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QUARRY REHABILITATION PLANNING:

THE CASE OF 'WORKU-SEFER' QUARRY PROJECTS, ADDIS ABABA


M.Sc. Thesis in Environmental Planning and Landscape Design

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Declaration and Confirmation

I, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged, following the scientific guidelines of the Institute.

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Confirmation

The thesis can be submitted for examination with my approval as an Institute's advisor.

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Abstract

Mining and quarrying are extractive enterprises and involve the complete destruction of the habitat of an area where they take place. However, rehabilitation offers a method of restoring habitat and ecosystem function to areas degraded by extractive industries. This paper therefore examines quarry rehabilitation planning practice in purposefully selected quarry site in Addis Ababa in a locality named 'worku-Sefer', Akaki Kality sub city.

The study employed systematic random sampling method to select households and woody species for this paper. Furthermore, primary and secondary data were collected by the use of interview, site reconnaissance survey and questionnaires. Satellite images were utilized to quantitatively measure and observe the trends & patterns of land use and land cover of the study area. The findings of the paper have been presented in maps, tables, graphs and figures. Percentages were used to show the situation in the site.

The findings of the paper revealed that the current quarry rehabilitation practice is very low, i.e., 2.4%. The miss management during quarry operation have created problems related to landscape degradation, changed the pattern of natural water flow and pollution of soil, water, air etc. The overburden materials that need to be kept protected at the site have all been taken away making the rehabilitation efforts very cumbersome and not cost efficient. In addition to these the site is endowed with indigenous and exotic woody species. However, the diversity and abundance of the woody species is affected by the quarry activity since they are found in few areas of the study site.

Therefore, the recommendations forwarded in this thesis are assumed to change the situation in practice and made the site more sustainable for the coming generation.

Key words: rehabilitation, woody species, quarry, quarry site, rehabilitation planning.

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List of Acronyms

AA	Addis Ababa
AACRA	Addis Ababa City Road Authority
AAEPA	Addis Ababa Environmental Protection Authority
CRBC	China Road and building Construction
CSA	Central Statistics Authority
DEM	Digital Elevation Model
ENVI	Environment for Visualization of Images
EPA	Environmental Protection Authority
ERDAS	Earth Resource Data Analysis System
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land use land cover
LULCC	Land use lands cover change
m.a.s.l.	meter above sea level
MIRO	Mineral Industry Research Organization
NGO	Non Governmental Organization
ORAAMP	Office for the Revision of the Addis Ababa Master Plan
SI	Site Investigation

CHAPTER I

1. Introduction

1.1.Background

In 2005 the human population of the world was more than 6.5 billion and is estimated that it will be over 9.1 billion by 2050 (United Nations, 2006). In many areas of rapid population growth, the infrastructure is becoming inadequate and new road, street and sewage systems must be built to meet the increased needs. On the other hand the development of these infrastructures requires large volumes of quarry material.

Quarries are generally used for extracting construction materials, such as dimension stone, ornamental stones, road, building and industrial raw materials. A quarry is a type of open-pit surface mining from which rock or minerals are extracted. However, mining and quarrying are destructive enterprises (Sinha, et al. 2000) and involve the complete destruction of the habitat of an area where they take place (Martínez-Ruiz, et.al. 2007). The destruction and fragmentation of habitat is the greatest threat to biodiversity and the primary cause of species extinction (Aronson et al., 1995).

Quarry sites are worked from a few years to many years and are abandoned when they are exhausted or become uneconomic to work. Hence, their rehabilitation process is complex and difficult although careful planning can increase the chance of success.

Rehabilitation offers a method of restoring habitat and ecosystem function to areas degraded by extractive industries (Bauer, 1991). The overall aim is to make economic exploitation and development to become ecologically sustainable by restoring degraded areas. Rehabilitation can be divided in to two; progressive and final. Progressive rehabilitation is the rehabilitation that is performed sequentially, in a reasonable period of time, while the aggregate is being excavated. With good planning, the extraction of aggregate proceeds in a logical sequence so that depleted areas can be rehabilitated while extraction continues in other areas of the pit or quarry. The final rehabilitation is the rehabilitation that is performed, as set out by the site plan, after the site is depleted of aggregate material (Abdullah, S.H, 2010).

In Addis Ababa, it is well known that a wide range of infrastructure development activities are under progress. Among these, the constructions of road and bridge networks, multi-story buildings, condominium houses, real estates, schools, manufacturing industries and other public service giving facilities are some of the activities that can be mentioned. For this construction work locally obtained construction minerals are crucial. Fortunately the city is endowed with construction minerals such as basalt for the production of crushed aggregates, sub base and base course materials, weathered and

fractured basalts used for the production of selected material, ignimbrite for masonry work and cobblestone production, red ash and red clay.

Apart from satisfying the ever increasing demand of minerals in the construction sector of the city, quarry activities can lead to loss of vegetation cover, soil removal, spring eye spot extinction, scenic quality loss, formation of ugly scenery, susceptible geomorphology for erosion, land stability problem, destruction of the existing natural landforms & resulting in fast degradation. Generally, the net effect of quarrying operations could be an irreversible process unless careful rehabilitation planning takes into account. This indicates that any development activity, particularly the quarrying industry have to be well aware of environmental issues in that sustainable development would not be achieved without environmental protection. Sustainable development can only be achieved if and only if environmental concerns are integrated into development activities. That is why the government of Ethiopia has formulated a well-designed environmental policy, which is part of the development policy and strategy of the country.

However, still there are no environmental interventions incorporated in the operation of most quarry projects in Addis Ababa. As a result different problems have occurred and become a set of environmental issue that need to be considered in order to reduce the problems of these activities and ensure that the quarrying operation could be carried out in an environmental friendly manner by designing quarry rehabilitation program.

1.2.Statement of the problem

Currently extensive infrastructure development projects are under way in Addis Ababa most of which need the supply of construction materials. Right now over 400 quarry projects in Addis Ababa are distributed in six sub-cities: Bole, Akaki-Kaliti, Yeka, Gulele, Kolfe-Keranio, and Nifassilk-Lafto (AA EPA, 2011). Among these quarry projects in the city, 11 projects are found in the study area "Worku Sefer", found along Great Akaki River side in Akaki-Kaliti and Southern part of Bole sub city.

According to the mining proclamation and regulation of the Federal Democratic Republic of Ethiopia (Mining proclamation No 52/1993 and Mining regulation No 1982/1994) the following principal activities have been prohibited:- Granting license for any mineral works which is within 100 meters of a site of archeological, cultural or religious or public building, railway, highway, airport, dam, reservoir, pipeline, factory or other government installations, unless the licensing authority decides otherwise. Prospecting minerals on land, which is within 100 meters of a municipal area, village community or burial ground or which is on a land actually under cultivation, unless the licensing authority decides otherwise. The proclamation also indicated some important safety precautions and environmental

management and restoration activities that have to be taken into account while mining projects are planned for development. Among these issues are:

The proponent should fill, close; block or otherwise render safe all tunnels, pits and other installations of a potentially dangerous nature prior to the expiration or termination of his license. The proponent should also progressively restore or reclaim his license area, or prior to the termination of his license, the area should be restored or reclaimed for beneficial future use.

The proclamation also provides a legal base for the effective means of harmonizing and integrating environmental, economic, cultural and social considerations in to the planning and decision making processes there by promoting sustainable development. Moreover, it serves as a basic instrument in bringing about administrative transparency and accountability, to involve the public and the communities in particular, in the planning and execution of development programs that may affect them and their environment.

However, there are gaps to enforce the law and implement to the ground. These are mainly due to lack of monitoring & evaluation of projects by concerned governmental organizations, lack of trained man power on different administration levels (City, Sub city and Woreda administrations) lack of awareness creation to the quarry developers and for the concerned stakeholders in general.

Quarries around '**Worku-Sefer'** is one of the most potential site to create huge job opportunity and supply different construction materials such as crushed basalt aggregates, selected material and ignimbrites. In fact the quarry work in a small scale started since 1986 and expanded in the last decades. However, the old quarry sites of the study area are abandoned without rehabilitation and exhausted or become uneconomic to work. Furthermore, still some quarry projects existing in the study area are unlicensed and abandoned, and most of them, even the authorized ones, have not respected legal outlooks in terms of material extraction and site rehabilitation. Particularly the Addis Ababa City Road Authority and CRBC Addis Engineering quarry projects in the study area are exploiting construction materials without undergoing environmental impact assessment process and rehabilitation program. As a result the quarry brought various environmental problems, such as the excavated site is abandoned and left as wasteland, the resource is not well utilized, the overburden materials are improperly dumped for future rehabilitation, soil erosion and land degradation, diversion of natural river water flow, etc. So that, it can be concluded that the quarry sites in 'Worku-Sefer', have great problem on the management practice which can be characterized as poor mining plan, lack of ecological considerations, inadequate quarrying process and rehabilitation planning, technical and policy enforcement barriers, which brought significant degradation on the environment and socio-economic development endeavors in the city.

1.3. Objectives of the research

1.3.1. General Objective

The general objective of the study is to examine the current quarrying & rehabilitation mechanism and provide environmental planning solution for rehabilitating 'Worku-Sefer' quarry sites

1.3.2. Specific Objectives

- To examine the existing situation and practice of quarry rehabilitation in the abandoned and active quarries
- To examine quarry operation practice and on site management of overburden materials
- To investigate land use land cover changes in the study area
- To assess the woody species composition of the study area
- To identify the barriers that hinders the development and implementation of quarry rehabilitation program in the study area
- To provide environmental planning solution to rehabilitate the quarry sites in 'Worku-Sefer'

1.4. Research Questions

In order to address the stated problem and objectives, the study will attempt to answer the following research questions:

- What are the trends and practice of quarry rehabilitation in the study area?
- How is overburden materials managed on the site?
- What was the spatial extent of the land cover change and where was the highest rate of changes in the study area?
- What are the woody species compositions of the study area?
- What are the barriers that hinders the development and implementation of a sustainable quarry rehabilitation program
- How can the abandoned and active quarry sites be rehabilitated based on environmental planning principles?

