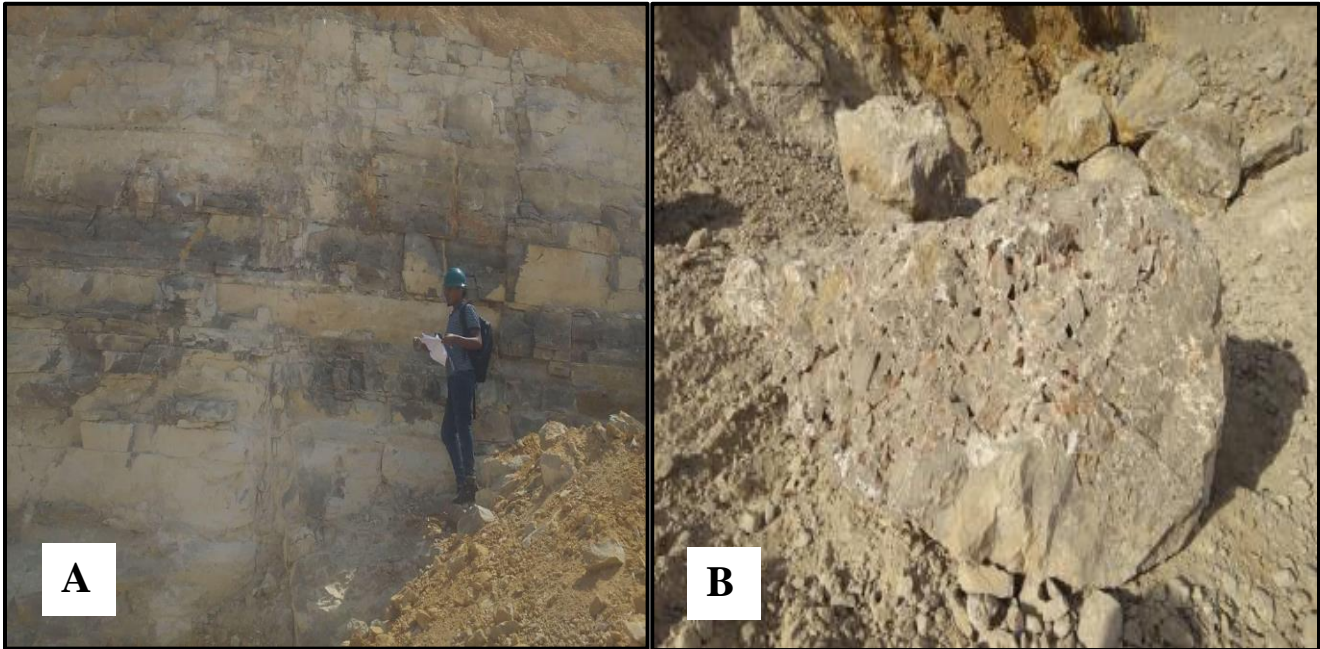


Figure 6. A) Photo plate showing massive limestone in quarry site (study area) B) Photo Plate showing brecciated limestone boulder

Sandstone

The limestone of the quarry area is overlain by Upper Cretaceous sandstone. The sandstone is exposed in a limited area towards the southwest corner of the quarry area. In general, the sandstone is massive, fine to medium-grained, red to brown, and ferruginous (Fig 7).



Figure 7. Photo plate showing Sandstone in quarry site (study area)

Basalt and Rhyolite

The rhyolite (Fig 8) and basalt are yellowish-grey to grey and sometimes brown, weathered, and fine-grained.



Figure 8. Photo plate showing Rhyolite in quarry site (study area)

Alluvium/Soil

The entire quarry area is covered with limestone and is devoid of alluvium/soil. However, there exist scanty pockets of soil, which may have accumulated over some time, in the crevices or cavities of limestone in the mining area.

CHAPTER FOUR

4. Materials and methods

4.1. Materials and Data

Spatiotemporal and multispectral images were used to land use land cover change detection. Images were acquired from the Geospatial information institute with high-resolution images namely SPOT-6 for 2006/6 m. For the other years (i.e., 2016 and 2021), sentinel 2 were employed. All the images were projected into the projected coordinate system WGS-1984-UTM-Zone 37. The data source and type are described in Table 2 below.

Table 2. Data source and description.

No	Name	Data	Data type	Date of acquisition	Spatial Resolution	Data Source
1	Satellite images	Spot 6	Raster	2006	6 m	Geospatial Information institute
		Sentinel-2	Raster	2016	10 m	Copernicus open access hub
		Sentinel-2	Raster	2021	10 m	Copernicus open access hub
2	Thematic map	Topographical map of Dire Dawa	Raster	-	1:50,000	Geospatial Information institute
		Geologic Map	Raster	-	1:250,000	Geological survey
		Meteorological data	-	-	-	WorldweatherOnline.com
3	Field data	Geotechnical measurements	-	-	-	Field
		GPSpoints(Taring samples)	-	-	-	Field
		Questionary feed backs	-	-	-	Field

4.2. Methods

To accomplish the main and specific objectives of these studies different methods are used.

4.2.1. Field observation

Field observation is aimed to evaluate the overall activity of the quarry and which natural environment is vulnerable to the impact of the quarry operation and examine the existing practice of quarry licensing, administration, and management of quarry operation process in the study area. The GPS (Global Positioning System) data were also gathered and used for accurately checking the LU/LC classified image into different classes. After the Random point, the generated GPS point was collected from different LU/LC classes. Field data was used for validation accuracy assessment based on ground truth.

4.2.2. Develop and organize a database of quarries in Dire Dawa

Inventory of quarries in and around Dire Dawa was conducted to compile necessary information on quarries of the area. Data such as location (x, y coordinator, and elevation) name, purpose, starting time, lithology, closeness. were organized in a geospatial database for creating maps and further analysis.

4.2.3. Land use land covers classification and change detection

Image preprocessing

The image preprocessing includes i) clipping, which is creating a study area image from the satellite images. ii) Layer stacking: this preprocessing is a method of producing one multispectral image from each band of the collected Landsat satellite image.

Image enhancement

Image enhancement is the procedure applied to image data to make a more effective display or record the data for subsequent visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinction between features in the scene (Billah *et al.*, 2004).

Image classification

In remote sensing, Image classification is the task of extracting information classes from multiband raster images or extracting information based on the reflectance of the object and it serves specific aims; which is converting image data into thematic data. Digital image classification techniques

assemble pixels to represent LU/LC classes. This study uses maximum likelihood classification to classify a land cover image object (Deilmai *et al.*, 2014). When giving training samples for the identified classes to the area of interest supported by online Google Earth considering it as ground truth data. Post classification of this image was done to increase the accuracy of the classified image this was completed by majority analysis, unwanted pixels also sieved and raster data were converted into vector Land use land cover data. Digitization of different classes will complete then areal coverage/ha of all classes in a specific year has been calculated. Land-use/Land-cover Map. Land-use and Land-cover classes and their description are presented in Table 3.

Table 3. Land-use and land cover and description of the study area.

No	Land cover class	Description
1	Built-up	Areas covered by considerably constructed materials (e.g., Buildings, towns, villages, etc.) that can be for residential, commercial services, transportation, communication and industrial purposes.
2	Bare land	with no vegetation cover on the area An Open space, bare land exposed soil, stony
3	Forest	Area cover by trees higher than 4 meters and a tree canopy cover of more than 10 %, or with trees that will be able to meet these criteria., Dense Vegetation areas
4	Shrubland	Area covered by a woody plant that is typically less than 3 meters tall
5	Quarry	The area used for rock excavation’s purpose and aggregate

A. Maximum likelihood classification

The maximum-likelihood classification is a classification system where the unknown pixels are given to the specific class by using the probability of contours around the training area using the maximum-likelihood approach. It is assumed that the statistical value for every class in every band is normally distributed and then the probability value that the pixel is appropriate to in a certain class is calculated. Every pixel is given to the class that has the highest probability.

B. Ground truthing

A ground truthing activity was carried out in the study area, in which different LU/LC classes were validated. The observed LU/LC includes shrubland, Forest, bare land, built-up, and quarry. These LU/LC classes were used in producing the map legends and with the assistance of GPS, the training set data used for image classification were acquired.

Classification accuracy assessment

Assessing classification accuracy requires the collection of some original data or prior knowledge about some parts of the terrain, which can then be compared with the RS-derived classification map. Thus, to assess classification accuracy,

The supposed true map may be derived from in situ examination or quite often from the interpretation of remotely sensed data obtained at a larger scale or higher resolution. Shortly, accuracy assessment is performed by comparing the created by Remote Sensing analysis to a reference map based on a different information source. Using a handheld (GPS) field survey was conducted in the study area and about 70 points were identified. The field survey and Google Earth were used as a ground for evaluation of the LU/LC classification accuracy. The final output of classification accuracy was calculated for the years 2006, 2016, 2021 Land-use/Land-cover Map.

Change detection

The classified image for the years 2006, 2016, and 2021 demonstrates how the area diverts its use by anthropogenic activity through time and it can show how much the natural environment is affected by other land use such as quarrying activities. This aims to generate a temporal land use map of the area separately for each year from this land use, land cover change map of the area generated and detection of quarry expansion rate will be analyzed according to (Suleiman *et al.*, 2017).

The detection analysis result is important to understand which land use is rapidly increasing and which land use is shrinking. Net change detection from 2006-2021 was done by intersecting the digitized and classifying two temporal images on the Arc map after the intersection has been done the area of each polygon were calculated in a hectare. The calculated area was pivoted in an excel sheet, as a type of row and column for considered years; this is to compare the total change of every class in all LULC maps to detect net spatiotemporal change.

4.2.4. Geotechnical data collection

Field study is done to document the present condition of the study area and based on reconnaissance surveys different sampling sites were selected to rock mass characterization of the quarry sites. Discontinuities, their frequency, dip, dip direction, and strike were measured. In addition, the Schmidt hammer was used to determine the uniaxial compressive strength of the rock mass.



Figure 9.Schmidt hammer in the field for compressive strength determination

The measuring tape was utilized to measure the volumetric count of rock quality designation (Bieniawski, 1989). In the quarry sites, a geotechnical investigation was carried out. Different representative sites were selected based on systematic and judgmental descriptions according to the characteristics of the rock mass visual description. Techniques of geomechanics classification (rock mass rating system) by (Bieniawski, 1989) were applied to collect measurement data from the field. Because this technique is very simple to use and the classification parameters are simply obtained through measurement. In addition, the method is appropriate and adaptable to many different situations including, coal mining, hard rock mining, slope stability, foundation stability, and tunneling (Nicholson *et al.*, 1986). To determine the rock mass rating (RMR) the following six parameters were measured.

- uniaxial compressive strength (UCS)
- rock quality designation (RQD)
- spacing of discontinuities
- condition of discontinuities
- groundwater condition and
- Orientation of discontinuities

The unconfined compressive strength of the rock is the stress required to break a loaded sample that is unconfined at the sides. If 'P' is the load tending to break the sample, and 'A' is the cross-sectional area of the sample. The UCS in kg/cm² is defined as;

$$\text{UCS} = A/P$$

The compressive strength of rock depends on the direction of the acting compressive stress with bedding or foliation. The compressive strength is highest when the compressive stress is applied normally to the bedding. The uniaxial compressive strength (UCS) of rock material can be determined in the laboratory on rock samples or at the field in-situ conditions. If cores are available, UCS can be determined in the laboratory by a UCS testing machine. Infield UCS of rock can be determined by the Point load Index method or by using Schmidt hammer. (Barton *et al.*, 1977). The Schmidt hammer provides numeric rebound value, which can be correlated to UCS by using Barton and Choubey (1977) relation, which is expressed as:

$$\log \log 10 (\sigma_c) = 0.00088\gamma R + 1.01$$

Where; 'σ_c' is the uniaxial compressive strength (UCS) in Mpa, 'γ' is the dry rock density in kN/m³ in the study area, the dominant material is limestone the density is taken for limestone (23 kN/m³), and 'R' is the rebound number of Schmidt hammer (Barton & Choubey, 1977).

The discontinuity data like dip, dip direction, strike, and slope direction are measured in the field. The rock quality was determined by using the Palm storm relation method.

For the study, RQD is a significant parameter to describe the engineering properties of the rock mass. RQD is defined as the percentage of intact core pieces longer than 10 cm in the total run.

$$RQD = \frac{\text{length of core pieces} > 10\text{cm long} \times 100}{\text{total length of corerun}}$$

The availability of drill cores is the core problem to deal with or work the RQD but there are two empirical methods devised to utilize the RQD by simple field observations. These approaches are

- The scan line method was proposed by Priest and Hudson (1960)
- Palmstorm's relation (Palmstrom, 1982).

For the current study to test the RQD at several locations in the study area Palmstrom relation has been chosen. Palmstrom relation, also called volumetric count method, can be determined as;

$$\mathbf{RQD = 115 - 3.3 J_v}$$



Figure 10.1 1m Volumetric count of an exposed rock face in the study area.

Spacing is determined by simple measurement through measuring tape. Visualization, condition of discontinuities, groundwater condition, and orientation of discontinuities were determined by characteristics of the geological condition. The shear strength parameter (cohesion and angle of internal friction) is determined based on the result of rock mass rating by Bieniawski and Hoaks (1986).

Romana (1985) proposed a classification method for determining the stability of rock slopes called the slope mass rating (SMR) system. For slope mass rating, Romana used Bieniawski's Rock Mass Rating System (RMR). Romana developed SMR to account for only plane and toppling modes of failure; later, Anbalagan, Sharma, and Raghuvanshi (1991) changed it to account for wedge mode of failure as well. Slope Mass Rating is defined as; $SMR = RMR + (F1 * F2 * F3) + F4$. Where, RMR is evaluated according to Bieniawski (1979, 1989) by adding the Parameters of five parameters (Bieniawski, 1978, Bieniawski, 1989).

Assessment of Social and management Issues of the quarries

4.2.5. Questionnaire surveying

A questionnaire for the quarry workers and the residents was employed to identify the problems they experience as they carry out the quarrying activity and the daily effect, they face due to the occurrence of quarries in the area. The collected questionnaire data from them were analyzed and presented by using SPSS software to generate frequency and percentage results. The social and environmental impact of the quarry sites were assessed through open and close-ended questionnaires. From the study area, four representative sampling sites were selected based on the quarry location. Quarry workers and the community near the quarry site were interviewed by visiting their homes or places of work. For this purpose, a different number of respondents were selected randomly from each locality. A total of 100 respondents were contacted from the selected representative quarry sites in the study area.

4.2.6. Focused group discussion

Focus group discussion (FGD) is frequently used as a qualitative approach to gain an in-depth understanding of social issues. In this study, the method aims to obtain data from purposely selected groups of individuals in addition to a statistically representative sample of a broader population.

Purposely selected groups for the focused group discussion were

1. The quarry owners
2. Community representatives
3. Water mining and energy bureau officials
4. Forest and climate change authority bureau officials

4.3. Analysis and interpretations

The data from respondents were fed and analyzed by using a statistical package for the social sciences software, (SPSS) to produce frequency and percentage. The Open-ended questionnaires were included in the assessment to analyze the community opinions on quarry impact. Therefore, the gathered information from the close-ended questionnaires, the ideas raised by the proposed agendas, and the information from the focused group dissection were summarized. Based on the

output from the SPSS software and from open-ended questionnaires the quarry impact on residents' lives near the quarry sites will be assessed.