1.5. Scope of the Study

The scope of the study is limited in space and theme. The research is limited to an area locally known as "Worku-sefer" quarry projects. It starts from the confluence of Kebena River at South part of Bole Sub City and Great Akaki River in Akaki-Kality Sub City; it covers an area of about 328 hectares. However, the planning intervention area limited on rehabilitating abandoned quarries along river buffer zones.

The scope of this paper with respect to the subject raised include the quarry operation and environmental issues, examining of the factors, extent and patterns of land use and land cover changes as well as identification of only woody species found in the site. The study does not dwell on the potential impacts that the project caused on the environment, biota and socio-economic aspects of the project. The study highlighted the potential drawbacks on legal aspects, the overall barriers of quarry rehabilitation program being practice on the site.

1.6. Significance of the study

Since the research focuses on sustainable quarry rehabilitation planning, I believe, it will be an important document for Addis Ababa City Administration in different levels, quarry companies and other stakeholders to have an overview about the strengths, weaknesses, opportunities and threats of the current quarry planning and management with respect to sustainable quarry rehabilitation. The collected data about quarry management and rehabilitation system in the study site can be useful for all those involved in quarry operation and people affected by the adverse impacts of quarrying activities. The rehabilitation scenario of the project can be multiplied for other similar quarries.

1.7. Limitations of the study

The limitations of this paper include that the respondents may not accurately state and prioritize their problems that hinder sustainable quarry rehabilitation program. Particularly, most of quarry project owners in the study area were not willing to give the relevant data with respect to quarry rehabilitation planning, these impediments in understanding the status of the quarry. The other limitations include the availability of limited literatures, developing countries' experience, on the issue under consideration. Furthermore, limited finance and resource may limit the access to get necessary images and data that are used to land use/land cover change detection and quarry rehabilitation analysis.

1.8. Organization of the research

The thesis is organized into six chapters. The first chapter is the introductory section which depicts the overview of the research where introduction, background, statement of the problem, objective, research questions, scope, significance and limitation of the study are included. The second chapter is the review of relevant literatures on the topics of rehabilitation of quarries – scenarios and strategies. The third chapter deals with description of the study area with methodological approach to the research. The fourth chapter presents the findings of the research along with the analysis. The fifth chapter will present an environmental planning solution proposal on how to do quarry rehabilitation in the study area. The sixth chapter provides conclusions and recommendations of the study.

CHAPTER II

2. Literature Review

This chapter mainly deals with literatures highly related to quarry rehabilitation planning. The main points discussed in this section of the paper include the following issues: definition of terms and concepts, quarrying operation, the environmental problems of extractive industries, planning for Mining and Sustainable use of natural resources, review of quarry planning and management in selected countries and their strategies, objectives and principles of quarry rehabilitation. Finally the legal frameworks of Ethiopian mining activities were discussed.

2.1. Definitions of terminologies: Rehabilitation, Restoration and Reclamation

Several expressions are used in reference to efforts for improvement and recovery of degraded sites, such as mines and quarries; the most common of which are: rehabilitation, restoration and reclamation. Each of these terms has a distinct meaning from a technical and environmental standpoint. Moreover, the exact meaning of these expressions varies greatly across different countries. 'Rehabilitation' holds a strong recuperative meaning of site reinstatement to an enhanced ecological capacity and environmental condition. This term often embeds the sense of sustainability of the site condition. 'Restoration' embodies the meaning of returning the site or ecosystem to the greatest extent possible to its original condition. In cases where rehabilitation involves returning the site to its original status, rehabilitation coincides with restoration (Newton and Claassen, 2003). According to the state of California, 'reclamation' entails the return of a site, usually unsuitable for any use, to an acceptable condition for a specific, and possibly temporary, use such as cultivation.

According to University of Applied Science, 2006, quarry rehabilitation means: "To restore the land affected by raw materials extraction and related operations to a satisfactory state, with particular consideration of future land use, soil quality, biodiversity, landscape, and appropriate beneficial use".

For the purpose of this section, rehabilitation shall refer to the measures and actions used to reinstate land disturbed by quarrying and excavation activities to an enhanced and sustainable ecological capacity.

2.2. Quarrying operations

Stripping is the initial step in the quarrying operation and involves removal of topsoil and sub soil that covers mineable materials. A variety of equipment is used to strip, transport and redeposit sub-soil

(Bauer, 1991). Excavating equipment and procedures also vary with each operation. For purposes of clarification, excavation operations are described by mine type and more specifically for the two main categories: Stone quarry and sand quarry (Bauer, 1991).

- **Stone quarries**: Excavation of quarry material involves a three-step process. The first step is to break the stone away from the quarry wall and break the stone into small pieces. This is accomplished by the use of explosives. Holes are drilled behind the quarry wall (cut face) within which explosive charges are placed. Depending on the deposit depth, a standard procedure is to create a series of terraces or "benches". The second step is to excavate broken stone by either front-end loaders or any other similar types of excavations equipment. The third step is to transport broken stone to the processing plant.

- **Sand and natural aggregates quarries:** Sand and natural aggregates excavation is a two-step process. No blasting is required in this type of mining. The first step is to excavate the material/deposit by using the appropriate type of excavators. The second step is transport the excavated material to the segregating plant.

2.3.The environmental problems of extractive industries

There is a range of negative environmental impacts associated with extractive industries. This is especially true of opencast mining of the sort used in extracting construction materials (Bauer, 1991). The greatest problem is the destruction of the habitat where the quarrying occurs (Walker and del Moral, 2003). As mining strips the substrate down to the rock layer no biological legacy remains on the site.

Other problems of mining on the environment reported include;

- ✓Land degradation and Soil contamination
- ✓Degradation of forest and loss of biodiversity.(habitat loss, loss of flora and fauna)
- ✓Air pollution
- ✓Surface and groundwater pollution
- ✓Noise and vibrations
- ✓Deterioration of natural drainage system
- ✓Landscape change, change to the visual scene,
- ✓Security problem,
- ✓High traffic and waste materials etc.

2.4.Planning for Mining and Sustainable use of natural resources

Planning is figuring out what needs to be done and how to do it. It is the process of Applying "knowledge to action" or basic problem solving. It requires determining ends and means relationships. Simply, planning involves: setting objectives, gathering and analyzing information and formulating and evaluating alternative policies, projects or design to meet the objectives. Planning for the mineral extraction industry consists of answering the questions of "where? "how much?" and even "whether?" to extract minerals with the long-term view in mind. The development of quarries has the potential to create environmental problems which requires planning system to assess the range of likely environmental effects, and to propose appropriate mitigation measures, particularly at the pre-application consultation stage (Bauer and FASLA, 2000). Resources are the backbone of every economy. In using resources and transforming them, capital stocks are built up which add to the wealth of present and future generations. However, the dimensions of our current resource use are such that the chances of future generations to have access to their fair share of scarce resources are endangered. Moreover the consequences of our resource use in terms of impacts on the environment may induce serious damages that go beyond the carrying capacity of the environment. Hence for beater utilization and management emphasis should be given on quarry planning, management and development of rehabilitation program.

2.4.1. Earthwork planning

In general, before any construction work could start, a proper site investigation and earthwork must be done first. Information gathered through the desk study and site exploration will be used for future planning on how the construction works could be employed. Earthwork involves site clearing, excavation of overburden, and leveling the site to a desired platform level. Method of excavation for soil and rock are different since soil has high excavateability rather than rock. Planned stripping and replacement of topsoil, subsoil and overburden materials allows the licensee or permit to establish vegetation in as much area as possible, and a start can be made towards developing the site for a particular after use.

2.4.2. Site Investigation

Site investigation is the gathering of information about the proposed location of a project. The site investigation is aimed at providing sufficient reliable subsurface information for most economical, satisfactorily safe foundation for the proposed structure. Specifically, the site investigation should reveal sufficient subsurface information for the design and construction of a

stable foundation safe from both collapse and detrimental movements. It should provide enough information for the computation of lateral earth pressures and should reveal the nature of the material to be excavated and indicate potential construction problems.

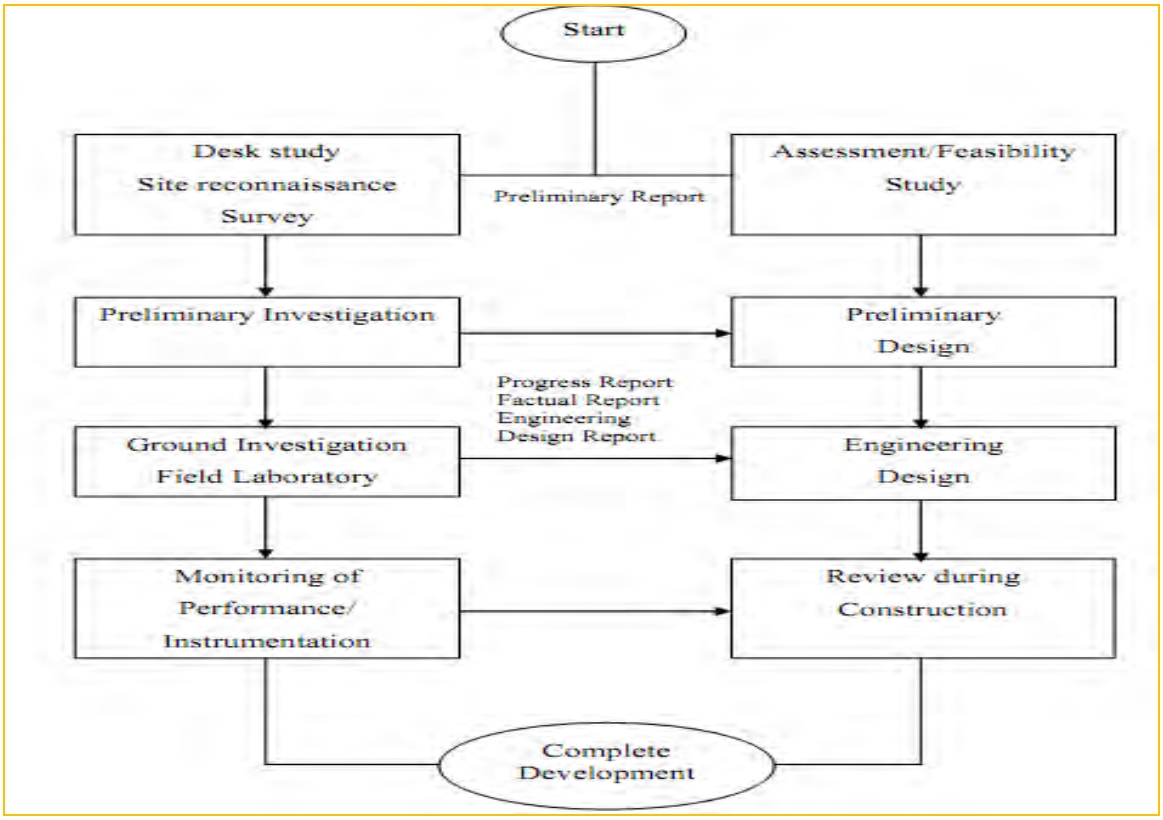


Figure 1: Sequences of ground investigation in relation with quarry design stages *(Source: Nurly Gofar et.al; 2007)*

According to Cheng Liu and Evett, 2005, reconnaissance is a preliminary examination or survey of a job site. Usually, some useful information on the area (e.g., maps or aerial photographs) will already be available, and a brilliant person can learn much about surface conditions and get a general idea of subsurface conditions by simply visiting the site, observing thoroughly and carefully, and properly interpreting what is seen.

The first step in the preliminary soil survey of an area should be to collect and study any pertinent information that is readily available. This could include general geologic and topographical information available in the form of geologic and topographic maps. After carefully collecting and studying available pertinent information, the geotechnical engineer should then visit the site in person, observe thoroughly and carefully, and interpret what is seen. The ability to do this successfully requires considerable practices and experience.

In all civil engineering works, the most crucial is the reliability of the information about the ground on which the civil engineering project will be founded which is called Site Investigation information, or simply SI. There are various methods of obtaining SI information. Almost all SI is remotely carried out and because of this; it is necessarily the most procedure oriented operation. Therefore, for SI information to be meaningful, it requires strict adherence to procedures and good practice.

2.5.Quarry Design

Some basic principles should be applied to all quarries to ensure safe and efficient sites during extraction, restoration and subsequent use. Quarries operate within a strict planning system and the issues of safety, visual appearance, environmental protection and the future use of the site will be investigated and incorporated into the quarry design before a planning application is submitted. The quarry boundary is defined as the edge of the planning permission within which a working quarry operates.

2.6.Review of quarry planning and management in selected countries

The countries and states selected for the study review of international quarry management were chosen based on highly developed and elaborated quarry management practice and legal frameworks.

In Great Britain, France, and Malta, national or regional land-use planning for minerals is adopted and the planning activities are based on the following principles

- Minerals should be conserved, as far as possible, whilst securing an adequate supply to meet the needs of the economy and society.
- Environmental impacts caused by mineral operations and the transport of minerals should be kept to an acceptable minimum through good operational and management practices.
- Restoration of sites should preserve or enhance the overall quality of the environment after working has ceased and, where appropriate, make contributions to improved habitats and biodiversity.
- Areas of designated landscape, nature conservation or heritage value should be protected, as far as possible, from mineral development.
- The unnecessary sterilizing of mineral resources by using the land permanently for other purposes should be avoided.

In Canada (Québec), quarry reclamation must be completed within a time limit of one year exceptionally two years after the date when the operation of the pit or quarry has ceased (Canada-Quebec Regulation respecting pits and quarries, art. 45. No date is specified).

- Where the operator has chosen to restore the site simply by leveling and revegetation, the land restoration plan must be carried out concurrently with the operation of the pit or quarry.
- If the topsoil and overburden are preserved during the operation of the pit or quarry, they must be stored separately. The topsoil and overburden shall later be deposited on the leveled surface during restoration, to facilitate the growth of vegetation (Canada-Quebec Regulation respecting pits and quarries, art. 40. No date is specified).
- In the case of a pit, the restoration plan must not allow the slope of the worked surface to be more than 30º from the horizontal unless the ground is to be stabilized in some way to prevent landslides and erosion. Where a quarry is located on the side of a hill, mountain, cliff or slope, the final vertical cut must never exceed 10 meters. The operator may make several superimposed vertical cuts of at least 10 meters provided such cuts are separated 57 by horizontal terraces at least 4 meters in width (Canada- Quebec Regulation respecting pits and quarries, art. 38. No date is specified).
- Each horizontal terrace must be covered with vegetation.
- Where the restoration project consists in creation of an artificial body of water, it must be designed to prevent water stagnation. Such artificial body of water must be at least 2 meters in depth at its shallowest point (Canada-Quebec Regulation respecting pits and quarries, art. 42. No date is specified).
- On completion of the land restoration project, the surface of the pit or quarry must be free of all debris, rubbish, stumps, non-usable material, pieces of machinery or other such litter.

In Canada/ Québec, several funding approaches towards rehabilitation are undertaken, following certain criteria and principles in order to decide as to who shall pay and how for quarry creation. These principles and criteria are used in Canada to assess funding approaches to abandoned mine (or quarry) rehabilitation. These principles and criteria are adopted from Castrilli 2003.

Table 1: Principles and criteria to assess funding approaches

	Principles and Criteria	Description
1	Polluter pays	The one in responsibility for the quarry should finance rehabilitation costs
2	Beneficiary pays	The ones who benefited from the quarry (e.g. public) should finance rehabilitation costs
3	Fairness	Fairness refers to notions of certainty of process, effectiveness, efficiency, clarity, consistency, and timeliness in achieving environmental objectives. It is related to Polluter and beneficiary pays principles.
4	Sustainable development (SD) goals	SD should provide the overall framework in which a quarry rehabilitation program should be developed.
5	Openness, accessibility, participation	Public input and access to information about the quarry rehabilitation needs to be always taken into account.
6	Revenue generating capacity	The funding mechanism needs to generate sufficient funds for the task at hand.
7	Administrative ease	The generation of revenue, its collection and application needs to be through a relatively simply process.
8	Economic impacts	The economic impacts of the funding approach undertaken needs to be assessed in order to safeguard the competitiveness of the industry among other things.
9	Discourage future site abandonment	The funding approach should also discourage future abandonment of quarries without rehabilitation.
10	Public perception	The perception of the public towards the funding approach is important, as it also impact political initiatives towards rehabilitation.

Source: (Castrilli, et al, 2003)

2.7. Rehabilitation of quarries

2.7.1. Objectives of Rehabilitation

The United Nations Environment Program (UNEP) has published several objectives for the closure and rehabilitation of mines and quarries. Oberholzer and Harrison (2003) summarized the objectives of rehabilitation into three main categories: safety, socio-economic and environmental.

i. Safety Objectives

The rehabilitation of damaged ecosystems such as quarried lands may aim at ensuring public safety by improving site stability, preventing accidents and injuries, in addition to the deterrence of landslides, mudslides, and rock fall.

ii. Socio-Economic Objectives

Social objectives include appeasing public fears and concerns, and diminishing public opposition to quarrying practices. An improvement of public opinion of the quarrying industry would bring major benefits to future quarrying activities and projects. From an economic standpoint, raising the value of estate near quarry sites after rehabilitation is an important objective, often resulting in improving livelihoods and income as well in tourist and commercial areas.

iii. Environmental Objectives

There are numerous environmental benefits associated with quarry rehabilitation, such as the recuperation of ecological conditions, restoration of green spaces and vegetation, and decrease in soil losses and erosion. Figure 2 describes the correlation that joins the rehabilitation process and the three main pillars of sustainable development.

Figure 2 Rehabilitation and the three base process of sustainable development *(University of Applied Science, Switzerland, 2006)*

2.7.2. Principles of Sustainable Rehabilitation

There are many principles that must be taken into consideration or adopted to ensure the successful rehabilitation of a quarry site and its proper closure. The Australian and New Zealand Minerals and Energy Council and the Minerals Council of Australia in the year 2000 claim that successful rehabilitation is guaranteed by accomplishing the following:

- All stakeholders' interests are considered.
- Rehabilitation and closure occur in an orderly, cost-effective and timely manner.
- Rehabilitation and after care costs are adequately forecasted.
- There is clear accountability of all stakeholders in their rehabilitation responsibilities (planning, regulating, monitoring, operating, aftercare, etc).
- A set of indicators are established to evaluate the completion of rehabilitation.
- A landform with similar capability to that of the site prior to extraction is achieved, unless other beneficial land uses are pre-determined and approved.

2.8. Rehabilitation methods

The method for quarry rehabilitation or restoration depends on several factors, among which is the selected after-use of the quarry site. In general, rehabilitation can be either rehabilitation with backfill, or low level (partial) rehabilitation. In most cases, governments encourage rehabilitation to achieve to the highest extent possible a land contour similar to that of the origin. For example, the United States government has set performance standards for the reclamation of surface mines and quarries that specifically request "the post-mining graded slopes must approximate the pre-mining natural slopes" (United States Code of Federal Regulation, 2002). Of course, exceptions are made based on the approved after use of the site.

2.8.1. Rehabilitation with Backfill

This rehabilitation method is fundamentally adopted when there is a need to alter the landform of the excavated site. Whether the topography is restored to its pre-quarrying conditions or adjusted to another form ultimately depends on the selected site after-use. However, this method enables options both to occur.