4.4. The software used for the current study

- ArcGIS 10.8 was used to extract satellite images for land use land cover change purposes and used to prepare a study area location map.
- Google Earth Pro used for exploring the background and current use of the study area before field investigation, for accurate assessment of the prepared LU/LC map.
- QGIS 3.10.1 was used for classified image land use land cover change detection analysis and to generate random X and Y points for accuracy assessment.
- SPSS (statistical package for the social sciences) software was used to analyze data from respondents.

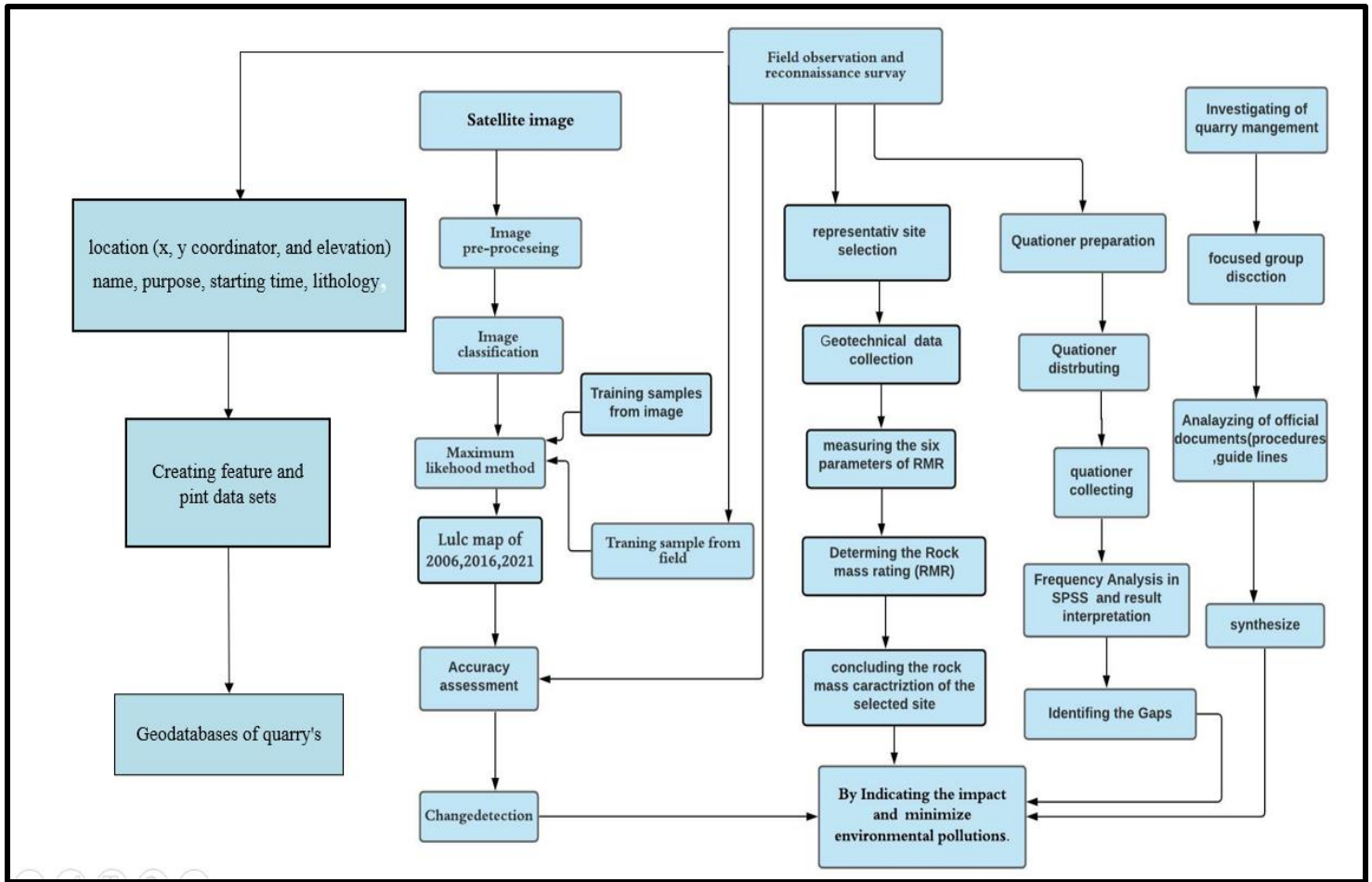


Figure 11. Summarized methodology flow chart

CHAPTER FIVE

5. Result and Discussion

5.1. Land-use/land-cover change in 2006, 2016 and 2021

5.1.1. Existing land use land cover

The final classification results provide an overview of the research area reserves' main land use/land cover features for the years 2006, 2016, and 2021. The following five land use/land cover (LULC) categories were identified: bare land, built-up, forest, shrubland, and quarry as shown in (Fig12 a, b and c)

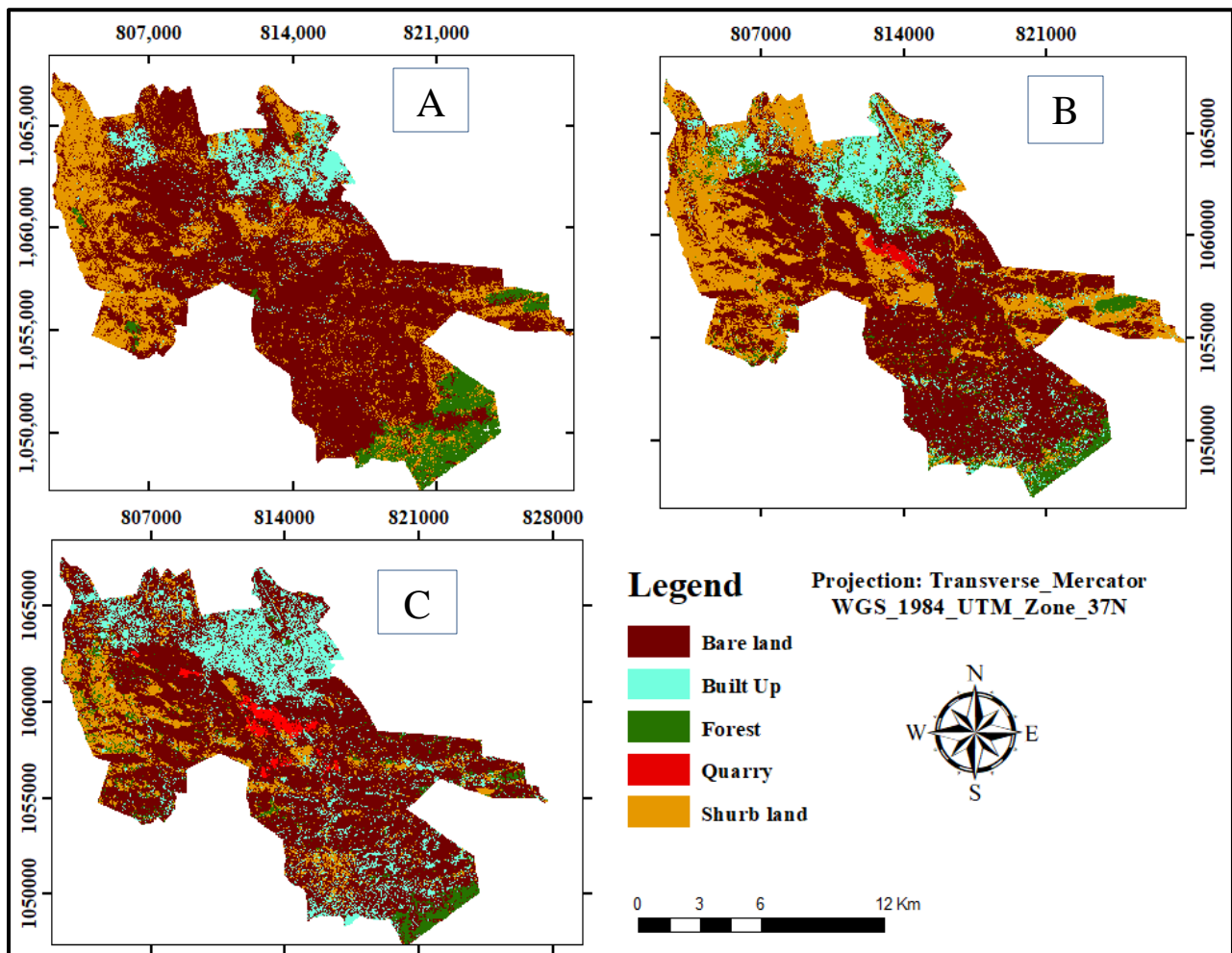


Figure 12. Land-use/land-cover maps of the study area of the years 2006 (a), 2016 (b), and 2021 (c).

The land-use/land-cover classification result of 2006 presented that the dominant LU/LC classes were bare land and shrubland. These classes accounted for 87 % of the overall area coverage. From the total area of 23,390.24 ha, Bare land accounted for 15121.43 ha (64.65%) and shrubland accounted for 5227.58ha (22.35%). On the other hand, LU/LC the Forest built up, and quarry together accounted for 3041.66 ha (13.01%) of the total area. The quarry site covered the smallest area than all other classes as shown in (Table.3 and Fig12).

Table 4. Land-use/land-cover classes and area coverage of 2006, 2016, and 2021 in the Study Area. ha(hectare)

No	LU/LC classes	2006		2016		2021	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
1	Bare land	15121.43	64.65	12574.91	53.72	14618.4	62.43
2	Shrub land	5227.58	22.35	6188.15	26.44	2988.9	12.76
3	Forest	1524.93	6.52	1650.49	7.05	1097.1	4.69
4	Built up	1512.72	6.47	2840.66	12.14	4346.8	18.56
5	Quarry	4.01	0.02	151.99	0.65	364.384	1.56

Analysis of the 2016 map also presents that the bare land constitutes the largest proportion of land in the study area with the value of 12574.91 ha (53.72 %), followed by shrubland, which accounted for 6188.15 ha (26.44 %). Other LU/LC classes such as Forest, built-up, and quarry together accounted for 19.79 % of the total area. In 2016, quarry covered the smallest area than all other classes as shown in Table 3 and Fig 12.

Land-use/land-cover classification results of the 2021 image revealed that the largest LU/LC categories were bare land and built-up together accounted for 80.99 % of the total area coverage. Bare land accounted for 14618.4ha (62.43%) and Built-up accounted for 4346.8 ha (18.56%) Other LU/LC classes were bare land, Shrubland, forest, and quarry, which together accounted for 19.01% of the total area. However, the coverage of the quarry is smaller relative to other classes but it shows a high percentage of expansion in the study area. The area expansion of quarry 2021 increased by 1.56 % from 2006. Generally, bare land is the major LU/LC of the area with area

coverage, followed by shrubland. Full statistical data for each of these classes and the LU/LC map of the study period are shown in Table 4 and Fig 13.

Bare land had the largest extent of all LU/LC in the study area during 2006–2021. But, the extent of quarry increased by 4.01ha (0.02%) in 2006 to 151.99 (0.65%) ha in 2016 and increased by 364.384 (1.56%) ha in 2021. Abate Zelalem (2016) also found that the rate of change in quarry land use functions increased by 18.09 percent yearly. Also, the agricultural and forest land decreased by 21.33% and 2.51% respectively in the considered year as a result of the quarry activity.

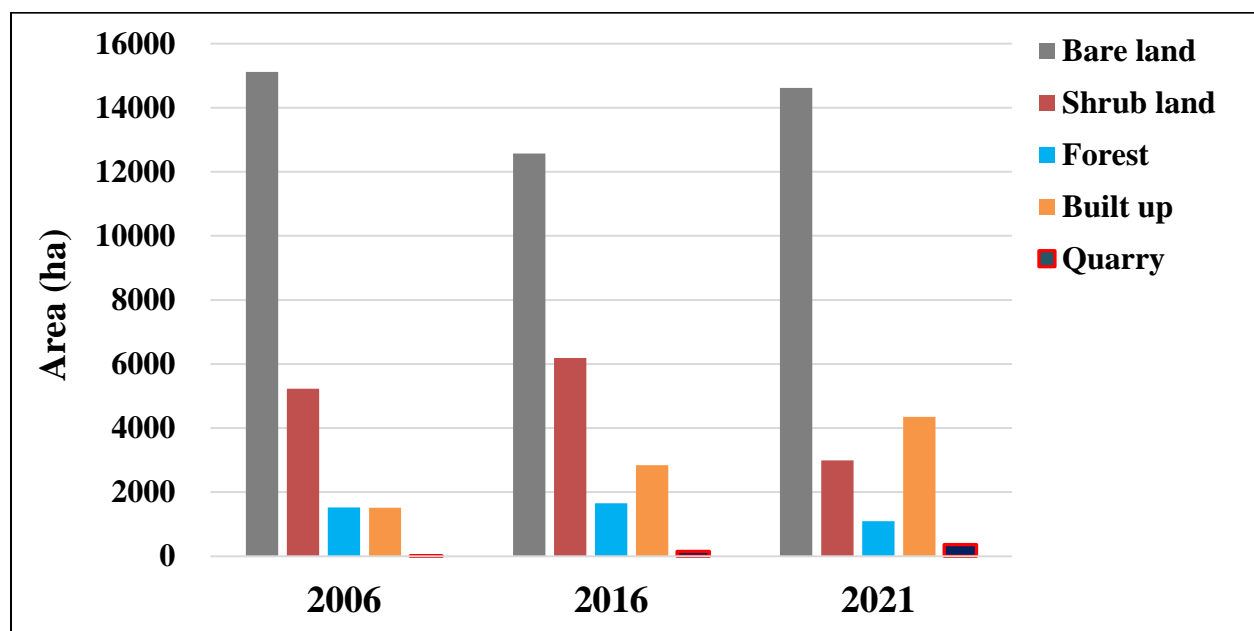


Figure 13. Distributions of land use land cover class on study area from 2006 to 2021

5.2. Change detection analysis

Land-use/land-cover classes in the study area have indicated a vital change between 2006 and 2021. Among the five main LU/LC classes, bare land and shrubland covered more than 80% of the area in all the study years. The built-up area has been increasing from 2006 to 2021. It has increased from 1512.72ha (6.47%) in 2006 to 2840.66ha (12.14%) in 2016 and 4346.8ha (18.56%) in 2021. The quarry area increased from 4.01ha in 2006 to 151.99 ha by 2016 and 364.384 ha in 2021. Forest and bare land showed an increase and decrease in the study years. Bare land was 15121.43ha in 2006, which was decreased to 12574.91ha by 2016 and then increased to 14618.4 ha by 2021. Forest also decreased from 2006 to 2021. It increased from 1524.93ha by 2006 to 1650.49ha by 2016 and decreased to 1097.1ha by 2021.

Table 5. Land-use/land-cover distribution and net changes during 2006–2021.