Another decision inherent to this rehabilitation method is the choice of backfill material, which can include rubble, inert or non-inert waste, in addition to the site overburden, subsoil and soil layers overlying the excavated or quarried material. Key considerations for the type of fill material include material availability and cost, bulking and settlement characteristics, and site after use.

2.8.2. Low Level or Partial Rehabilitation

When the after-use of the site does not require major changes to the landscape, low level or partial fill rehabilitation can be adopted. In this case, excavated or quarried voids are shaped to landforms appropriate to the topography of the area, while backfilling is kept minimal. Such a method may be appropriate to use in the rehabilitation of an abandoned quarry site, which is to be converted into an amphitheater or a rock-climbing arena.

There has been an increasing trend for this rehabilitation type in various regions in the United Kingdom, despite the fact that it maintains "alien features and breaks in the landscape," which had been introduced from the excavation activity (SCC, 2002). However, landscape features such as plants can be used to screen steep breaks and harmonize the landscape. In the case where the water table is high, and flooding of the quarried site has taken place, wet partial fill restoration can be used, allowing for a wide range of after uses, such as water recreation, wetland or reservoir creation.

2.9. Phasing of Rehabilitation

The rehabilitation of extraction sites serves to minimize and in some cases, alleviate the environmental, economic and social impacts resulting from quarrying or excavation activities.

The earlier a site is rehabilitated, the quicker these impacts are dealt. Based on the above, phased or progressive rehabilitation is the preferred alternative to rehabilitation that commences only after cessation of all extraction activity and quarry closure. Progressive rehabilitation involves the staged treatment of disturbed areas during the extraction operations rather than undertaking large-scale rehabilitation works at the conclusion of the works.

According to the Queensland Government Department of Mining and Energy, the advantages of progressive rehabilitation include:

- satisfying the neighboring community
- reassuring government agencies and decision-makers
- reducing projects costs and time
- reducing environmental impacts due to minimized soil erosion, water contamination, and visual impacts
- allowing for practical trials of rehabilitation methods prior to widespread use
- maintaining topsoil fertility due to shorter storage time
- improved operations cash flow

2.10. Rehabilitation considerations: internal and external factors

As a rule, each quarry site is unique, creating its own site conditions and rehabilitation opportunities. However, there is a set of factors that are usually considered before commencing rehabilitation activities, which determine the best end-use alternative for that site. Some factors cited as affecting the choice of the restoration schemes are listed in the following table.

Table 2: Internal and external factors affecting restoration schemes

Internal factors	External factors
Climate conditions	Public Concerns
Slopes and land surface	Land use planning
Site topography of the determined area	Legislation and Enforcement and land

	Ownership
Soil characteristics and quality	Cost Implications
Geologic formation	Alternatives for Rehabilitation
Location of a quarry site	Budget availability Local public opinion
Quarry site stability	Extent of required/desired public access
Surface water	
Invasive plant species	
Site accessibility and re-use	
Likelihood of Vandalism	

Source: *MIRO, 2006*

2.11. Legal frameworks in Ethiopia governing mining activities

Ethiopia has Federal and Regional environmental bodies that are mandated by proclamation and regulation.

2.11.1. Proclamation of the constitution of the Federal Democratic Republic of Ethiopia (proc. No 1/1995)

In the constitution, a national guiding principles, environmental rights and objectives have been clearly considered for the implementation of policies and other laws that govern environmental protection activities. The following important points were particularly proclaimed in this constitution.

- The government is to try its level best to secure every citizen with clean and safe living environment.
- The design or implementation of any development program should not be in a manner to destroy or damage the environment.

2.11.2. Environmental policy of Ethiopia

The environmental policy of the nation is to enhancing the living conditions of every citizen by promoting sustainable development through sound environmental management systems. To achieve these goals, a comprehensive environmental management plan has to be produced based on the anticipated impacts and as per the mentioned policy provisions and requirements, i.e.

- Considering the impacts of the project both on humans and on natural environment,
- Recognizing the importance of consulting the local people,
- Compromise between short term economic growth and long-term environmental impact, and
- Sustainable resource management and proper balance in utilizing the resources and rehabilitation of the area.

2.11.3. Environmental Impact Assessment proclamation (proc. No 299/2002)

This proclamation clearly indicates that major development programmes, plans and projects of the private or public enterprises shall be subjected to Environmental Impact Assessment study before their approval for implementation. The proclamation also provides a legal base for the effective means of harmonizing and integrating environmental, economic, cultural and social considerations in to the planning and decision making processes there by promoting sustainable development. These include:

- The application of this proposal at the early stage of project formulation,
- Undertaking the assessment by a neutral consultant,
- The involvement of community members & concerned governmental organs,
- Consideration of the guiding principles and policies on the major issues of significant impacts,
- Identification of appropriate measures for monitoring and managing of the impact,
- Submission of report to the concerned institution for sound review and decision, etc.

2.11.4. Environmental pollution control proclamation (proc. No 300/2002)

This proclamation is aimed at eliminating or, when not possible, to mitigate pollution as an undesirable consequence or social and economic development activities. It also stated that the protection of the environment and safeguarding of human health, as well as the maintaining of biota and the aesthetic value of nature are the duty and responsibility of all citizens. It further considers other important issues in some of its articles, among others:

- Control of pollution,
- Management of hazardous waste, chemical and radioactive substances,
- The importance and need to respect environmental standards,
- Punitive and incentive measures, etc.

2.11.5. Mining proclamation No 52/1993 and Mining regulation No 1982/1994

In the mining proclamation and regulation of the Federal Democratic Republic of Ethiopia the following principal activities have been prohibited:

- Granting license for any mineral works which is within 100 meters of a site of archeological, cultural or religious or public building, railway, highway, airport, dam, reservoir, pipeline, factory or other government installations, unless the licensing authority decides otherwise.
- Prospecting minerals on land, which is within 100 meters of a municipal area, village community or burial ground or which is on a land actually under cultivation, unless the licensing authority decides otherwise.
- The proponent should also progressively restore or reclaim his license area, or prior to the termination of his license, the area should be restored or reclaimed for beneficial future use.

2.11.6. Mining Operations Proclamation (proc. No. 678/2010)

Mining operations proclamation No. 678/2010 is proclaimed according to Article 55(1) of the Constitution of the Federal Democratic Republic of Ethiopia. The Constitution of the Federal Democratic Republic of Ethiopia provides that the right to ownership of all natural resources of Ethiopia is exclusively vested in the government and in the people of Ethiopia and that the government is the custodian thereof. Minerals are non-renewable natural resources and that the government shall ensure the conservation and development of these resources to the socio-economic progress of all Ethiopians; it is the obligation of the government to protect the environment for the benefit of present and future generations and to ensure ecologically sustainable development of minerals. The proclamation has nine parts which covered various issues including: General, fundamental principles and general provisions, licenses, certificates, administration, compensation, environment, royalty, income tax and other financial regime and miscellaneous provisions.

Mining operation for the extraction of construction materials is one of the licensing areas described in the proclamation including: basalt, ignimbrite, clay, selected material, aggregates.

Objectives of the proclamation

The proclamation has the following basic objectives:

- Give effect to the principle of the custodianship of the country's mineral resources by the government;
- Promote socio-economic growth of the country;
- Promote employment and advance the social and economic welfare of all Ethiopia;
- Provide for security of tenure for all investors in respect of exploration and mining operations; and
- Ensure that the country's mineral resources are developed in an orderly and sustainable manner.

The proclamation further proclaimed the requirement and types of licenses applicable in mining operations in Ethiopia. Furthermore, is has indicated on the 'Environment' part of the proclamation the submission of Environmental Impact Assessment study report along with rehabilitation fund for restoring the site at the time of closure .

Apart from these the proclamation provided that extraction of construction materials shall be liable with 3% royalty tax during its operation and based on the sales price of the commercial transactions of the minerals produced.

2.11.7. Labor proclamation No 377/2003

This proclamation highly emphasizes that an employer should take the necessary measures to safeguard the health and safety of his workers. The employer shall in particular:

Comply with the occupational health and safety requirements provided for in this proclamation are to:

- Take appropriate steps to ensure that workers are properly instructed and notified about the hazards of their respective occupations and the precautions necessary to avoid accident and injury to health.

- Provide workers with protective equipment, clothing and other materials and instruct them of its, use etc.

In general, to ensure workers safety and job security the need to respect this proclamation has been clearly stated in the document.

2.12. Summary of literatures

Mining as practiced in most parts of the world fails to meet the above principles of sustainability. This is particularly the case in economies that rely on development to sustain immediate human needs. In part, the difficulty is inherent in the nature of the activity itself. Every mining operation is recognized as causing two immediate effects on the surrounding environment. The first effect is the depletion of the natural resources base (natural capital) during the lifespan of the mine and the second is the negative biophysical impact of the mining activities. While the mine is operating, there is a constant depletion of the natural capital available to the region or the country within which the mine is operating. As the mineral is extracted and sold the total amount of the natural capital available to the region is diminished.

The end result of this process is the total removal of the mineral resource, leading to the closure of the mining operation. The United Nations Environment Program (UNEP) has published several objectives for the closure and rehabilitation of mines and quarries. Oberholzer and Harrison (2003) summarized the objectives of rehabilitation into three main categories: safety, socio-economic and environmental.

The method for quarry rehabilitation or restoration depends on several factors, among which is the selected after-use of the quarry site. In general, rehabilitation can be either rehabilitation with backfill, or low level (partial) rehabilitation. In most cases, governments encourage rehabilitation to achieve to the highest extent possible a land contour similar to that of origin. For example, the United States government has set performance standards for the reclamation of surface mines and quarries that specifically request "the post-mining graded slopes must approximate the pre-mining natural slopes" (United States Code of Federal Regulation, 2002). Of course, exceptions are made based on the approved after use of the site.