No	LU/LC classes	2006		2016		2021		Net changes during 2006 - 2021
		Area(ha)	Area (%)	Area(h)	Area (%)	Area(h)	Area (%)	
1	Bare land	15121.43	6.47	12574.91	53.72	14618.4	62.43	-503.03
2	Shrub land	5227.58	22.35	6188.15	26.44	2988.9	12.76	-2,238.68
3	Forest	1524.93	6.52	1650.49	7.05	1097.1	4.69	-427.83
4	Built up	1512.72	6.45	2840.66	12.14	4346.8	18.56	2,834.08
5	Quarry	4.01	0.02	151.99	0.65	364.384	1.56	360.37
Total		23407.20	100	23407.20	100	23407.20	100	

NB: The plus (+) sign represents an increase in the particular LU/LC class while the minus (-) sign represents a decrease in the particular LU/LC class. The rate of LU/LC for each class was calculated as follows: Rate of change (ha/year) = (A-B)/C. Where A= recent land use/cover area in ha. B= Previous area of land use/cover in ha. C= interval between A and B in years.

The LU/LC change tendencies of the study area revealed that quarry and built-up have increased by quarry 2,834.08 ha and 360.37ha, respectively. Other classes showed increasing and fluctuating area coverage. As shown in graph (Fig 14).

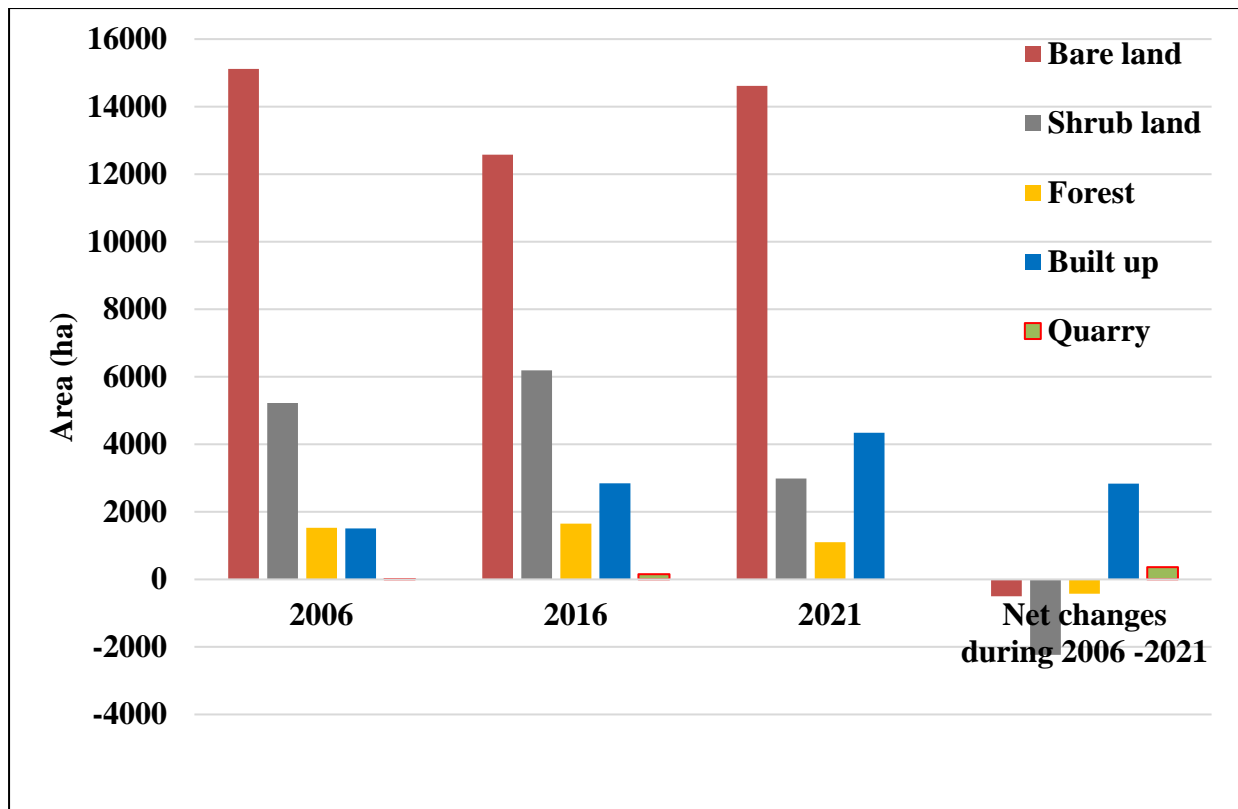


Figure 14. A chart showing the LU/LC changes in the study area

According to (Samrawit Yimame, 2020) study on the Environmental Impact Assessment of Quarrying Activities on the Downstream Section of the Big Akaki Catchment, she made LULC change detection between 2000 and 2020 find the change to recognize which natural environment is impacted by quarry expansion. And the results were built up and expanded about 3366.05 ha in between the last 20 years. The overall expansion of quarry sites was about 698.68 ha, it was cover only 27.61 ha. The same is true in this study the change detection in the LU/LC of the study area in the period from 2006 to 2021 indicates the change in all classes. There are different causes for change but the study focused on the change due to quarry expansion and aggregate production. Fig 15 shows the change in the area of each category during the 15 periods in ha. It also indicates the change of one into another new class for the 15 years periods. Quarry site expansion is dangerous nowadays in the area because the plantation of quarry sites excavates green land.

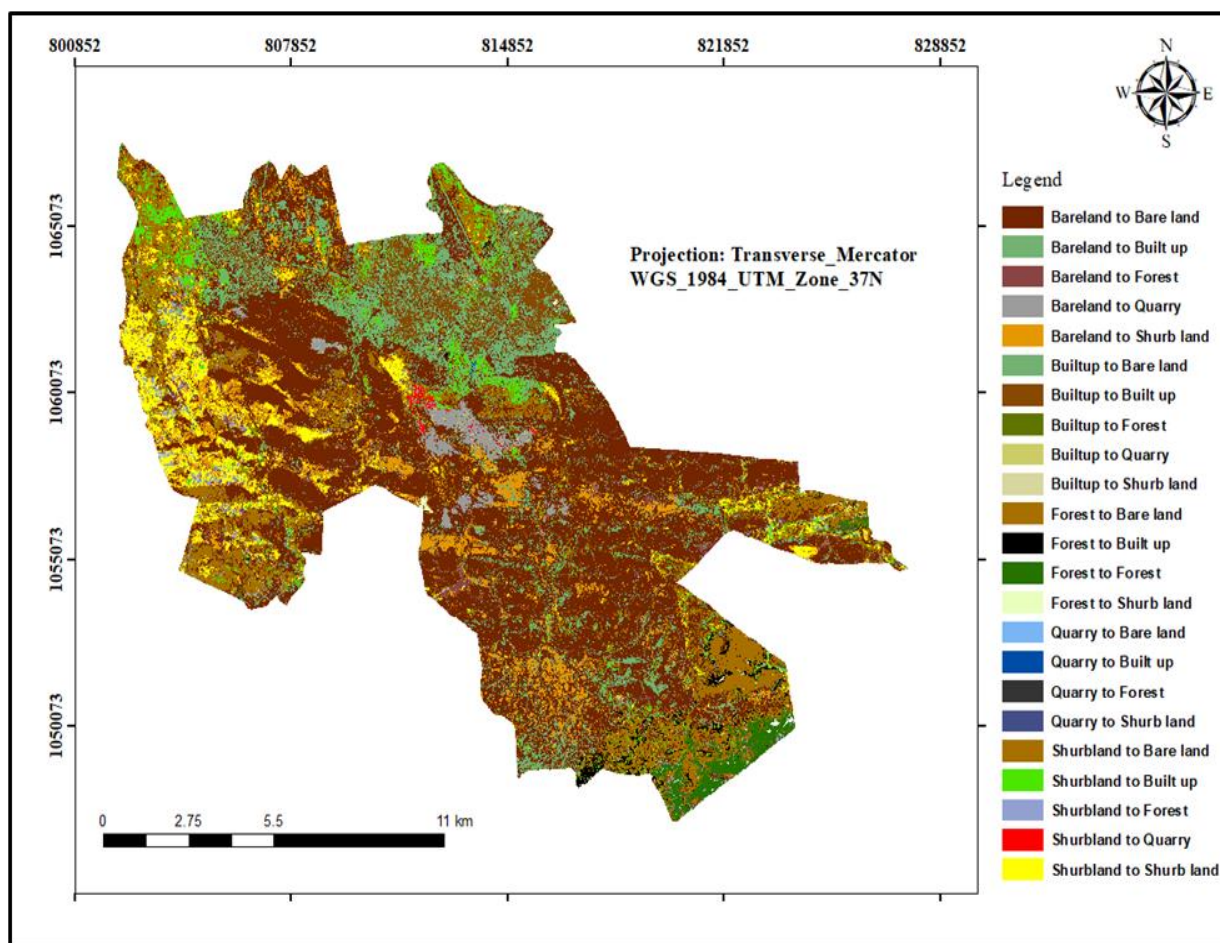


Figure 15. Map showing in LU/LC from 2006 to 2021

Table 6. The changes of the LU/LC between 2006 -20201

From	to	Area change
Bare land	Bare land	10389.35
Bare land	Built-up	2421.08
Bare land	Forest	413.53
Bare land	Quarry	328.35
Bare land	Shrub land	1564.77
Built-up	Bare land	642.38
Built-up	Built-up	819.50
Built-up	Forest	15.30
Built-up	Quarry	17.01
Built-up	Shrubland	18.14
Forest	Bare land	866.34
Forest	Built-up	245.45
Forest	Forest	383.91
Forest	Shrub land	27.56
Quarry	Bare land	1.14
Quarry	Built-up	2.79
Quarry	Forest	0.07
Quarry	Shrub land	0.02
Shrubland	Bare land	2894.49
Shrubland	Built-up	824.39
Shrubland	Forest	260.87
Shrubland	Quarry	41.68
Shrubland	Shrub land	1203.27

5.2.1. Accuracy assessment

Accuracy evaluation is a critical component of remote sensing classification and change detection applications. Accuracy assessment is used to control land management, decision-making to an error matrix. The error matrix can be used as a starting point for a series of descriptive and analytical statistical analyses. Overall accuracy, producer accuracy, and consumer accuracy are all associated evaluation components (Congalton, 1991, Congalton et al., 1999, Foody, 2002). The sampling strategy for collecting ground data to evaluate overall accuracy is one of the most important steps in classification. Some analysts continue to perform error evaluations based only on the training pixels used to train or seed the classification algorithm. Unfortunately, the location of these training sites is usually not random and, at the same time, biased by the analyst's a priori

knowledge of where certain land-use/land-cover types existed in the scene (Jensen 1996). However, the purely random sampling method is not practical because it may ignore many smaller categories. For these reasons, stratified random sampling is usually recommended so that the sampling points are fairly spread in each land-use change. The total number of reference pixels (ground data) is another crucial factor in accuracy assessment. Congalton (1991) suggested that a good rule of thumb was to collect a minimum of 70 samples for each land-cover class in the error matrix. If the area is especially large or the classification has a large number of land-use categories, the minimum number of samples should be increased.

The accuracy assessment of LU/LC for the years 2006, 2016, and 2021 documented the overall classification accuracy of 91.05, 85.71, and 89.31, respectively. The detailed information of producers' and users' accuracy is shown in Table 6.

Table 7. Information of accuracy assessment for the years 2006, 2016, and 2021.

Class Name	2006		2016		2021	
	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer accuracy	User's accuracy
Quarry	82.61	90.24	80	94.12	88.89	100
Forest	88.57	86.11	77.78	87.5	90.00	90
Shrubland	94.12	94.12	83.33	71.43	85.71	85.71
Bareland	100	92.86	91.67	84.62	93.62	93.62
Built Up	66.67	66.67	100	100	86.54	88.24
Overall accuracy	91.05		85.71		89.31	

5.3. Organized a geodatabase for quarries in Dire Dawa

Geodatabases have a comprehensive information model for representing and managing geographic information. This information model is implemented as a series of tables holding feature classes and attributes. In addition, advanced GIS data objects add real-world behavior, rules for managing spatial integrity, and tools for working with spatial relationships of the core features and attributes (Line, 2009). The analysis and interpretation of the non-spatial data contained in the geodatabase can give an interesting perspective of the nature of the quarries in the study area.

The study illustrated the work related to the construction of a geodatabase of the quarry activities located in the Dire Dawa. In the geodatabase, all the basic data and relevant information are stored to produce different maps able to support the planning and management of extraction sites. The information contained in the geodatabase would be essential for undertaking the Strategic Environmental Assessment of the planning operations of the mining activities on the regional territory. Thanks to the flexibility of the provided tool, the geodatabase could be implemented in a multi-disciplinary evaluation of the impacts produced by mining activities, including social, ecological, and environmental effects (Bottero *et al.*, 2014).

Geodatabase of quarries in Dire Dawa is prepared. It contains data on location (x, y coordinate, and elevation), name of the quarry, purpose of the quarry, starting time of the quarry, lithology, proximity to rivers, and institutions such as schools, hospitals. A geodatabase file was created containing feature classes, raster datasets, and feature datasets. File geodatabases feature class contains different classes which are quarry maps and quarry location and their attributes. Fig 16 shows the information about the quarry name, the starting time, the elevation, the lithology of the quarry, and the closeness of the quarry to institutions.

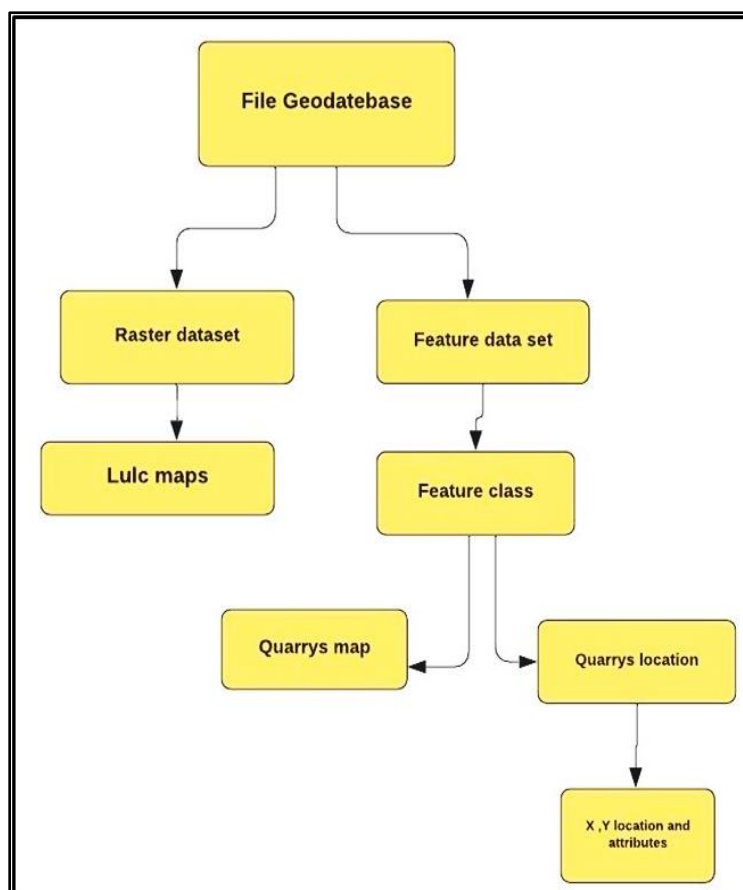


Figure 16. Flow chart of geo-database components

All the data that were organized in the geodatabase give services for managing and accessing the quarry site by offices that are responsible for managing and licensing (Fig 17). The absence of any geodatabase for quarries operating in Dire Dawa made their management difficult. Therefore, designing and developing this geodatabase can make a difference in facilitating the management of quarrying activity in the research area. Moreover, the possibility of easily visualizing the information contained in the geodatabase using specific thematic maps will help the communication of the planning decisions to the stakeholders, thus ensuring participatory decision processes (Mondini 2016).