Generally the reviewed from the selected country shows us, sustainable mining/quarrying development can only be achieved through principles of sustainability and policies that have taken in to account the concepts environmental considerations in the long-term and capable of being implemented by an efficient and effective system of government. A sustainable mining region is one that uses mineral extraction to enhance and diversify community development beyond the life of the mineral resource, while maintaining the health of the biophysical environment, and eliminating negative social and cultural impacts of mining on the local population, over a multigenerational time scale. To achieve this goal, a number of prerequisites, including political will, must be in place. A sustainable mining region must balance the views and influences of stakeholders and decision makers that range from global to local.

In the case of Ethiopia, the country has Federal and Regional environmental bodies that are mandated by proclamation and regulation provided for the establishment of environmental protection organization (Proc. No. 299/2002) and Environmental Impact Assessment proclamation (proc.no.299/2002) and other relevant laws to oversee and facilitate the implementation or administration of environmental issue for various project to be implemented. Thus, those authorities provide binding environmental impact assessment guide lines for various projects.

This is an important and crucial section that will have importance in identification, prediction and evaluation of impacts (both negative and positive). However there is no guiding principle regarding quarry development and rehabilitation projects by FEPA. Fortunately, Addis Ababa Environmental Protection Authority prepared environmental impact assessment guide lines in 2007 (Annex A), however the guideline provided is not legally binding by laws and regulation and it is difficult to implement. Hence the quarry operation can be done with different company and they are not responsible for the environment and the consequence of the operation problem is wide.

CHAPTER III

3. Materials and Methods of the Study

3.1. Description of the study area

3.1.1. Location

The study area is found in Akaki Kality Sub City, Woreda 05 & 10, around Wehalimat, commonly known as 'Woreku-Sefer' and to small extent in south Bole Sub City, at the confluence of Kebena and great Akaki River, which flows in the study area from north to south eastern direction. The study area lies between 38046'30" E-38^{0}47'30" E latitudes and 8^0 55'15" N- 8^{0}56'15"N altitudes. It covers a total area of 328 ha of land. It is characterized by steep slopes covering significant portion of the river side's. The area is accessible along Megenagna - Bole - Saris Abo Ring road and bending at Wehalimat, Akaki Kality Sub City, toward east and driving for about 2 kms from the point of bending.

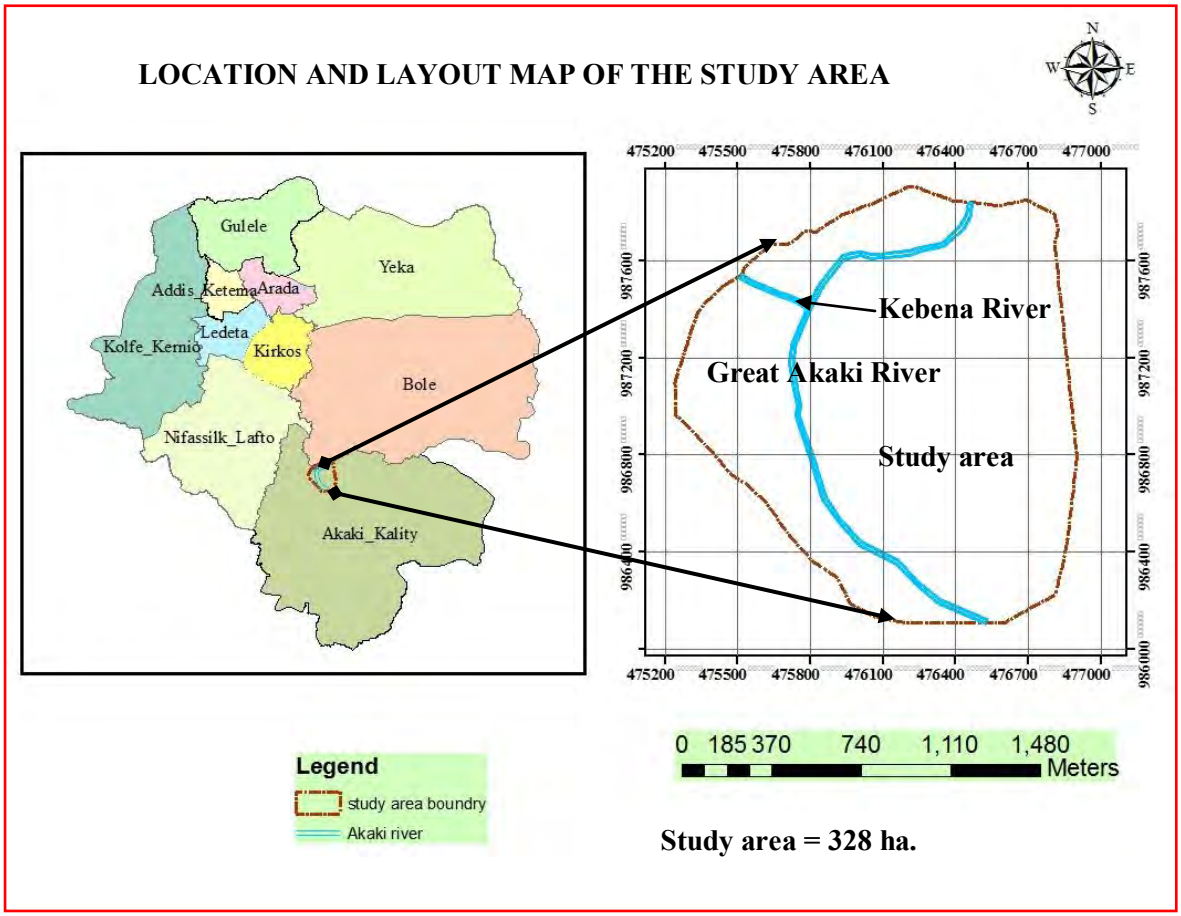


Figure 3: Location of the Study Area in Addis Ababa *(Source: Addis Ababa City Base map, 2005)*

3.1.2. Topography/relief of the study area

The study area is dissected by valley formed by the Great Akaki River. Due to quarrying activity and flooding, the study area has an irregular land form and is characterized by uneven topography with an altitude difference ranging between 2040- 2155 meter above sea level. However, the area is below the average elevation of the city i.e. 2500 m.a.s.l. This makes the area to have warmer temperature than the average temperature of the city.

The slope of the area varies significantly from one area to another (see figure 4 in the next page), but it is dominated by flat area which is suitable for quarrying activities. The river side of the study area has slope greater than 20% which is covered by steep slope and is not suitable to any development initiative. Taking in to consideration, the structural plan of the city proposed those areas with slope of greater than 20% reserved for forest and restricted any types of development other than urban greenery.

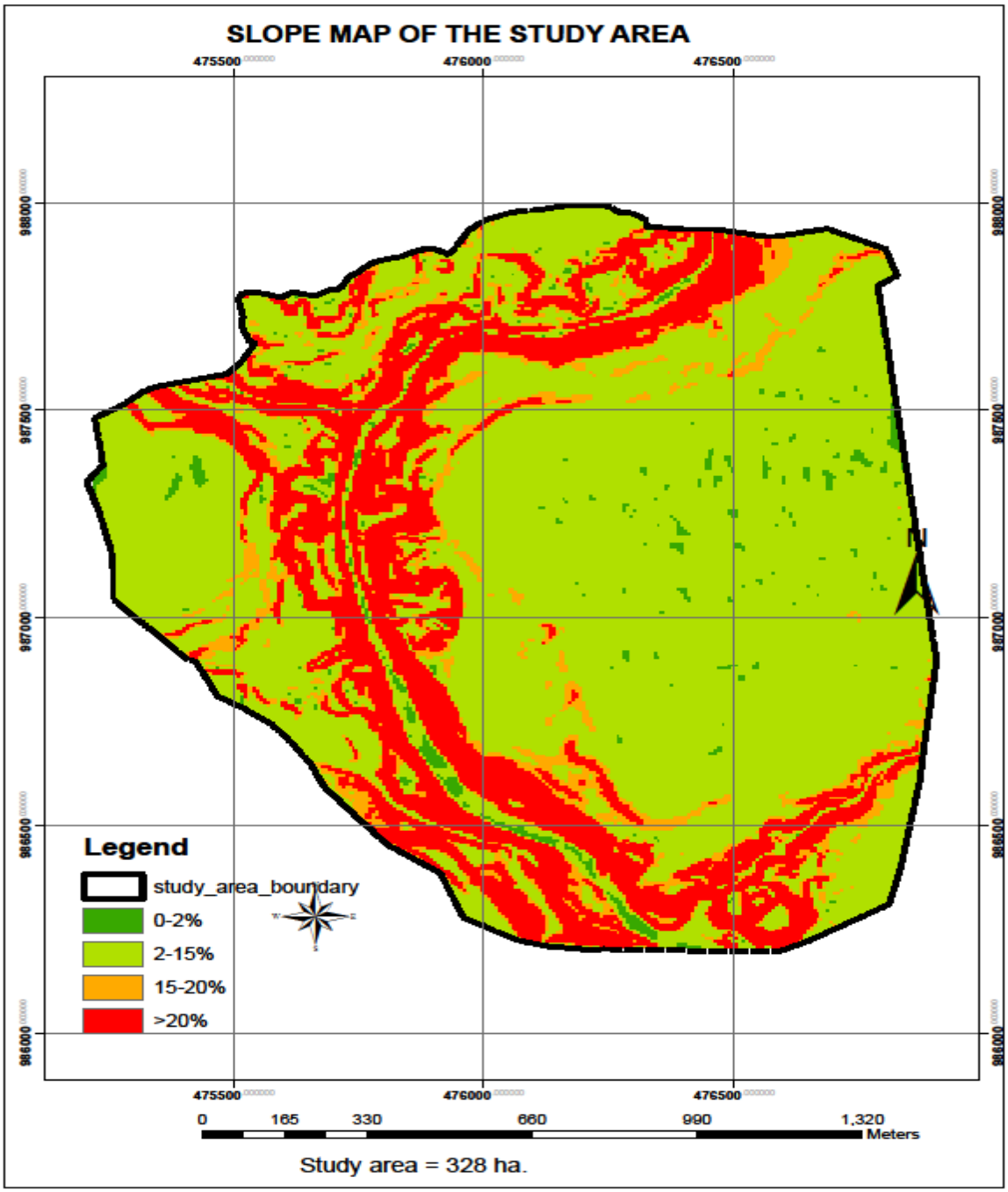


Figure 4: Slope map of the study area *(Source: Addis Ababa City Base map, 2005)*

The above slope in the study area is majorly less than 15%. But the part of the site found along the river side where abandoned and quarrying activity is underway has a steeper slope above 20%.