OBJECTID*	SHAPE*	Name	SHAPE_Length	SHAPE_Area	Purpose	Lithology	Nearing_setilment	kebele	Elevation
1	Polygon	H AND H	315.238695	4382.169897	Quarry for Aggereget	Limestone	65m	Lege Aneni	1315
2	Polygon	National cement	8088.686076	2349891.690657	Quarry for cement	Limestone,Basit,Righolit	50m	Lege Aneni	1221
3	Polygon	Sun in night	1042.559801	27778.138558	Quarry for Aggereget	Limestone	50m	Felema	1260
4	Polygon	Yared Germa	1356.225141	48552.769624	Quarry for Aggereget	Limestone	80m	Genderge	1467

Figure 17. Screenshot of the designed geodatabase and its attribute table

5.4. Social impact of quarrying activities

5.4.1. Quarrying impact on the community

Demographics description

Data were collected across all the communities where quarrying is being carried out. The opinion community members were interviewed to enable a passable understanding of the situation on the ground. This section of the thesis, therefore, presents the background of the community respondents in terms of sex, age, education, and occupations.

The study discovered about 5 (10%) of the respondents were primary school level, 24(48%) Secondary level, 7(14%) University level, and the rest of the respondents were able to read and write (Table 8). This situation facilitated the collection of data as the majority of the respondents administered the household questionnaires themselves. The information on the marital status of the respondent indicated that around 12(24%) were single, 36(72%) were Married, and 2(4%) Widow. The household size was also considered, about 45(90%) of the households had 1 to 3 family members, 3(6%) 4 to 5 family members, and the remaining 2(4%) are 6 and above household size. The occupation of the respondent about 22 (44%) had their own business, 9 (18%) of them Government employs, 19 (38) private sector employs 17 (34%) of them have lived for <5 years and 58% have lived for 6 -10 years around the area and 8% of them lived around the quarry

area 11-25 years. 30 (60%) of them were residing before quarry sites started and 20 (40%) of them reside after quarrying activity started.

Table 8. Demographic description of respondents in the community

Variable	Category	Total Count (%)
Age	18-25 years	6 (12)
	26-33 years	12 (24)
	31-41 years	17 (34)
	42 and above	15 (30)
Sex	Male	28 (56)
	Female	22 (44)
Education Level	Primary	5 (10)
	Secondary	24 (48)
	University	7 (14)
	Read and write	14 (28)
Marital Status	Single	12 (24)
	Married	36 (72)
	Widow	2 (4)
Household Size	1-3	45 (90)
	4-5	3 (6)
	6 and above	2 (4)
Occupation	Own business	22 (44)
	Government employs	9 (18)
	private sector employs	19 (38)
Duration of residence	< 5 years	17 (34)
	6-10 years	29 (58)
	11-25 years	4 (8)
Reside near/around before quarry operation	Yes	30 (60)
	No	20 (40)
The purpose of the quarry site before quarry operation	Cultivated land	9 (18)
	shrub land	20 (40)
	I do not know	21 (42)
Quarry activity related complaint	Dust	6 (12)
	vibration	15 (30)
	Noise	9 (18)
	All	20 (40)

From the selected communities near the quarry site, respondents were negatively impacted by quarry activity. Forty (40 %) of the respondents said that three of the listed problems (i.e., dust, vibration, and noise) hurt their health; the remaining 6(12%) said dust, and 9(18%) of them said noise (Fig18).

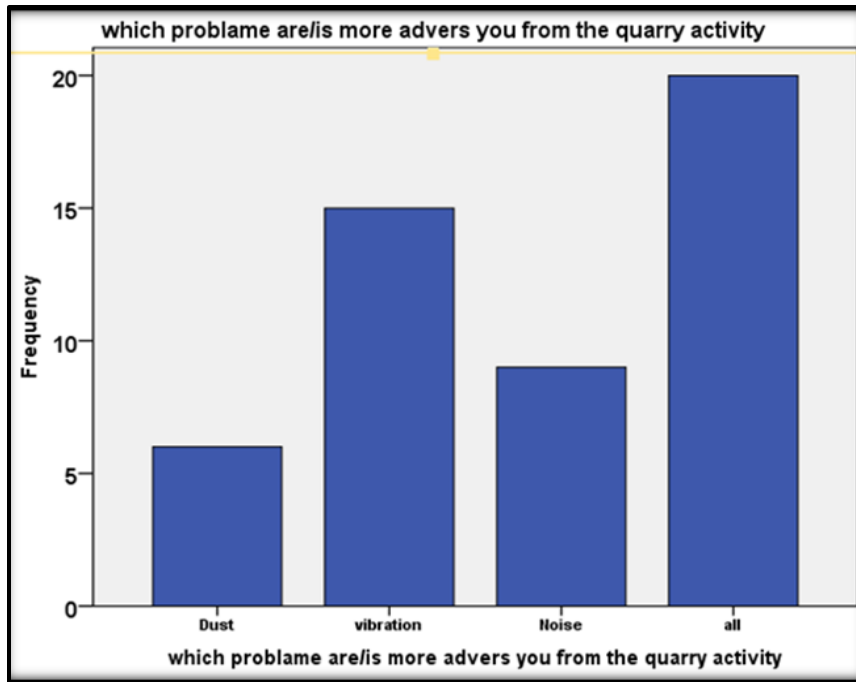


Figure 18. quarry problem that adverse the community

They also responded on the open-ended questionnaire that the vibration, especially the blasting negatively affects their hearing ability. The blasting problem extends to death where a person was dead according to the evidence recorded by the police administration office. The presence of flying rocks emanated primarily from the blasting of rock products using powerful explosives like dynamite. Flying rocks had caused various degrees of damages. A mother from the community said flying rock harmed her son on his head and nobody was accounted for. As shown in Fig 19 cracked house walls and floors were in the area due to the blasting. Additionally, the blast led to constant damage in the pit toilets where equipment fell from tables and became damaged. According to the data obtained from the community leader, some of the electric poles scattered and fell on the ground in the area.

Further to this, residents in the blasting area are unable to lead their day-to-day activities because of the vibration and noise of the quarry. For instance, students can't study properly, patients are unable to recover at home. Besides, house roofs were damaged due to the flying rocks from the

rock crusher. Some of the respondents are disappointed with the activities and demand immediate and appropriate action to be taken by the government.



Figure 19. Series of cracks and collapse in buildings

5.4.2. Quarrying impact on the quarry workers

Demographic description of the quarry workers



Figure 20. Photo plate while interviewing the quarry workers

The majority of the quarry workers are men and they are in large numbers. The women in the quarry site are not directly involved in the quarrying activity. The quarry companies have employed people of different ages” 10% between 18-25 years, 46% between 26-33 years and 34% between 31-41 years. Some of them are over 42 years as shown in (Table 9).

The impacts of stone quarrying on the local environment information were generated through interview techniques. This helped to reveal vital information from the respondents. Regarding the educational level, it was found out that 56% of the respondents were able to read and write. Quite a few had gone beyond secondary education (8%). Due to the poverty level, they were not able to go to school and as a result, they were not aware of safety regulations required in the workplace. Thirty (30) percent of the workers didn’t have any form of education (Illiterate), 6% have gotten primary education as shown in Table 9.

Table 9. Demographic description of quarry works who participated in the survey

Variable	Category	Total Count (%)
Age	18-25 years	5 (10)
	26-33 years	23 (46)
	31-41 years	17 (34)
	42 and above	5 (10)
Sex	Male	42 (84)
	Female	8(16)
Education Level	Primary	3(6)
	Secondary	4 (8)
	University	15 (30)
	Read and write	28 (56)
Marital Status	Single	11 (22)
	Married	36 (72)
	Widow	3 (6)
Have you got the safety guides before you start the work	Yes	9(18)
	No	41(82)
Do you ever face accidents from the quarry activities	Yes	28(56)
	No	19(38)
How long you have work in the quarry activity	< 5 years	20(40)
	6-10 years	25 (50)
	11-25 years	5(10)
Do you use job safety equipment	Yes	10 (20)
	No	40 (80)
What looks the supply of continuous safety equipment from the quarry company	Low (per year)	10 (20)
	None	40(80)
Could you indicate if you have faced dust-related problems from the quarry operations	Skin allergic	9 (18)
	Irritation of eyes	19(38)
	Respiratory problem	22(44)
Could you indicate if you have faced noise-related problems from the quarry	Loss of peace after work	6(12)
	Ear problem	20 (40)
	Headache	24(48)

Within the surveyed quarry area, the respondents were reported to have worked on the quarry activity for several years. About 50 % of them work for 5-10 years. 20 % works for < 5 years and 10 % works for 10-20 years. The quarry workers were not staying in their working place for a long period because of the bad effects of the quarrying activity on their health (Fig 20). Due to lack of any other form of training, getting another job can be very difficult.

Protective safety equipment used during quarrying activity

Workers have to use the correct safety equipment provided by their employer. Workers who have a problem with the personal protective equipment (PPE) issued must raise it with their employer to see why it is required and what alternatives may be available. In different jobs, there must be disciplinary personal protective equipment that every employer should provide and keep the employee's safety in the first place (Honda, 2016). Equipment like effective and suitable protective clothing and appliances including suitable gloves (where necessary), footwear, goggles, and hallmate especially for the employees who are involved in activities such as breaking of stone.

During the study, it was recognized that about 20% of quarry employees were provided with the protective gear but the remaining is not as shown (Fig 21). Even those who had the protective gears were not used to it because do not know how to use it and they are not completely protected.

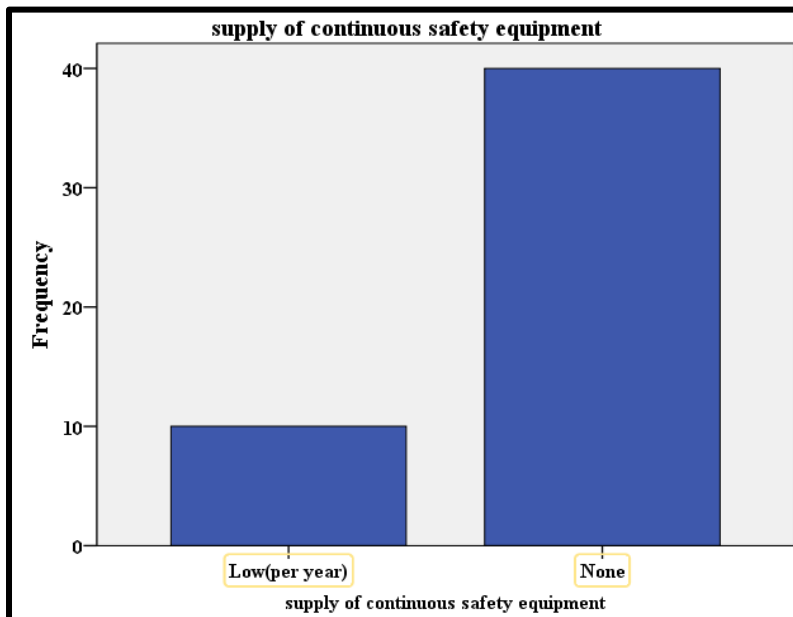


Figure 21. Graph showing the continued supply of safety equipment.

The absence of personal protective equipment during work time makes the quarry workers susceptible to accidents and injuries. Due to the hazardous nature of quarrying activity, all range

of workers at the site needs to be provided with protective clothing to minimize or halt the occurrence of accidents (Wilson, 2015). Generally, the lack of safety regulations, law enforcement, education, training, and equipment are the commonly reported reasons that are believed to have increased injuries among quarrying activities.

Safety guides before the quarry worker started the work

Giving a guideline for the worker is the basic step for good work but in this study, it has been revealed that most of the quarry companies didn't give safety training and guideline to the employees 82% of the quarry worker did not get the safety guide before they start their work and only 18% of the quarry workers get the safety guides (Fig 22). They did not even know what to do to protect themselves from hazards.

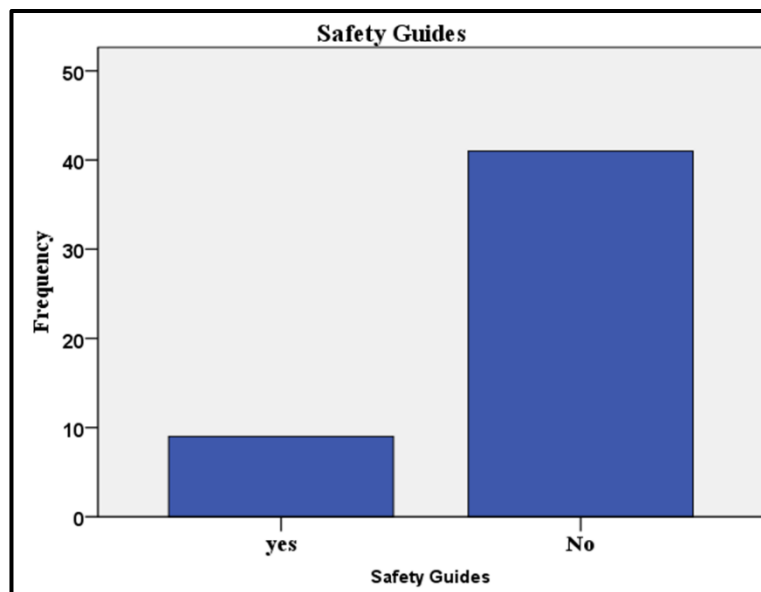


Figure 22. Level of the safety guide

Accidents that happen on respondents

As revealed in the study, about 56% of the quarry workers face an accident during quarry activity as shown in (Fig 23). According to Samrawit Yimame in her study Environmental Impact Assessment of Quarrying Activities on the Downstream Section of the Big Akaki Catchment, revealed result from the total 50 respondents 32 (72%) of them said they had an accident during quarry work and the remaining 18 (28%) had not (Samrawit Yimame, 2020). In this study, the percent of the workers that face the accident in case of lack of supply on safety equipment and

guidelines from the quarry companies and it is a factor for the accident that happened to workers. Lack of training for those who have the PPE is also a factor.

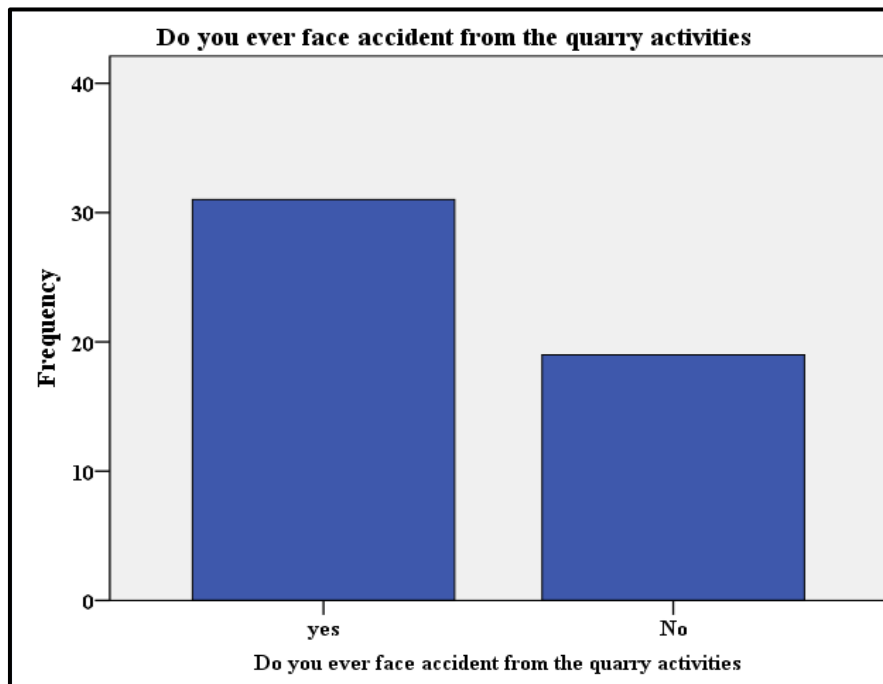


Figure 23. The frequency of accidents faced at the quarry site

Dust and noise-related problems

Quarry operations are noisy and create vibrations. Blasting poses the danger of fracturing quarry walls, increasing permeability, and increasing drainage towards the quarry face (Gunn *et al.*, 1993). The majority of the respondents in this study revealed that they experienced negative effects of dust pollution due to quarrying and stone crushing activity. The negative effects of dust pollution, due to quarrying and stone crushing, on the health of the quarry workers as quoted by the respondents were impact respiratory problems 22 (44%), skin allergic 9 (18%), and irritation on the eyes 19(38%) as shown in Fig.23. As I revealed in my study there is the same finding on Samrawit research: 23 (46%) of workers are vulnerable to dangerous dust-related problems and 10 (20%) of them to very high dust-related problems and also health problems.

from the observations made during the field survey of quarrying sites, the negative excessive emission of dust into the atmosphere was evident (Fig 24).



Figure 24. A photo of dust accumulation.

The dust tends to affect local air quality. Dust emission into the atmosphere was primarily caused by excavation, drilling, blasting, and the crushing of rock products into their respective aggregate sizes (Howard and Cameron, 1998). The dust particle in effect does not only affect the quality of local air but results in serious respiratory disorders like cancer, tuberculosis, and silicosis in the nearby community (Fig 25). In terms of dust emissions, the workers at the quarrying sites were the most vulnerable since they had no protective clothing like a nose mask to reduce the inhalation of these dust particles. It was also reported that the degree of proximity to the quarries has a direct linkage to the extremes of effect on victims (Howard and Cameron, 1998).

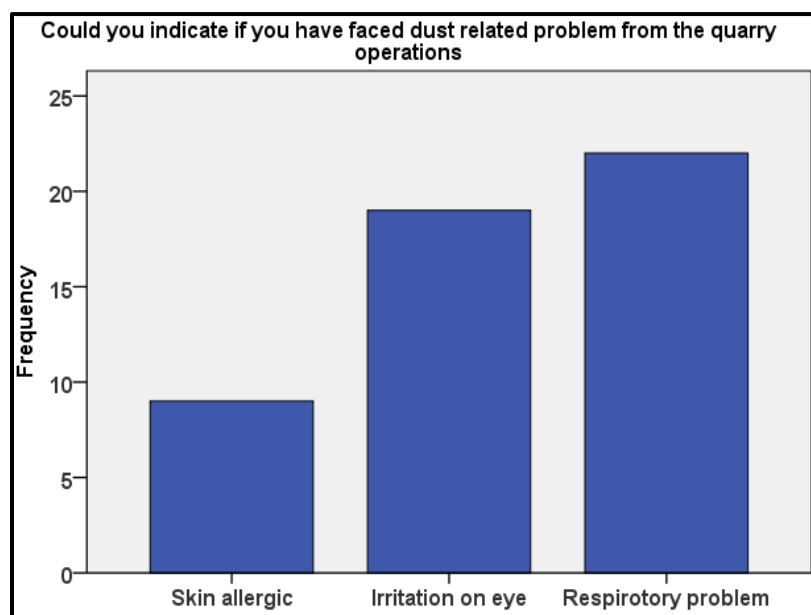


Figure 25. Dust-related problems

The effect of noise pollution from blasting affects humans, animals, and buildings. Excessive noise is a pervasive occupational hazard with many adverse effects, including elevated blood pressure, reduced performance, sleeping difficulties, annoyance, and stress, noise-induced hearing loss, and temporary threshold shift (Deborah, *et al*, 2005).

In this study, a vast majority of the respondents stated that they suffered harshly from the noise pollution caused by stone quarry-related activities. The major effects of noise pollution on the health of the quarry workers, as per the respondents, were, 6 (12%) loss of peace after work, 20(40%) ear problem, 24(48%) headaches for more information (Fig 26). One notable incident is a man who lost his hearing from the noise (Fig 27).

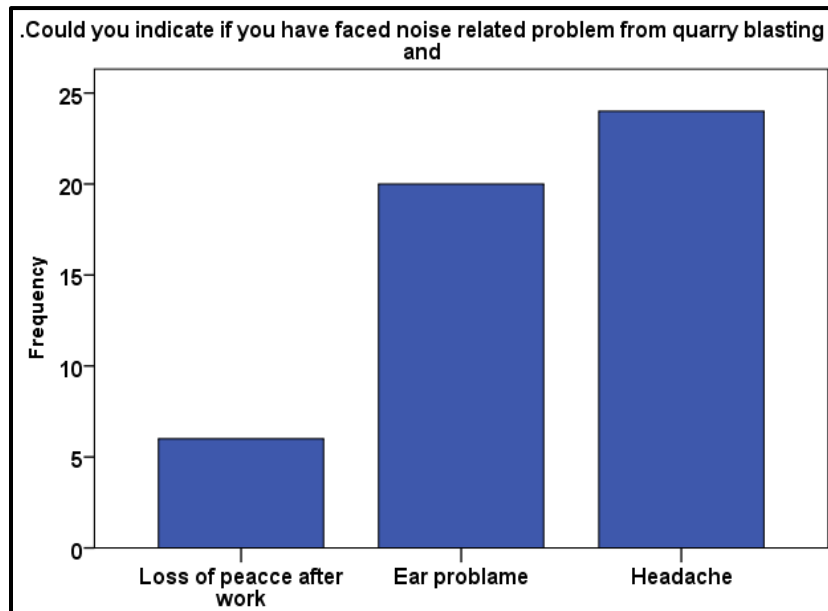


Figure 26. Noise-related problems

Noise pollution is prevalent in all quarry operations. This takes place from the inception stages of drilling to crushing. However, the blasting stage produces the highest levels of noise pollution. This is occasioned by a vibratory sound like the detonation of bombs or other forms of explosives. When an explosive is detonated enormous amounts of energy are released. Most of the energy of a properly designed blast works to displace rock from the quarry face. The remaining energy is released as vibrations through and along the surface of the earth and through the air. (Khopkar, 2007). The study observed from the field survey that quarrying has a negative environmental consequence on the natural environment the survey revealed was severe noise pollution and sustained vibration, culminating from the blasting of rocks. The main cause of the noise was from the excavation, drilling, blasting, and movement of loading vehicles. Residents in the adjoining communities indicated categorically that the noise emanating from the quarries was unbearable, thus creating a nuisance. More so, vibrations resulting from stone blasting with the use of explosives like dynamite were so severe that it resulted in the sudden shaking of the ground.



Figure 27. Photo plate showing a man with an ear problem

The respondents revealed that their breathing systems were affected by a repeated common cold. They indicated long-term exposure to dust without safety equipment caused permanent lung and other breathing diseases like (pneumoconiosis) They also responded that they face respiratory allergies including sinus and asthma. Furthermore, the fine particles of dust cause allergies in the eyes. In addition to questionnaire analysis, the researcher also realized that most of the quarry workers have experienced several problems by the quarry activities. To mention, lack of safety material, and health-related issues (loss of hearing, sinus, asthma, etc.). Therefore, the companies should provide attention to control the accidents and keep the safety of workers at a good level. The study also revealed the effect of quarrying on the destruction of green areas and land degradation. Destruction of green areas. In the study area quarrying is gradually destroying the shrubs and green areas. This destruction is caused primarily by excavation works that involve the removal of plants and vegetation to expose the burden rock for subsequent exploitation by the quarrying companies. Khopkar (2005) in his study also gets a result that activities like mining, quarrying, construction, transportation, and industrialization alter this natural balance leading to the generation and release of objectionable materials into the environment thus rendering life miserable and uncomfortable.

The other environmental impact that the study identified is land degradation. Land degradation is a process in which the value of the biophysical environment is affected by the combination of

human-induced processes acting upon the land (Johnson, 1991). Quarrying activity plays a negative role in land degradation and the loss of top soils (Ata-Era, 2016). In this study, it was observed that quarrying has a negative environmental consequence on the natural environment by way of forest degradation and loss of fertile topsoil. There was an indication of deep large pits, trenches, and deep gullies, resulting from the excavation activities. These big pits had been created due to the continuous extraction of rock products. It was revealed from the field survey that no measures have been put in place by the quarrying companies to reclaim the degraded lands as a result of their activities (Fig 28).



Figure 28. Photo plate shows degraded land

5.5. Analyzing the Focus group discussion (FGD) Data

Focus group discussion is perceived to be a “cost-effective” and “promising alternative” in participatory research Morgan (1996) offering a platform for differing paradigms or worldviews (Orr, 1992, Guba et al., 1994, Morgan, 1996). In response to the issue of *why they engaged in stone quarrying activities?* They responded that poverty is a big issue. Moreover, most respondents prefer this job over private-sector jobs and daily labor since it provides them with more privacy and a higher income. A similar study was also reported by (Zelalem., 2016). Places

like Dire Dawa with full of rock resources are welcomes areas for job creation by quarrying companies. Town expansion will always need rocks and cement for construction purposes. And it is easy for people to get jobs to fight poverty.

To achieve a considerable reduction in the occurrence of environmental problems linked with quarrying, current mining and environmental legislation must be strictly enforced. Timely limitations on quarrying activities and the placement of signals along blasting sites are examples of laws and regulations that must be rigorously followed. Regulatory authorities such as the Environmental Protection Agency and the Municipal Assembly must conduct frequent and ongoing field checks and monitoring to verify that the various regulations in place to improve environmental sustainability are being followed (Ata-Era, 2016).

Regarding the second agenda (*what were the effects of stone quarrying on the environment?*), common problems were given by those governmental authority members saying that companies could have reported their impact assessment once in every while even though they were told to do so but they didn't. The discussion made clear that the FDRE DD Administration Agriculture, water, mine, and energy bureau was responsible for giving licenses to those companies and they needed to work closely with environmental compliance and environmental and social impact assessment authority. Not only that what was understood but also companies were not given the license according to the criteria and the regulation as well. Although the Ministry of Mines and Petroleum (MoMP) set those core criteria for mining licensing and legislations, what was implemented by the responsible body at Dire Dawa was not accordingly. To mention some of the core proclamations by (MoMP).

- Mining Operation Proclamation No.678/2010 (as amended by Proclamation No.816/2013)
- Transaction of Minerals Proclamation No.1144/2019
- Environmental Impact Assessment Proclamation No.299/2002
- Cooperative Society Proclamation No.985/2016
- Organization of Civil Societies Proclamation No.1113/2019

When it came to the community, almost all of the problems were there among them throughout the whole time. It's been said how every reason that came out of the quarrying company like dust, blasting vibration, and noise became part of their lives. They tried every possibility to talk to the

concerned bodies yet no solutions were made. These showed that the communities were still in need of help.

According to Ata-Era (2016) in his research to Quarrying businesses are taking practical steps to reduce noise and disturbance from their operations by strictly observing the Environmental Protection Agency's noise emission regulation. The Environmental Protection Agency's quarrying guidance says that the noise levels allowed by law by firms during the day and night shall not exceed 55 decibels and 48 decibels, respectively. However, it was found that the quarrying businesses are rigorously following the Environmental Protection Agency's mandate. Compliance with policy can reduce costs. The same as that the concerned body should implement noise emission regulations.

The last agenda was about “*What mitigation measures are put in place to reduce these problems and to rehabilitate the sites after closing?*” Regarding mitigation measures that were put in place to reduce these problems and to rehabilitate the sites after closing, one of the company’s members said that none of those reduction measures were implemented by the companies. The concerned bodies must check once in every while he said. In a conclusion, he suggested that trends like that have to come to an end as everybody knows how important it is to take good care of the environment and all quarry companies should work on protecting the environment from different pollution.

The rest of the members kept silent on this one and that was all the ideas that have been raised throughout the discussion. All members agreed that there was a tremendous gap especially when it comes to the communities who suffered the most. Companies promised to prepare reports on impact assessment and work closely with FDRE DD Administration Agriculture, water, mine, and energy bureau.

5.5.1. Rock mass classification

Rock slope in most quarries is susceptible to instability due to the variability in the rock mass condition at the site, intensive weathering in tropics, and seismic activities (Abdullah, 2018). The subsurface geological features such as the existence of joints, folds, and properties of rock play an essential role in the instability of rock slopes (Hoek, 1997). Moreover, the rock slope stability may also be influenced by height, material characteristics, face angle, and rock joint orientation.

For the current study, a quarry site was selected to investigate the slope stability using Bieniawski's rock mass rating method classification systems. The quarry is divided into ten sites. (Table 10 and Fig 29).

Table 10. Location of the slope sites

Data Location	Location Coordinated (UTM)		Elevation (m)
	Northing	Easting	
Site 1	1059478	812700	1268
Site 2	1059335	812556	1260
Site 3	1059392	813181	1307
Site 4	1059874	813578	1287
Site 5	1058282	811843	1278
Site 6	1058299	812716	1257
Site 7	1061337	808684	1226
Site 8	1057275	811569	1207
Site 9	1056172	811715	1260
Site 10	1061433	808659	1191

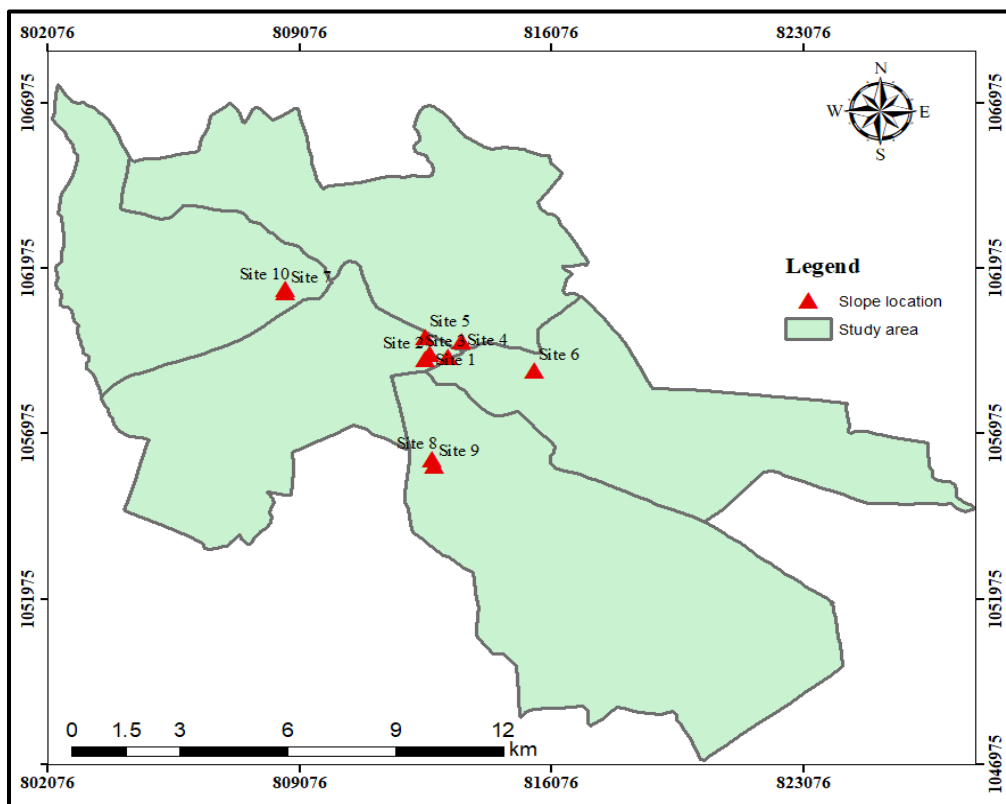


Figure 29. The map showing the Location map of slop sites.