3.1.3. Climate

The project area shares the climatic conditions of Addis Ababa city; the city has a long rain period in the months of July, August and September and short rain period in March and April. The average maximum and minimum temperature are 22.9 and 10.8 ºC respectively. The annual rainfall ranges from 1200 mm to 1400mm and the mean annual rainfall is about 1179.6mm (CSA, 1999). However, due to relief variability micro-climatic differences are visible within the city limit. In other words, thus, the relatively elevated northern part of the city is comparatively wetter and cooler than the South. Due to the change of the climate and rainfall of Addis Ababa, it might also be a change in rainfall and climate in the particular study area of the research.

3.1.4. Natural Resources

The water unit found in the study area is Great Akakie River. However, a considerable part of the river sides in the study area are affected by intensive quarry, landslide, and soil erosion .This part of the study area is characterized by active gullies and severe sheet erosion.

The existence of perennial streams that are tributaries of Great Akaki River indicates that the area is getting sufficient rainfall with maximum annual precipitation of 1400 mm particularly in between Augest and September. The study area and its surrounding are now intensified with quarrying process. This makes the vegetation cover of the area depleted from time to time. However there are some indigenous grasses, bushes, different shrubs, trees (*coroton macrostachia*, *Acacia abyssinica,Millettia ferruginea, ficus sur.etc.*) and exotic trees like Eucalyptus trees. The soil development in the study area is mostly due to the physical disintegration and chemical decomposition of volcanic rocks (AAEPA, 2012).

3.1.5. Demographic and Socio economic of the study area

According to the 2007 Census, Addis Ababa City Administration has a total population of 2,738.248. Among this, the number of female population is 1,433,730 (52%) and the remaining 1,304,518(48%) population is male. The city has an average population growth rate of 2.1% per year. Hence, the population in 2012 is assumed to be 2.984 million based on the projections for five years. On the other hand the total population size of Akaki Kality sub city is 181, 202 with the same average growth pattern.

Based on data obtained from Woreda administrations the total population of Woreda 05 & 10, where the study area is located, is 23,500 and 15,000 respectively. Out of these, the total household of the intervention area, 'Worku Sefer', is about 900 and 60 from Galan Gura , with an average household size of 3.9, i.e. the total population is about 3510 and 234 respectively (CSA, 2010).

The Female proportion in the Woredas is slightly greater than that of the City which is 52.4% and the Sub-city, which is 53.3% (CSA, 2010). The lives of most of the residents of the project area were

dependent on agriculture. Now a day, expansion of mining activities created large number of jobs. Particularly the recent establishment of coble stone project in the area had been creating job opportunity for the residents. Other business activities (market interaction) like hotels, restaurants and different shops were the major means of income generation to local community.

3.1.6. Geology

The typical volcanic centers of the region, (Addis Ababa) are the Entoto Ridge (3200 m a.s.l), Mt. Wochacha (3385 m a.s.l), Mt. Yerer (3100 m a.s.l), and Mt. Furi (2839 m a.s.l).

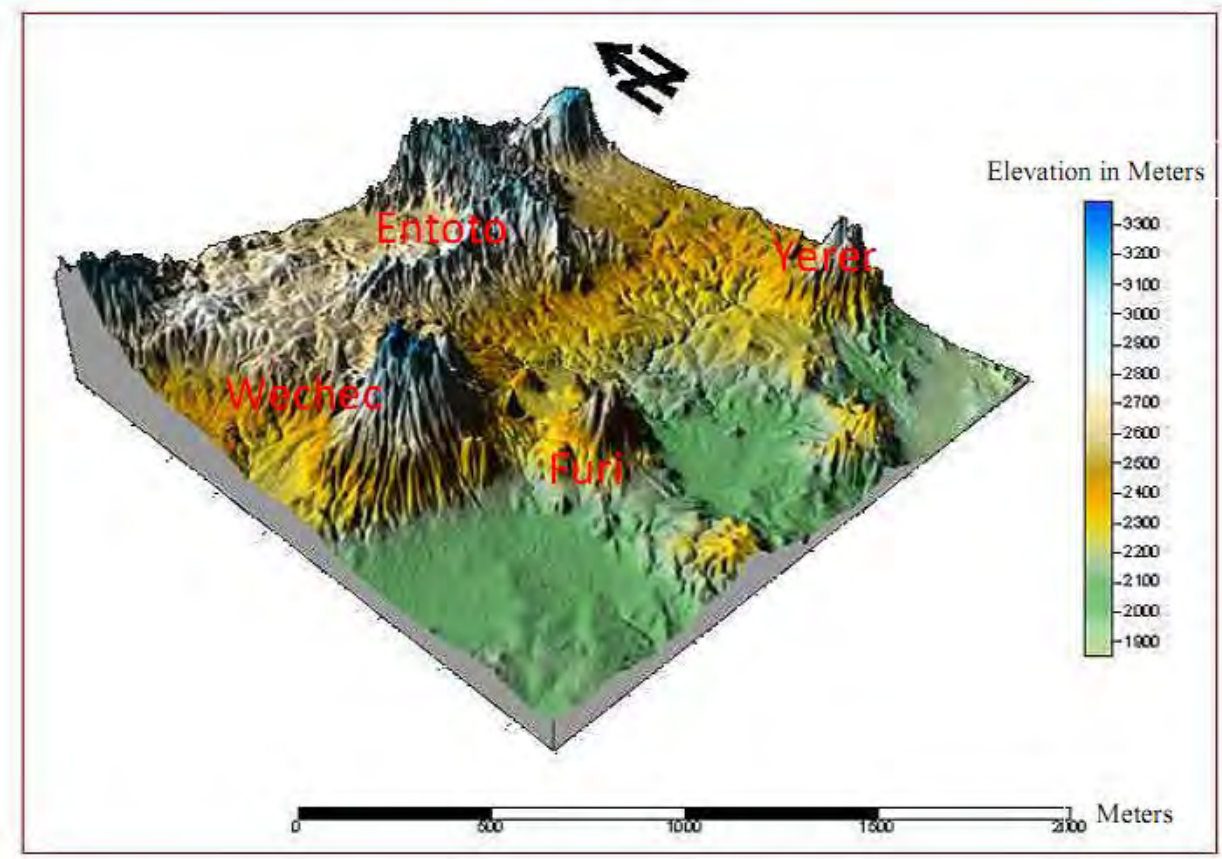


Figure 5: Physiological Model of Addis Ababa (cited from Hiwot Abrha, 2012)

The geology of the study area is characterized by Nazreth group and Akakie basalt rock types where basalt extractions are inter spread with large accumulations of basalt flow, ignimbrites and related volcanic rocks (AAEPA, 2012). The rock is mainly greenish grey to dark grey but rarely of pink color. This rock is porphyritic olivine and aphanitic with top part mostly vesicular. Weathering of the rock forms different colors of mainly dark brown. Spheroidal weathering is more conspicuous phenomenon. It is mainly affected by joints making it fissile functions.

3.2. Selection of case study area, materials and sampling method

3.2.1. Selection of case study site

Purposive sampling technique is used to select the study area. Because "Worku-Sefer" quarry site is one of the potential sites to supply different construction material to the city infrastructure development plan such as basalt aggregates, selected material for any concrete mix and ignimbrites for cobble stone projects in the city of Addis Ababa.

However the problems of quarrying operation along with little rehabilitation planning makes the negative impacts to the environment are very severe than other quarry projects found in Addis Ababa. This is due to the fact that:

- The quarry projects are found on environmentally sensitive areas and quarrying without leaving appropriate space the river banks,
- Many government's project are conducted without environmental impact assessment and rehabilitation planning,
- The earliest established quarries become non active and abandoned,
- The majority of the resource in the study area is depleted.
- Now a day, attention is given by the sub city administration and AAEPA to rehabilitate the site through plantation.

Thus, this site is purposively selected as a case study and the study has the potential for the practical implementation of the proposals of AAEPA project.

3.2.2. Materials and source maps

Equipments used to conduct the study include: compass, hand held GPS devices, digital camera and the following source maps as a material were used for this study:

- Base map- to investigate and extract the contours of the site to help make analysis on slope and topographic related issues of the study area.
- Satellite images (Multi temporal Landsat TM, Spot-5 and Google earth) to verify and ground truth the existing situations in the map and to carry out the analysis and support the photographic images. In addition, software's such as Arc GIS 9.3 (analysis and image processing), ERDAS IMAGINE 2011(image processing), ENVI 4.7(change detection and classification), Ms Excel (charts and graphs), MS Word for word processing and others were used.

3.2.3. Household Sampling Methods

Systematic random sampling methods have been employed to choose the households found in the study area. The bases for randomizing have been carried out by obtaining the housing number offered by the Woreda 05 & 10 Administration and GIS data base. Based on these 6,026 and 3,846 households are estimated in the two Woredas respectively. Out of these, about 900 households are estimated in Woreda 05 'Worku- sefer' and similarly 60 households are estimated in Woreda 10 Gelangura cobble stone project area. Thus the total households in the study area are about 960. Hence, to draw a representative sample of households (n) from the population the following formula used by Tiwari, A. and Ezana Haddis (2012) was used for one thousand households with commonly used confidence level were:-

$$n = \frac{t^2 \times p\ (1-p)}{m^2}$$

where, n is required sample size

t is confidence level at 90% (standard value is 1.645)

p is the probability of sample (50%=0.5)

m is margin of errors at 10%(confidence interval is 0.1)

So that,

$$n = \frac{(1.645)^2 X 0.5\ (1-0.5)}{(0.1)^2} \Longrightarrow 67.650625 \sim \mathbf{68}$$

Thus, from the total 960 households in the study area 68 housing units have been taken as a representative of the total population and studied for this paper. Therefore, based on more vulnerable to quarry operation problems in the study area, about 68 households have been systematically selected in the interval of 14 households to gather relevant data in the study area.