5.6. Description of the rock mass

Different rock units are exposed in the quarry area, and three kinds of rock units exposed are limestone, basalt, and rhyolite. But, for this study, we selected only the limestone. The reason is, it is the most widely used for quarrying to cement production as raw material. The name of the quarry and precise location are listed in Table 11 below.

Table 11. Name of the quarry, rock type, and precise location

Quarry sites	Site (plate)	Rock-type
Quarry site 1	Site 1	Limestone
	Site 2	Limestone
	Site 3	Limestone
	Site 4	Limestone
Quarry site 2	Site 5	Limestone
	Site 6	Limestone
	Site 7	Limestone
Quarry site 3	Site 8	Limestone
	Site 9	Limestone
Quarry site 4	Site 10	Limestone

Limestone

As observed in the field the limestone exposure has a slightly too recently weathered appearance. as Fig 30 shows the area has lost its natural slope as a result of rock extraction, and a shift in landscape has been noted. The joint openings are filled with silt to clay material, and the joint spacing is about 3 to 26 cm. Rock block failures have occurred as a result of slopes cut at steep angles ($> 70^{\circ}$). At the bottom of the rock slopes, rock blocks of various sizes are accumulating.



Figure 30. photo plate of limestone exposure in the study area

5.6.1. The strength of the intact rock material (compressive strength)

The strength of a rock is the amount of applied stress at rock failure or rupture. The compressive strength of the rock is the stress required to break a loaded sample of rock. Compressive energy has unique values for each rock pattern, and it is proportional to confining stress and stress utility intensity at the same time. The compressive strength can also be classified into two;

- Unconfined compressive strength (uniaxial compressive strength).
- Confined compressive strength.

The strength of the rock material constitutes the strength limit of the rock mass. The uniaxial compressive strength of rock material can be determined in the field indirectly by using Schmidt hammer (Franklin, 1970).

According to Hoek and Bray, 1997 the density of limestone is 23 KN/m³. The average UCS values, thus, determined at various sites in the study area are presented in Table 12. The table below indicates that the uniaxial compressive strength of the rock exposed in the study area, overall, varies in the range of 52 to 114 Mpa with an average value of 74.8 Mpa. As to classification proposed by Hoek and Bray (1997) such rockfalls in the moderately strong rock category (Hoek, 1997).

Table 12. Average UCS values determined at various sites in the study area

Location	Rock type	Rock density (kN/m ³)	Schmidt rebound Value	Average uniaxial compressive strength (Mpa)
Site 1	Limestone	23	52	114
Site 2	Limestone	23	48	95
Site 3	Limestone	23	47	114
Site 4	Limestone	23	50	141
Site 5	Limestone	23	42	72
Site 6	Limestone	23	36	54
Site 7	Limestone	23	41	69
Site 8	Limestone	23	38	60
Site 9	Limestone	23	45	83
Site 10	Limestone	23	35	52
Overall Average			74.8	

5.6.2. Rock quality designation (RQD)

In the study to characterize the rock mass, the significant parameter was Rock Quality Designation. It was invented by Deere (1967) to provide a quantitative estimate of rock mass quality from drill core logs (Deere, 1967). In our study, the results presented in Table 13 specify that the Jv value varies from 18 to 30 and the RQD value falls in the range of 16 to 49 %. The average RQD for

overall rock mass exposed in the study area is 38.25 %. According to Deere’s classification of rock mass with an average value of 38.25 %, RQD can be classified as ‘poor’ rock mass as far as stability condition is concerned.

Table 13. The average value of RQD at various locations in the study area

Location	Rock Type	Jv Value	RQD (%)
Site 1	Limestone	28	22.6
Site 2	Limestone	21	45.7
Site 3	Limestone	20	49
Site 4	Limestone	18	55
Site 5	Limestone	27	25
Site 6	Limestone	19	52.3
Site 7	Limestone	22	42
Site 8	Limestone	23	39.1
Site 9	Limestone	24	35.8
Site 10	Limestone	30	16
Overall Average			38.25

5.6.3. Discontinuity characteristic

The important factors of discontinuity planes that influence the properties of the rock mass are; orientation, spacing, continuity, surface characteristics, separation of discontinuity surface thickness, and nature of filling material.

Orientation

Orientation of the discontinuity planes plays an important role in the strength of the rock mass. The rock mass fails along one or more discontinuity planes. The role of the orientation of discontinuities becomes most important for rock slope stability if:

A) discontinuity plane or plunge of a line of intersection of two wedge forming planes daylight the slope at less than the slope angle.

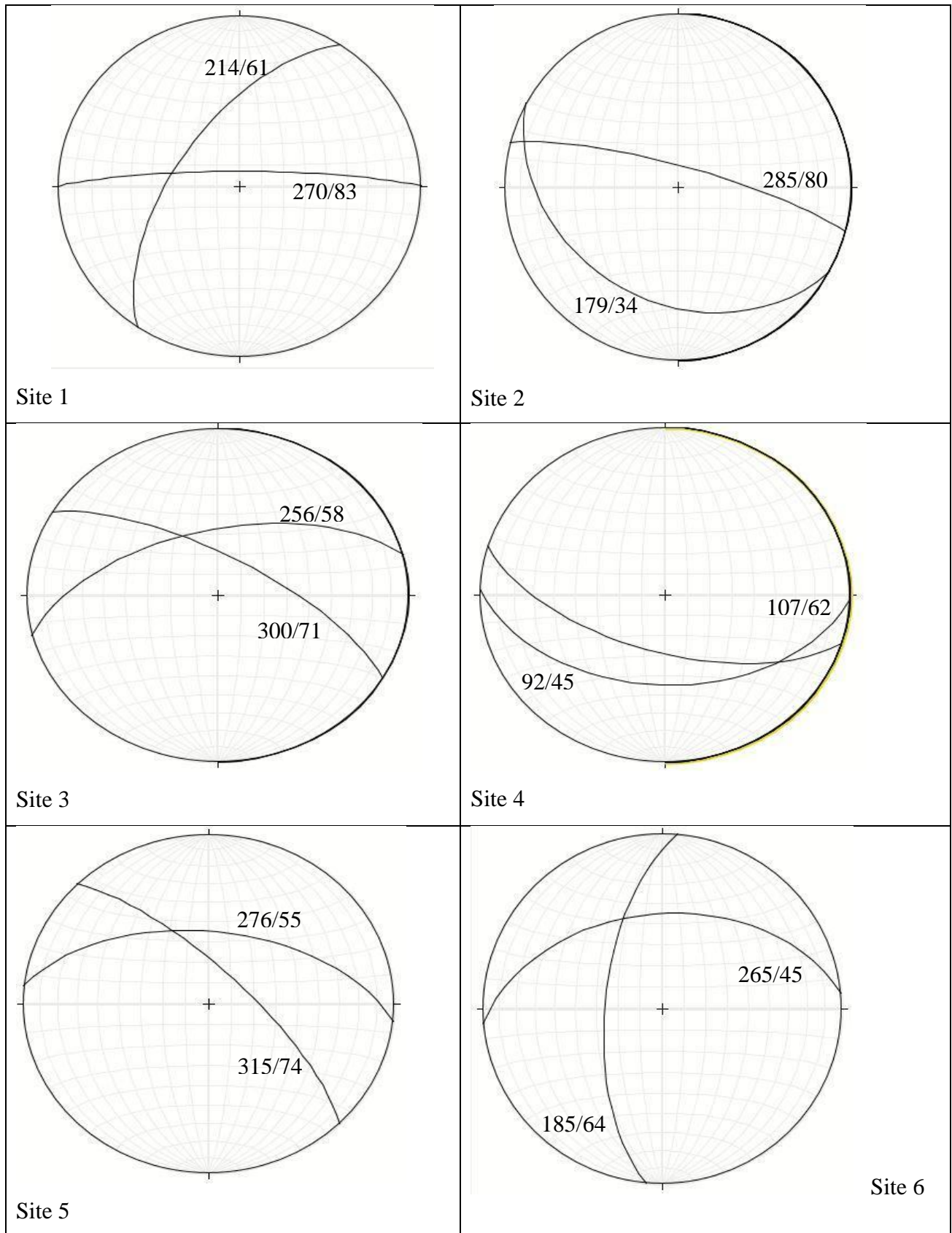
B) Whether the dip of the joint plane or plunge of the line of intersection exceeds the angle of internal friction. If these conditions are prevailing the slope is kinematically unstable. The orientation of discontinuities also influences the strength of the rock mass.

For the present study discontinuity orientations data, mainly joints were collected from ten (10) locations. For this, the dip direction and dip amount for each discontinuity were observed and recorded as shown in Table14.

Table 14. Recorded dip direction and dip amount

Site 1	270	83
	214	61
Site 2	285	80
	119	34
Site 3	300	71
	256	58
Site 4	107	62
	92	45
Site 5	276	55
	315	74
Site 6	265	45
	185	64
Site 7	205	62
	164	71
Site 8	185	79
	120	39
Site 9	240	35
	310	56
Site 10	295	60
	205	45

The later preferred orientation of these discontinuities was worked out by a stereographical method for each site, separately. The preferred orientations of discontinuities as determined for each site are presented in Fig 31.



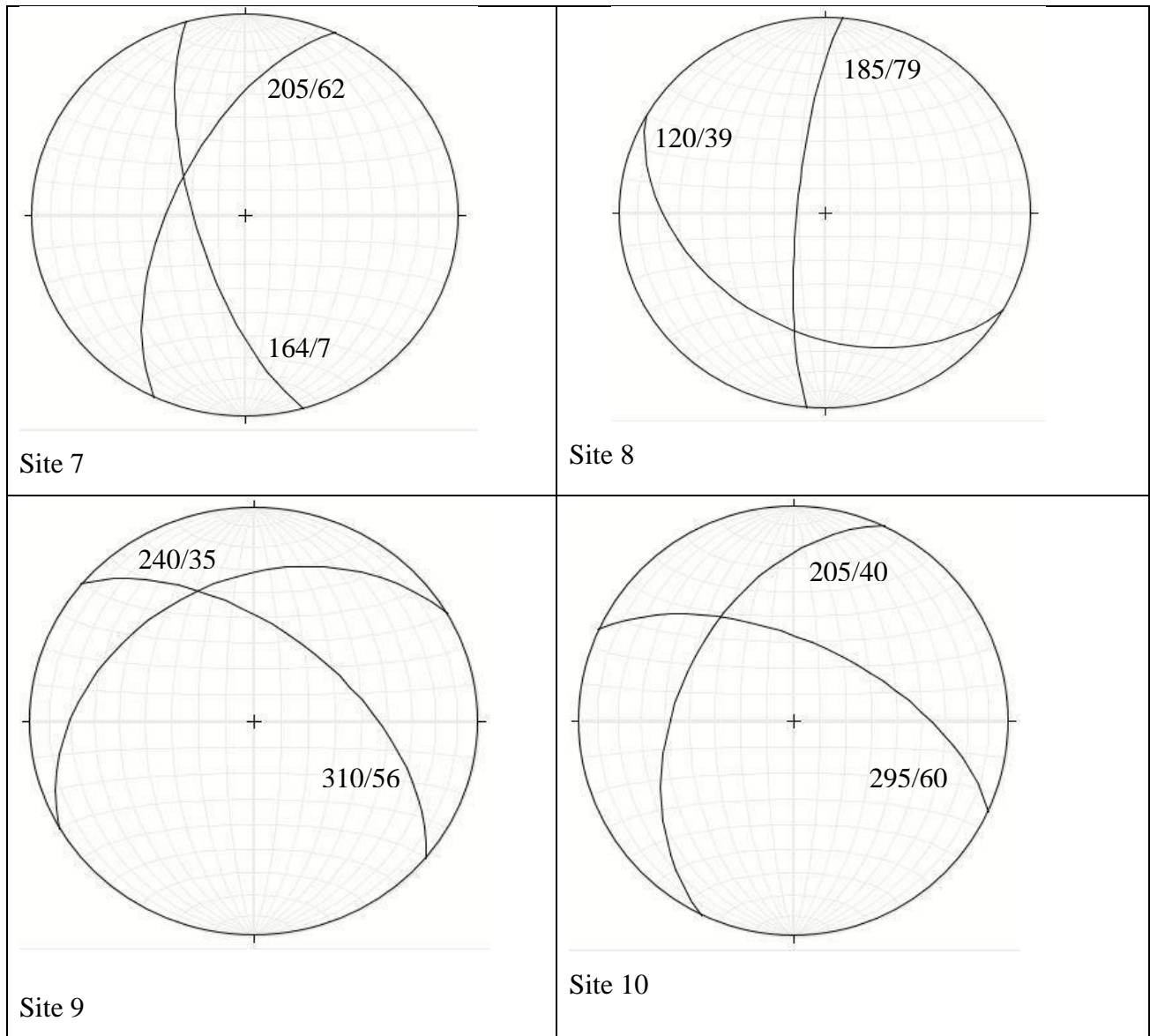


Figure 31. Preferred orientations of discontinuity planes as observed at different localities in the study area

Spacing

Spacing of discontinuity is the perpendicular distance between the two discontinuities, which belong to the same discontinuity set. As observed in the study area the average spacing of the discontinuity planes at different locations is presented in Table 15. The average spacing of the rock mass at various locations falls in a range of 3 to 26 cm. This result indicates that the strength of the rock mass is less because the spacing of discontinuity affects the overall strength of the rock mass.

Continuity

If the direction of the discontinuity is kinematically important, the consistency of discontinuity planes affects the rock mass's stability. If the discontinuity planes are more continuous, the rock mass's power would be lower than if the planes are less continuous and there are bridges between them. In general, discontinuity consistency in the sample region ranges from 0.04 to 8m, with an average continuity of 1.66m. for more information see (Table 15).

Surface characteristics

In this research, three factors were involved when the surface characteristics of discontinuities are considered: the first is waviness of the surface, which results in variations in orientation or attitude along a given discontinuity; the second is the smaller scale roughness of the surface, which provides friction between two adjacent blocks. And the physical properties of the in-filled material between the two surfaces of the discontinuity plane.