3.2.4. Vegetation Sampling Methods

Reconnaissance survey has been made during February 2013 and a map of the study area was sketched. This was used to identify the vegetation that are found into different land category in the study site: surrounding active mine area (532,500 m^2), abandoned quarry site/spoil heaps (676,600 m^2), plantation area (77,300 m^2) and remnant natural wood land (34,536 m^2) were the identified land category in the study site. Then, a systematic sampling method was used to locate the sample plots in order to generate the woody plant inventory data that could help to investigate species composition, diversity, abundance and dominance (Kent and Coker, 1992). The transect lines were laid in the ground starting at a purposely selected point at the edge of each land category to have a good opportunity of vegetation composition information in the study area. Keeping the north south directions with the help of a GPS compass parallel and straight transect lines was constructed. The transect lines were spaced 100-150 m between and within

the parallel lines (based on the area coverage and availability of woody vegetation from each land category in the study site). Hence, for tree and shrub assessment quadrants of 40m x 60m (2400m^2) were placed next to each other at the interval of 100 -150 m, followed the transect line at each site. The aim was to have a minimum of two sample plots at each land category depending on its size. The surrounding woody species within 200 m distance from the quarry centre, excluding the working quarry were documented.

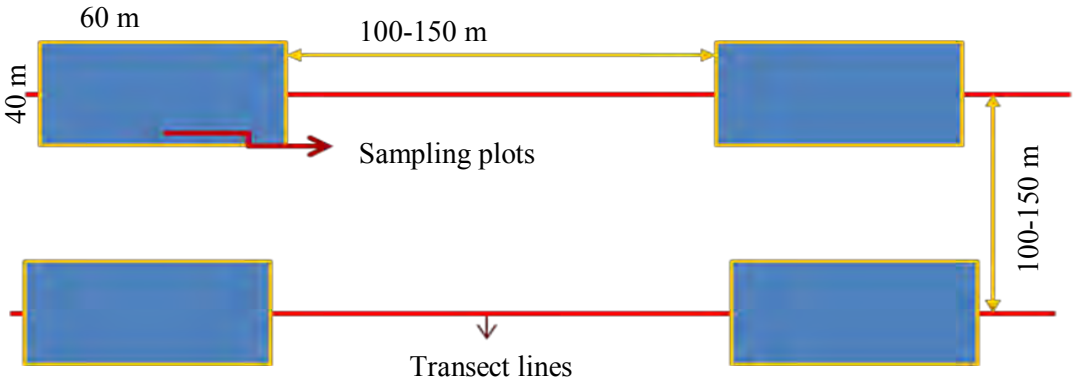


Figure 5: Sampling design to assess the woody species in the study area

In total twelve quadrants were sampled across the four land categories in the study area (annex C). Note, in all quadrats, additional trees and shrubs outside the quadrat boundaries but within 5m distance were collected and noted as present.

3.2.5. Data types

There were both primary and secondary data used for this study.

Primary data

The primary data sources for this paper were obtained from the cross-sectional survey through questionnaire, interviews and observation. Questionnaires were collected from the community, quarry operators, workers, Sub City of Akaki Kality Environmental Protection Office and Woreda 05 &10 Administrations and Addis Ababa City EPA. Questionnaire were administered to these groups of respondents to get their views and perception on the status and characteristics of the quarry operations based on the basic principles of environmental planning interventions for sustainable quarry rehabilitation program. In addition, extensive personal observations were also made to assess vegetation type and the environmental quality of the area.

Secondary data

Relevant secondary sources had also been consulted. Particularly, literatures including published reports, and unpublished sources from Federal institutions, Ethiopian legal frameworks of mining operation (policy, proclamation and regulations of mining activity), Addis Ababa City EPA, NGOs, ORAAMP (Office for the Revision of Addis Ababa Master Plan) documents, and the academia were extensively used. Moreover, Internet browsing and literature reviewing of best practices from selected countries in the areas of sustainable quarry rehabilitation planning and development were discussed.

3.2.6. Data collection instruments

Satellite image

Two cloud-free Landsat TM scenes, acquired on December 23, 1986, and December 10, 2012 with Row/Path: 54/168, were obtained to quantitatively measure and observe the trends & patterns of land use and land cover of the study area. The two images were taken at a similar time of year to minimize phonological effects. All images bands 1–5 and 7 have a spatial resolution of 30 m, and the thermal infrared band has a spatial resolution of 120 m. The image was acquired through the USGS Earth Resource Observation and Science (EROS) through http://glovis.usgs.gov/ free of charge, which had been geo-referenced by supplier to the Universal Transverse Mercator (UTM) map projection (Zone 37), WGS 84 datum and ellipsoid. In order to see the clear change in land use and land cover both satellite images of 1986 and 2012 were clipped by the same current boundary shape file.

Field survey

Field survey was employed with the help of base map and check list as per the objective of this study. The check list includes issues like the status of quarrying operation, rehabilitation, quarry planning and management practice and effects of quarry problem on the existing ecosystem, the drainage pattern of the site, the highly affected/problematic areas, and the condition of river bank, the condition of natural water ways, vegetation cover particularly woody species and other related issues in the study area.

Key informants Interview

It was conducted with people from different offices with different responsibility, knowledge and experience to collect data related to quarry planning, management problems, status of rehabilitation, land vulnerabilities occurred, major challenges to quarry rehabilitation program, the deriving factors to the change of natural water ways, and possible suggestions in the view of communities and quarry owners to handle the challenges of sustainable development. The community, quarry operators, workers, sub city of Akaki Kality Environmental protection office and Woreda 05 & 10 administrations, Addis Ababa city

EPA and other pertinent stakeholders working on mining sector were interviewed to get reliable data as they are the most concerned stakeholders (key informants) for sustainable development in the site.

Questionnaires

In order to obtain information the survey questioner were prepared in English and later translated to Amharic. The questionnaire includes both open-ended and close-ended questions. Open-ended questions enable respondents to freely express their options and view without prejudices, and hence obtain adequate information in relation to the objectives set for this study. However, the close-ended questions, apart from reducing time consumption, made it easier for data analysis and processing of factual information. This was particularly prepared to key informants to gather those data related to quarry planning issues, problems of quarry on rivers and the major challenges in promoting sustainable quarry restoration development in the study area.

3.2.7. Data analysis, interpretations and presentations

For the purpose of accomplishing the objectives of the study and to answer the research questions, the researcher edited, coded, classified and tabulated the collected raw data in order to make it ready for analysis. Information from primary and secondary sources was analyzed by using qualitative and quantitative methods. Data that have quantitative nature such as average, percentage and alike were compute with Microsoft Excel software.

Shannon-Weiner diversity index were used to infer about the total woody species diversity and evenness of species distribution (Kent and Coker, 1992). For analysis, either the cover-abundance value or individual abundance data of each encountered species were used.

$$\text{Diversity: } H' = -\sum_{i=1}^{s} pi \ln pi$$

$$\text{Equitability or evenness: } J = \frac{H'}{H'\max} = \frac{-\sum_{i=1}^{s} pi \ln pi}{\ln s}$$

Where:

H' = the Shannon diversity index

Pi = fraction of the entire population made up of species i

S = numbers of species encountered

ln = log basen

$\sum$ = sum from species 1 to species S

Moreover the species of the two different land categories were compared according to Sörensen (1948). The formula used to calculate the similarity indices is as follows:

Sörensen (1948): $Ks = \frac{2c}{a+b} * 100$

Where: Ks= Sörensen's similarity coefficient

c = number of species common to both sites

a = number of species found in site one

b = number of species found in site two

Whereas the satellite image for land use land cover change was analyzed using ERDAS IMAGINE 2011(image processing) and ENVI 4.7 software packages. Different preprocessing methods were implemented before the classification and the change detection. These include layer stacking, geometric, radiometric, atmospheric, and topographic correction. Subsequently, clearly recognized objects on Google earth and Spot-5 images were digitized and taken as AOI (Area of Interest) to classify the Landsat image with ENVI software. Furthermore, spatial analyses have been conducted using GIS (Geographic Information System), Archi CAD and Auto CAD software as analytical tools. Finally, the analyzed data were presented with maps, tables, graphs and pictures.