In the study for the surface characteristics, we observed in the field the roughness and the weathering of the rock mass. The observed Surface characteristics in all (10) selected sites are sites one, four, five, six, and ten are slightly rough. And the remaining sites are rough, the rocks are Slightly rough to rough. The weathering of sites one, six, and seven are slightly weathered, sites two, four, and eight are moderately weathered the remaining sites are highly weathered. According to Johnson (1991), Waviness and roughness are first and second-order irregularities based on their relative magnitudes (Johnson, 1991). The projections in a rough discontinuity surface are called asperities. Waviness has the greatest influence on the rock mass strength than roughness. For two adjacent blocks to move along a wavy surface there must be displacement normal to the surface. The amount of displacement is controlled by the roughness angle and the wavelength of the wave. The waviness angle reduces the dip angle and thus the tendency for sliding is also reduced.

Separation and filling of joints

In this study, the opening (the separation distance) of all sites is recorded and the site one and three infilling material is clay, for the site two, four, there is no observed infilling material but for the remaining sites, the material is silt and clay together for more mentioned in the table. 15. The research also revealed that the strength of a jointed rock mass is greatly influenced by the separation of the joint surface and the presence of filling material in between. The shear strength of the joint is affected by the separation distance. The asperities in the joint surface will interlock and increase the shear strength if the joint is close. The effect of the infilling content will decrease

the shear strength if the separation is large. Table 15 shows in detail the surface characteristics of different discontinuity planes found in the sample region.

Table 15. Surface Characteristics of the discontinuity planes as observed in the study area.

Location	Spacings (cm)		Continuity (m)		surface Characteristics (average)			
	Range	Average	Range	Average	Roughness	Weathering	Opening (mm)	Infilling
Site 1	4-12	8	0.04-8	4.02	Slightly rough	Slightly weathered	1-4	clay
Site 2	7-16	11.5	0.2-4	2.1	Slightly rough	Moderately weathered	2-7	None(open)
Site 3	3-9	6	0.3-2.5	1.4	rough	Highly weathered	1-3	clay
Site 4	10-26	15	0.5-5	2.75	Slightly rough	Moderately weathered	1.5-4	none(open)
Site 5	2-7	4.5	0.3-1.5	0.9	Slightly rough	Highly weathered	3-7	clay
Site 6	5-12	8.5	0.2-2	1.1	Slightly rough	Slightly weathered	2.5-8	Silt and clay
Site 7	6-14	10	0.1-1.8	0.95	rough	Slightly weathered	4-10	Silt and clay
Site 8	6-21	13	0.3-2	1.15	Slightly rough	Moderately weathered	>10	Silt
Site 9	3-11	7	0.1-2	1.05	rough	Highly weathered	2-8	Silt and clay
Site 10	5-15	10	0.3-2.1	1.2	Slightly rough	Highly weathered	3-7	Silt

There are numerous rock mass classification systems available, Bieniawski's classification system is commonly used. To classify rock mass, geomechanics classification or Bieniawski's rock mass rating (RMR) considers the following six parameters:

- Uniaxial compressive strength of rock (UCS)
- Condition of discontinuities
- Rock Quality Designation (RQD)
- Groundwater condition

- Spacing of discontinuities
- Orientation of discontinuities

RMR data was obtained from ten locations along the excavated rock slope face for the study, and values for each of the six parameters were assigned from the regular RMR table depending on the conditions, and then applied to obtain the RMR value. Palmstrom's Volumetric Count system Palmstrom, (1982), in the study, was used to assess the Rock Quality Designation (RQD). Visual observations and measurements were taken for other parameters such as spacing, discontinuity state, groundwater condition, and discontinuity orientation, and evaluations were assigned using the standard RMR chart. Table 16 summarizes the RMR data gathered from different sites.

The detailed RMR data is presented in Annex. Table 16 shows that the rock mass, in general, falls into fair to good class, with average conditions being represented as fair rock mass in terms of stability conditions.

Table 16. RMR data collected from various locations in the study area

RMR Data points	Parameters Ratings (Represents average values)										RMR	Rock mass Class
	UCS (Mpa)			RQD			Sp.	Con.	GW	Ori		
	SHV	UCS	Ra	Jv	RQD	Ra	Ra	Ra	C			
Site 1	52	114	12	28	22.6	3	8	25	None	Fair	55	Fair rock
Site 2	48	95	7	21	45.7	8	8	10	None	Fair	60	Fair rock
Site 3	47	114	12	20	49	8	8	20	None	Fair	58	Fair rock
Site 4	50	141	12	18	55	13	10	20	None	Favorable	60	Fair rock
Site 5	42	72	7	27	26	8	8	10	None	Fair	40	Poor rock
Site 6	36	54	7	19	52.3	13	8	25	None	Favorable	57	Fair rock
Site 7	41	69	7	22	42	8	8	25	None	Fair	57	Fair rock
Site 8	38	60	7	23	39.1	8	10	0	None	Fair	48	Fair rock
Site 9	45	83	7	24	35.8	8	8	10	None	Fair	48	Fair rock
Site 10	35	52	7	30	16	3	8	20	None	Fair	40	Poor rock

UCS – Uniaxial compressive strength, SHV – Schmidt hammer Value, Ra – Rating, Jv- Volumetric count, RQD – Rock quality designation, Sp. – Spacing of discontinuity, Con. – Condition of discontinuity, GWC – groundwater condition, Ori – Orientation of discontinuity, RMR.

Strength of the jointed rock mass

For this study, an effort has been made to empirically estimate the strength of rock mass. The empirical technique of Hoek and Brown (1980) was used for this purpose. Hoek and Brown (1980) formulated an empirical technique for determining the strength of jointed rock masses and proposed a failure criterion for them. Hoek & Brown in 1988, and later Hoek et al., (1992). updated these criteria based on the outcomes of many programs Hoek and Brown used Bieniawski's Rock Mass Rating System (RMR) to calculate the substance constants for this observational procedure (Hoek et al., 1973, Hoek et al., 1995, Hoek, 1997). For jointed rock mass, the Hoek-Brown criteria are:

$$\sigma_1' = \sigma_1' + \sigma_c \left(mb \frac{\sigma_3}{\sigma_c} + S \right)^a$$

Where, 'mb' is the value of the constant 'm' for the rock mass, 's' and 'a' are constant which depend upon the characteristic of the rock mass, σ_c is the uniaxial compressive strength of the intact rock pieces and σ_1' & σ_3' are axial and confining effective principal stresses, respectively.

For the current study RMR data, collected from several locations (Table 16) in the study area has been used as an input parameter for strength estimation. The uniaxial compressive strength has been determined by Schmidt hammer at all representative sites from where RMR has been collected. The value of material constant 'mi' has been directly adopted from the standard table (Hoek and Brown, 1980). The other material constants 'mb', 'S' and 'a' are determined by using the Geologic Strength Index (GSI) as;

$$\frac{m_b}{m_i} = \exp\left(\frac{GSI-100}{28}\right), \quad S = \exp\left(\frac{GSI-100}{9}\right), \quad a = 0.5$$

The input parameter used for Hoek and Brown failure criteria is presented in (Table16). The confining effective principal stresses (σ_3') considered for the determination of major principal stresses (σ_1') and the corresponding computed major principal stresses (σ_1') are shown in Table 17.

Table 17. Input parameter for failure criteria

Location	Average RMR Valu	UCS (Mpa)	Geologic Strength Index GSI	Material Constants Mi	Material Constants		
					Mb	S	a
Site 1	55	114	50	12	0.205	0.0001	0.5
Site 2	60	95	55	12	0.070	0.0000	0.526
Site 3	58	114	53	20	0.341	0.0001	0.5
Site 4	60	141	55	20	0.562	0.0002	0.506
Site 5	40	72	35	12	0.070	0.0000	0.526
Site 6	57	54	52	12	0.292	0.0002	0.507
Site 7	57	69	52	12	0.205	0.0001	0.509
Site 8	48	60	43	12	0.040	0.0000	0.544
Site 9	48	83	43	12	0.070	0.0000	0.526
Site 10	40	52	35	12	0.100	0.0000	0.518

According to Tables 17 and 18, the cohesion 'C' of the rock mass ranges between 0.3 and 1 Mpa as defined by Hoek and Brown Failure parameters, and between 1 and 3 Mpa as determined by Bieniawski's comparison using RMR values. Also, according to Hoek and Brown's Failure parameters, the angle of friction of the rock mass ranges from 12 to 41, while according to Bieniawski's relation using RMR values, this range varies from 17 to 33. The average Cohesion 'C' value for the rock mass in the study area is 2.07 Mpa, and the average angle of friction is 25.7. The cohesion and angle of friction values are used as input parameters to assess the quarry's slope stability.

5.6.4. Slope Stability Studies

The F1, F2, and F3 are adjustment factors related to joint orientation concerning slope orientation and F4 is the correction factor for the method of excavation.

F1 – depends upon parallelism between joints and slope face strikes. $(\alpha_j - \alpha_s)$ where α_j is joint strike and α_s is slope strike. **F2** – refers to joint dip angle (β_j) or plunge of a line of intersection of two wedge forming planes (β_i). **F3** – depends upon the relationship between joint dip or plunge of the line of intersection of two wedge forming planes and slope inclination. $(\beta_j - \beta_s)$ or $(\beta_i - \beta_s)$ where β_s is the inclination of the slope. **F4** – Method of Excavation. It includes the natural slope or the cut slope

excavated by pre-splitting, smooth blasting, normal blasting, poor blasting, and mechanical excavation. But before employing these parameters one has to identify the type of failure as the photo (Fig 32) taken on the field is a different failure. Are shown. i.e., Planar, Wedge, or Toppling failures using kinematic analysis using Stereo Nets. Generally, the stability condition of the quarry areas is shown in Table 18.

Table 18. stability condition of the selected site

Slop site	RMR	SMR	Stability condition
Site 1	55	12.5	Completely-Unstable
Site 2	60	60	Partially-Stable
Site 3	58	8	Completely-Unstable
Site 4	60	59.1	Completely-Unstable
Site 5	40	40	Unstable
Site 6	57	48.5	Partially-Stable
Site 7	57	13.65	Completely-Unstable
Site 8	48	40.35	Partially-Stable
Site 9	48	47.235	Partially-Stable
Site 10	40	40	Unstable
Slope Mass Rating (SMR) - Romana (1985) and Anbalagan et al. (1991)			

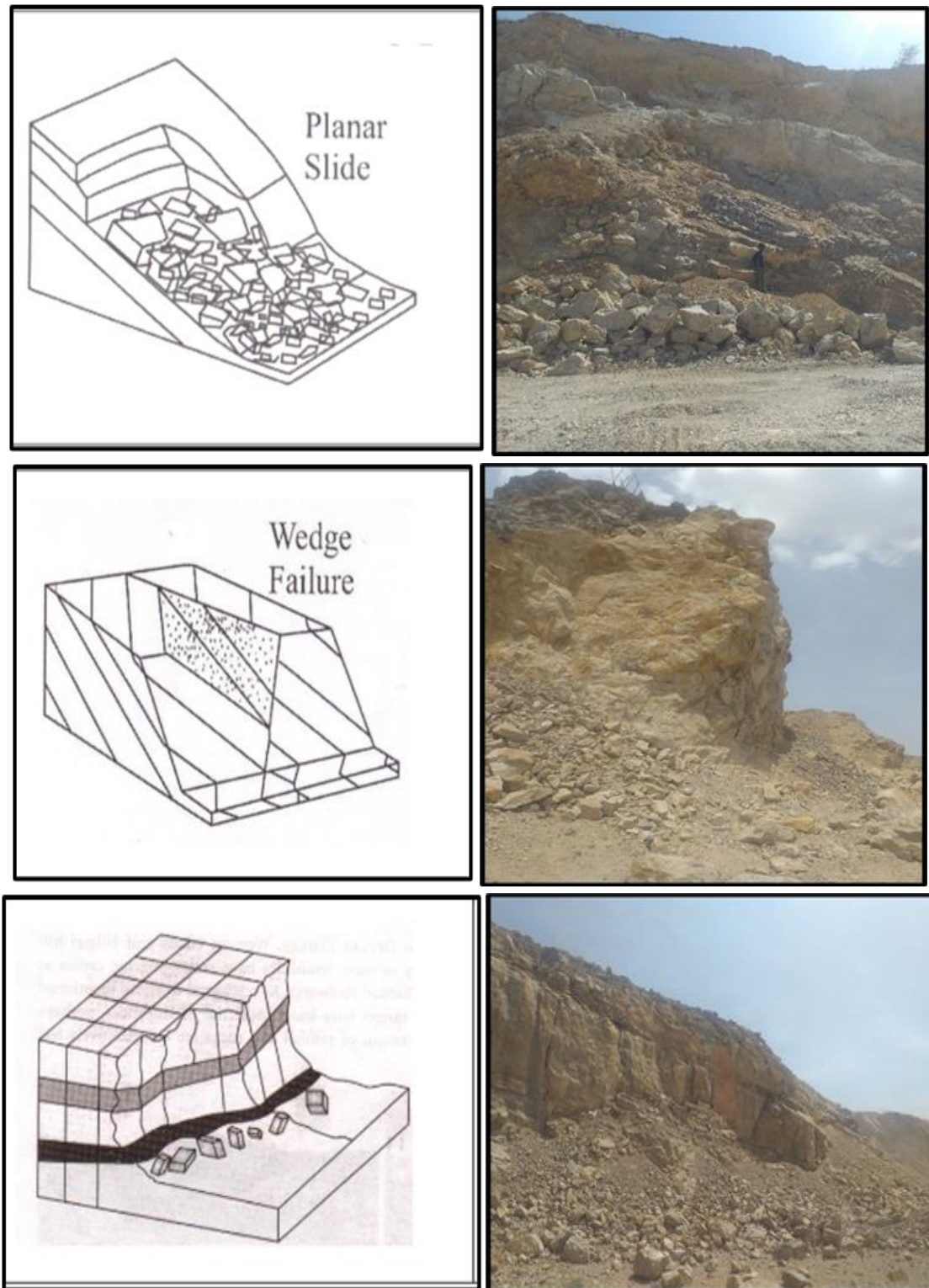


Figure 32. showing different types of failure in graphic form and as real field sites. Planar Failure, Wedge Failure and Toppling Failure

Table 19. Comparison of Bieniawski's RMR method shear strength parameters, cohesion 'C,' and angle of internal friction " ϕ " with Hoek and Brown failure criteria

Location	Average RMR Value	Shear Strength Parameters from RMR (Range)				Shear Strength Parameters from Hoek and Brown Failure Criteria	
		Cohesion (C)	Specific Cohesion (C)*	Angle of Friction (ϕ)	Specific Angle of Friction (ϕ)**	Cohesion (C) (Mpa)	Angle of Friction (ϕ)
Site 1	48	200-300	2.4	25-35	29	0.65	30.27
Site 2	33	100-200	1.65	15-25	21.5	0.33	19.90
Site 3	48	200-300	2.4	25-35	29	0.769	34.51
Site 4	55	200-300	2.75	25-35	32.5	1.047	40.42
Site 5	33	100-200	1.65	15-25	21.5	0.3	18.31
Site 6	53	200-300	2.65	25-35	31.5	0.56	27.80
Site 7	48	200-300	2.4	25-35	29	0.526	26.67
Site 8	25	100-200	1.25	15-25	17.5	0.182	12.98
Site 9	33	100-200	1.65	15-25	21.5	0.318	19.12
Site 10	38	100-200	1.9	15-25	24	0.323	19.21
Average Values	41.4		2.07		25.7	0.5005	24.919

C* is the specific value of Cohesion for a given RMR as determined using Eq. $C^* = 0.05 \text{ RMR}$

Φ^{**} is the specific value of angle of friction for a given RMR as determined using Eq. $\Phi^* = 0.5\text{RMR} + 5$

The above equations were proposed by Bieniawski, 1976.

5.6.5. Slope Stability Classes and Supports

Romana (1985) defined five stability classes based on slope mass rating (SMR). Table 19 lays out the details (Romana, 1991). Furthermore, stability steps have been proposed based on these stability groups, as presented in Table 20. This classification system may only attempt to identify the

standard techniques for each type of help. To stabilize a slope, however, both detailed research and sound engineering judgment are required.

Table 20. Rating values for different Slope Factors (Romana, 1985)

Case of slope Failure		Very Favorable	favorable	fair	Un Favorable	Very Unfavorable
P T W	$ \alpha_j - \alpha_s $ $ \alpha_j - \alpha_s - 180 $ $ \alpha_i - \alpha_s $	>30	30-20°	20-10°	10-5°	<5°
P/W/ T	F ₁	0.15	0.4	0.7	0.85	1.0
P W	$ \beta_j $ $ \beta_i $	<20°	20.30°	30-35°	35-45°	>45°
P/W	F ₂	0.15	0.4	0.7	0.85	1.0
T	F ₂	1.0°	1.0	1.0	1.0	1.0
P W	$ \beta_j - \beta_s $ $ \beta_i - \alpha_s $	>10°	10.0°	0°	0-(-10°)	<-10°
T	$ \beta_j + \beta_s $	<110°	110-120°	>120°	-	-
P/W/ T	F ₃	0	-6	-25	-50	-60
Note: P-Planar Failure; T-Toppling Failure; W-W failures; α_s -slope strike; α_j -joint strike; α_i -plunge direction of the line of intersection; β_s -slope dip and β_j -plunge of line intersection						

Romana (1985) gave five slope stability classes as per SMR (Table 21) which can be used in landslide zonation, cut slope design and deciding for the slope of open-cut mines.

Table 21. Slope Stability Classes Based on SMR Values.

Class No	V	IV	III	II	I
SMR Value	0-20	21-40	41-60	61-80	81-100
Rock mass Description	Very bad	Bad	Normal	Good	Very good
stability	Completely unstable	Unstable	Partially Stable	Stable	Completely stable
failures	Big planar or soil-like or circular	Planar or a big wedge	Planar and joints and wedges	Some block failure	No failure
Probability of failure	0.9	0.6	0.4	0.2	0

The stability condition of the excavated slopes in the study area was determined using an improved SMR method. The stability analysis was performed on ten different slope sections. A systematic approach was used to implement the Modified SMR technique, which included; Broad remedial measures that can also be suggested by detailed study of the problem, analysis of SMR values, and good engineering judgment as per Table 22.

Table 22. SMR Classes and Suggested Remedial Measures

SMR Classes	SMR values	Suggested supports
Ia	91-100	None
Ib	81-90	None to some scaling
IIa	71-80	Scaling, provision of toe ditch or fence net
IIb	61-70	Toe ditch or fence net, a spot to pattern bolting
IIIa	51-60	Toe ditch or fence net, pattern bolting, systematic shot crating
IIIb	41-50	Toe ditch or fence net, pattern bolting, systematic shot crating dental concrete
IVa	31-40	Anchors, systematic shot crating, dental concrete
IVb	21-30	Systematic enforcement shorter,
Va	11-20	Re-excavation, deep drainage gravity or anchored well, re-excavation

In the last three decades or more, SMR is being used very frequently to get:

1. Geo-mechanical classification system for rating of rocky slopes.
2. Preliminary investigations to find out the vulnerability of slope failure.
3. Served as a base indicator for engineering solutions on failing slopes.

However, some normal rock slope problems were not considered by SMR, resulting in bad performance. Many scientists have attempted to integrate these metrics, as well as additional ones, to obtain more realistic outcomes in general, a reconnaissance survey was conducted to identify potentially unstable slopes in the study area, during which field manifestations of slope instability were observed. Discontinuity alignment, slope steepness, slope discomfort traces, and rock block failures are all examples of this. As a result of the reconnaissance survey, ten vital slope sections were discovered. Along each of the critical slope sections, discontinuity orientations were identified. The dip direction and sum of each discontinuity were registered, and then stereographically analyzed to determine the preferred orientation of the discontinuity planes along each critical slope part. Annex. Preferential orientations of discontinuities and slope inclinations were used in stereo plots. The stability condition of each critical slope segment has been calculated using the SMR value, and additional effective support steps have been recommended. Generally, the stability analysis was completed, and all ten vital slope sections are at risk of failing, A suitable treatment, on the other hand, would be to dress the slopes by making them gentler.

CHAPTER SIX

6. Conclusion and Recommendation

6.1. Conclusion

The purpose of this study was to determine the effect of quarrying and aggregate production on the environment, community, and workers. The major conclusions of the study are the following: Quarrying activity has an impact on the local community, especially those living close to quarry sites. The social impacts include hazardous working conditions for quarry workers (accidents, health problems, especially respiratory problems due to dust inhalation) as a result of a lack of safety equipment, measures, and procedures, as quarry owners prioritize profits over safety. The social impact assessments are only conducted as a precondition for obtaining a quarrying license, with no regular follow-up from the concerned body.

During the social impact study for the current research, quarry workers worried about the challenges and dangers of the quarrying activities. Non-rehabilitated quarries have also been identified, prompting the responsible authorities to take such issues seriously. Communities are affected by exhaust emissions, constant noise, flying rock damage, and vibration issues at all quarry sites.

The study confirmed that there has been an extensive land use land cover change during the last 15 years in the study area. The quarrying activity has been extending in an unprecedented manner at the expense of the green land. Quarry expansion occurred at a pronounced rate at the expense of Greenland (shrubland) within the same catchment. All these led to the degradation of the land and soil, indirectly affecting the surface. Based on rock mass classification and study of discontinuities and their alignment and relationship to slope structure, the stability analysis showed that blasting and other quarry operations caused the rock mass of the area to lose its natural slope and change the landscape. In general, the joint spacing is wide, and the joint openings are filled with silt or clay. The strength and deformability of the rock mass determine the rock slope's stability and deformability.

A discontinuity plane runs through the research area, with different dips and dips directions. The existence of discontinuity limits the rock mass's power. The slopes are steeper than 70° (degrees), which has resulted in rock block collapses. At the bottom of the rock slopes, rock blocks of various sizes can be seen accumulating.

The slope stability of the sites in the chosen slope segment was investigated using the Romana (1985) procedure and evaluated using the slope mass rating system. The study's findings indicated that the study area's slope level was classified as unstable.

6.2. Recommendations

The research has brought to light several topics. This portion of the report makes further recommendations for reducing the environmental effects of quarrying operations in the study area.

- Lack of awareness and enforcement are the key barriers that slowed and aggravated the environmental effects of quarrying in the study area. As a result, the concerned body should implement a concrete awareness-building campaign for quarry owners, quarry employees, and the general public. Stakeholders in the quarrying industry should work together to increase awareness of environmental impact mitigation and mining law compliance.
- The field data revealed that due to a lack of safety and protective gear, worker protection at work is not assured and it is at risk. During the process, employees are exposed to severe workplace dangers and illnesses as a result of a lack of safety equipment. Company management should make conscious attempts to provide the necessary protective devices to their workers. Staff must also be trained about the various preventive measures and workplace safety & procedures that can be used to avoid such injuries and diseases.
- Most quarry sites are now within residential areas and proper land use planning should be directed and measures should be taken to close and relocate some of the active quarry sites. The site should be properly rehabilitated.
- Strict regulations of quarry operation and environmental laws should be in place to reduce environmental associated problems. Timely limits on quarrying operations and the erection of signals around blasting sites are examples of laws and regulations that must be strictly applied.
- The study area needs slope stabilization. The recommended measure is to smooth the excavated area for eventual rehabilitation.

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ANNEX

Annex A: Questionnaire to be filled by Quarry workers and community near to the quarry to assess the impacts of quarry operation

quarry operation

Dear Sir/ Madam

This questioner is prepared to assess the impacts of stone quarrying on the environment, local community, and quarry workers in Dire Dawa the case selected kebeles. The information is specifically for study purposes and is highly confidential. Please use a [] mark in a box related to your best answer. Your positive response is highly appreciated!

A. Date of Interview.....

B. Respondents number.....

Biographic Information

1. Age:

Less than 18 years 18-25 years 26-33 years 31-41 years 42 and above years 50+ years

2. Sex:

Male Female

3. Level of Education:

Illiterate Read and write Primary
 Secondary university

4. Marital Status:

Single Married Widow

5. Household size:

1 -3 4-5 6 and above

6. Occupation

Agriculture Government employs Private Sector employs
 Own business
 Non-quarry

Questionnaire to be filled by residents to assess the impacts of quarry activity

1. How long you have lived around this area.

<5 years 6-10 years 11-25 years >25 years

2. Have you resided near or around the quarry site before the quarry operates?

- Yes No

If your answer is yes; for what purpose was the land used before the quarry started?

- cultivated land Shrubland Forest Bare land
 If other, please mention here
- -----

3. From the following problems, which are/is more adverse for you from the quarry's activity?

You can select more than one.

- Dust Vibration Noise Other

4. Do you agree methods of stone quarrying are responsible for the environment and land degradation in the area?

- Strongly agree agree Disagree strongly disagree

5. Can you discuss dust-related problems you have faced from the quarry activities?

6. Can you discuss vibration problems you have faced from blasting and during quarry operation?

7. Can you discuss noise problems you have faced from the quarry activities?

8. If you have retained ideas or problems, you have been faced with quarry activities and if it is not included in this questionnaire please mention it hereunder.

Questionnaire to be filled by quarry workers to assess the impacts of quarry activity

1. How long you have worked on quarry operation.

- ≤ 5 years From 5-10 years ≥ 10 years

2. Do you use on job safety equipment?

- yes No

3. What looks like the supply of continuous safety equipment from the quarry company?

- Low (per year) Moderate (2 times a year)
 High (4 times a year) none

4. Do you ever face accidents from quarry activities?

- yes No

5. If your answer is yes, please indicating the rate and type of accident you or your friends faced.

6. Could you indicate if you have faced dust-related problems from the quarry operations.

- Skin allergic Irritation of eyes Respiratory problem

7. Could you indicate if you have faced noise-related problems from quarry blasting and types of machinery.

- loss of peace after work ear problem headache

8. Have you get the safety guides before you start the work

- Yes No

9. Can you list dust-related problems faced from the quarry

10. Can you list vibration and noise-related problems from machinery and blasting during quarry operation?

11. If you have any remaining ideas or problems, you are facing quarry work and if it is not included in this questionnaire please mention them hereunder.

Annex B: Rock mass rating system (after bieniawski 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
Parameter		Range of values							
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of		> 2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Sticksided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1, - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
		Rating	15	10	7	4	0		
B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)									
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable			
Ratings	Tunnels & mines	0	-2	-5	-10	-12			
	Foundations	0	-2	-7	-15	-25			
	Slopes	0	-5	-25	-50				
C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS									
Rating	100 ← 81		80 ← 61	60 ← 41	40 ← 21	< 21			
Class number	I		II	III	IV	V			
Description	Very good rock		Good rock	Fair rock	Poor rock	Very poor rock			
D. MEANING OF ROCK CLASSES									
Class number	I		II	III	IV	V			
Average stand-up time	20 yrs for 15 m span		1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span			
Cohesion of rock mass (kPa)	> 400		300 - 400	200 - 300	100 - 200	< 100			
Friction angle of rock mass (deg)	> 45		35 - 45	25 - 35	15 - 25	< 15			
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions									
Discontinuity length (persistence)	< 1 m		1 - 3 m	3 - 10 m	10 - 20 m	> 20 m			
Rating	6		4	2	1	0			
Separation (aperture)	None		< 0.1 mm	0.1 - 1.0 mm	1 - 5 mm	> 5 mm			
Rating	6		5	4	1	0			
Roughness	Very rough		Rough	Slightly rough	Smooth	Sticksided			
Rating	6		5	3	1	0			
Infilling (gouge)	None		Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm			
Rating	6		4	2	1	0			
Weathering	Unweathered		Slightly weathered	Moderately weathered	Highly weathered	Decomposed			
Rating	6		5	3	1	0			
F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**									
Strike perpendicular to tunnel axis				Strike parallel to tunnel axis					
Drive with dip - Dip 45 - 90°		Drive with dip - Dip 20 - 45°		Dip 45 - 90°		Dip 20 - 45°			
Very favourable		Favourable		Very unfavourable		Fair			
Drive against dip - Dip 45-90°		Drive against dip - Dip 20-45°		Dip 0-20 - Irrespective of strike*					
Fair		Unfavourable		Fair					

* Some conditions are mutually exclusive . For example, if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.

** Modified after Wickham et al (1972).

. Annex c: RMR data collection at selected critical slope section

Location	ucs			Rock quality designation (%)			Spacing of discontinuity (mm)		condition of discontinuity							G.W		RMR total	Rock mass Class
	SRV	MPA	Rating	Jv	RQD	Rating	Mean value	Rating	Length	aperture	infilling	weathering	roughness	rating	condition	Rating			
Site.1	52	114	12	28	22.6	3	4.02	8	<1m	1-4	clay	Slightly weathered	Slightly rough	17	Dry	15	55	Fair rock	
Site.2	48	95	12	21	45.7	8	2.1	8	<1m	2-7	None(open)	Moderately weathered	rough	17	Dry	15	60	Fair rock	
Site.3	47	114	12	20	49	8	1.4	8	<1m	1-3	clay	Highly weathered	rough	15	Dry	15	58	Fair rock	
Site.4	50	141	12	18	55	13	2.75	8	<1m	1.5-4	none(open)	Moderately weathered	rough	12	Dry	15	60	Fair rock	
Site.5	42	72	7	27	25	3	0.9	5	Continue	3-7	clay	Highly weathered	rough	10	Dry	15	40	Poor rock	
Site.6	36	54	7	19	52.3	13	1.1	8	Continue	2.5-8	Silt and clay	Slightly weathered	Slightly rough	14	Dry	15	57	Fair rock	
Site.7	41	69	12	22	42	3	0.95	8	<1m	4-10	Silt and clay	Slightly weathered	rough	19	Dry	15	57	Fair rock	
Site.8	38	60	7	23	39.1	3	1.15	8	<1m	>10	Silt	Moderately weathered	Slightly rough	15	Dry	15	48	Fair rock	
Site.9	45	83	12	24	35.8	3	1.05	8	Continue.	2-8	Silt and clay	Highly weathered	rough	10	Dry	15	48	Fair rock	
Site.10	35	52	7	30	16	3	1.2	8	Continue.	3-7	Silt	Highly weathered	rough	10	Dry	15	40	Poor rock	