Summarized methods followed to formulate this study

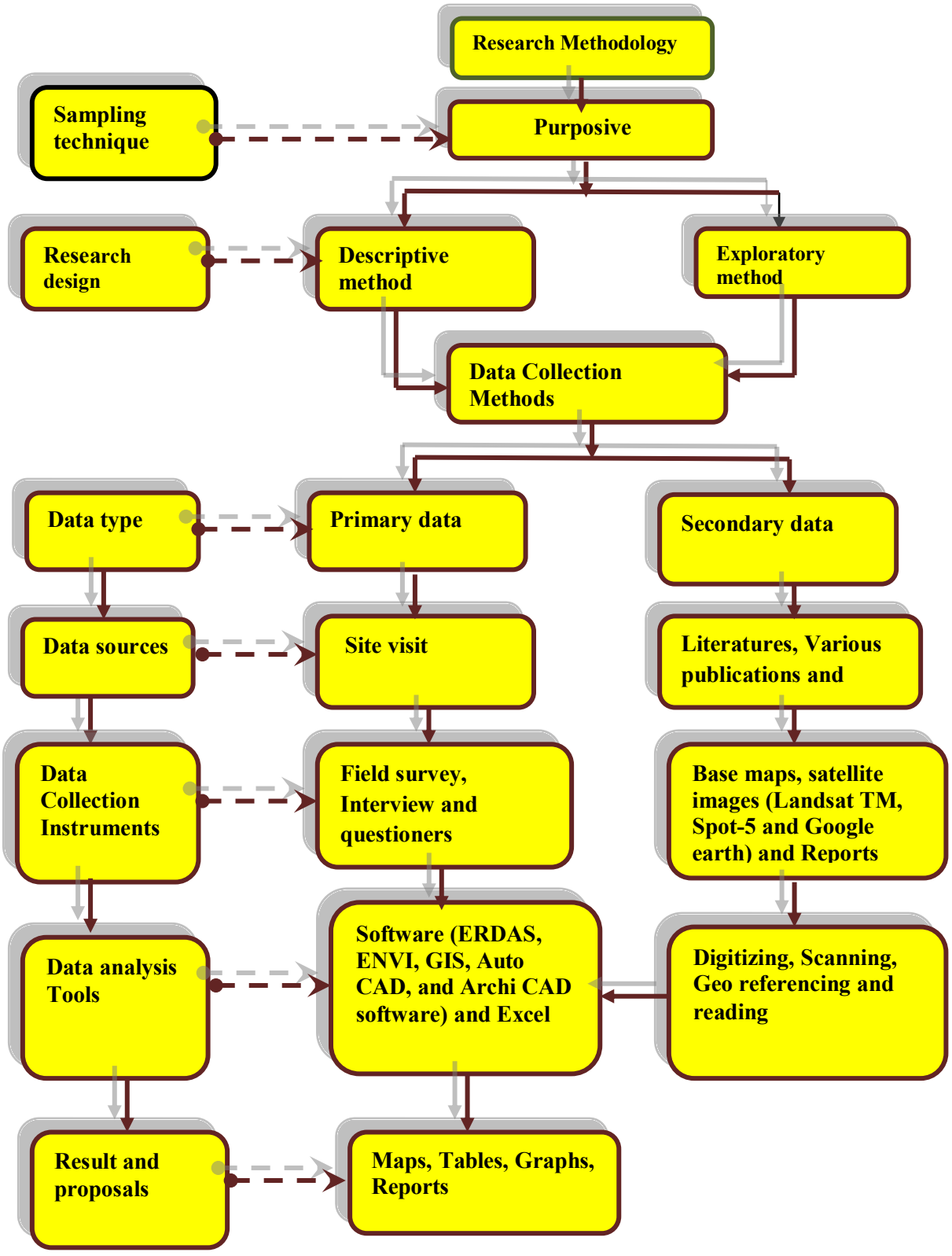


Figure 6: Flow chart of research methodology

CHAPTER IV

4. RESULT AND DISCUSSION

In this section, based on the information gathered by using questionnaire and interview from quarry developers and their employees descriptive analysis was employed. Hence, from proposed eleven quarry developer respondents all of them were interviewed and returned the questioners. Furthermore, other key informants: (Addis Ababa Environmental protection Authority (EIA and mining version), Environmental Protection Office of Bolie and Akaki Kality Sub Cities, Land Development and Urban Renewal Offices of Akaki Kality Sub City , Woreda 05 &06) were provided important data through interview and questioner.

4.1. Quarry operation in the area

There are government, micro and small scale enterprise and privately owned quarry sites in the study area. They are quarrying basalt, ignimbrite and selected materials. The operation of these materials also differs based on their capacity and machinery requirement.

Table 3: Distribution of quarry developers in the study area

Types of organization	Number of Quarry developer	Types of mine
Governmental	3	Basalt, Selected material and Ignimbrite
Private	7	Basalt and selected material
Small and micro enterprise	1	Ignimbrite
Total	11	

Based on the table above 27% of the quarry is administered by government, 63.5% owned by private investors while the remaining 9.5% is owned to micro and small scale enterprise.

According to field observation and interview made with the quarry developer there were different quarrying operations take place in the study area, such as:-

- Quarry site preparation
- Stripping of overburden
- Drilling

- Blasting
- Excavating
- Transporting
- Crushing
- Screening and
- Sorting of the products to appropriate sizes

Quarry Site Preparation

This activity includes stripping of soil and vegetation cover, surface leveling, construction of access road and site offices or camps, etc. However, the majority of access road in the study area was poorly designed and closing the natural flow of the river. In addition the roads were damaged during the rainy season through river flooding (figure 7).

Figure 7: The current access road block the flow of water

The above figure reveals different vehicles were cross the river through poor and temporary constructed road, which pollute the river and affect the river ecosystem at the whole.

Stripping

This is the operation of removing of volcanic tuffs together with black cotton soil (top soil). This material has excavated and stripped off by a dozer in order to exploit minerals with the required quality.

Figure 8: The striping of overburden material in the study area

Drilling

Particularly AACRA and CRBC Addis Engineering PLC used drilling and blasting methods of rock excavation in the study area. The principle of quarry drilling was to obtain blast holes and drilling operations carried out using hydraulic drills. The diameter, depth, number and spacing of boreholes require very careful considerations for getting the most beneficial results. In general, the type of the explosive being used determines the diameter of the hole. The depth of blast hole depends on the volume of rock to be broken in one shot. In this regard both AACRA and CRBC used 12 m depth hole.

Figure 9: Drilling and blasting preparation to fragment the rocks in the study area

These explosives can induce cracks, break, open or throw away limited volumes of rock around it on exploding. However, these depths were beyond the limit and result negative impact to the surrounding environment of the study area. According to AAEPA 2012 report on basalt and quarrying processing the maximum allowed quarrying depth is 10 m.

Excavation and loading

Following the blasting operation, the fractured rock has to be excavated prior to loading. Thus, dozers or excavators are alternatively performing the excavation activity in the study area.

Figure 10: Excavation and loading selected materials in the study area

Crushing & Screening

The objective of crushing is to accomplish size reduction and occasionally for obtaining additional requirements of different products used in various fields of applications. Specification on gradations shall be met by screening and classifying of the crushed aggregates with the use of vibrating screens. The crushing process in general starts with the feeding of blasted rock materials into the crushing unit of feed hopper by a front-end wheel loader or direct feed by a dump truck into the feeder.

Figure 11: Crusher plantation in the study area

4.2. Evaluation of the current situation of quarry operation and its effect

4.2.1. Excavation

The real geological condition of the site and their geological setting will be cleared to the operator or site engineer before they start the earthwork. Hence, it assists to carry out excavation work economically, safely as well as to efficiently utilize the limited natural resource.

From the definition, excavation is an act of removing, moving and depositing the surface of the earth's outmost crust. Successful excavation of solid rock necessitates preliminary determination of rock units and their boundaries or contacts, the nature of discontinuities to be encountered, the possible presence of water, and the presence of any weathering or alteration. Furthermore, the volcanic tuffs together with thick layer of black cotton soil have to be excavated and stripped off by a dozer in order to exploit minerals with the required quality. It is also strongly recommended that, the overburden debris to be excavated must be kept protected at specific sites for future rehabilitation program and get well compacted to protect pollution of the nearby stream from such loss of organic debris by erosion. According to the field observation and the respondent's explanations, however, the existing excavation and management practice of the mining activity in the study area is very poor and not consider the above listed issue. In addition the boundaries of the project area are not well demarcated to separate one project site from the other and the operation is not consider the environmental issue of the site. These are mainly the quarry projects in the study area starting without site investigation and as the sites are highly affected and left as degraded make the rehabilitation method complex and increase cost. The overburden materials were lost through erosion and it is thrown to the river carelessly. As a result it leads in diverting the natural flow of the river and highly affected the river ecosystem in general.

Figure12: Carelessly dumped overburden material and bridging of the river

4.2.2. Estimated loss of overburden material in the excavated site

The removal of overburden is the first stage of a quarry development where over burden (top soil and volcanic tuffs) materials are removed to expose boulders and the underlain rocks. Excavators and dozer are used to remove the overburden material. Nutrients are relatively abundant in the topsoil but are associated with the finer soil fractions that are most subject to erosion. Soil loss is, therefore, always accompanied by nutrient loss. In soils that are inherently fertile and deep, loss of fertility due to erosion may be short term and can be reversed by application of manure and fertilizers.

Erosion may, however, lead to a situation that cannot easily be reversed in areas with shallow soils or soils in which most of the nutrients are accumulated in the topsoil. It is, therefore, important that soil is conserved before such irreversible damage has taken place. Prevention is better than cure!

To estimate the loss of overburden material in the abandoned quarry site, based on the estimation of the quarry developer and field observation of the nearest mined out profile the average thickness of the overburden material was estimated to be 3 meters depth. Total areas of the abandoned quarry site in the study area were calculated to be 68 hectares (680,000m2). Therefore, the volume (V) of volcanic tuffs together with black cotton soil had been removed as useless is calculated as:

Volume = Total area of the abandoned quarry sites in the study area X average depth of the top soil with volcanic tuff materials

$$V = 680000\ m^2 \times 3\ m = 2{,}040{,}000\ m^3$$

Therefore about 2,040,000 m^3 top soil and volcanic tuffs (overburden materials) were lost through erosion. This is mainly because of poor practice and management of quarrying system (poor design of quarrying process in the site) such as: Poor design of cut of drain.

To protect the quarry site against the run-off water, a ditch has to be constructed above the quarry site. This ditch will then collect water from the catchments above the quarry and conveys to the downstream valleys during rainy season. However, the current quarrying operation is not consider the drainage system of the site and susceptible to all soil erosion types (sheet, rill and gully formation). As well as the stripping of soil and vegetation cover were simply dumped to the near river bank and transported by flooding.

4.2.3. The effects of quarrying operation in the study area

- **Problems on water resources (river)**
  - Altering the surface over which water flows
  - Changing the pattern of surface water flows
  - Changing the surface and groundwater resources quantity and quality, such as partial blockage of rivers due to roads or crushers construction over or within the right of way of streams and water contamination by particulate matter or by waste material deposited on river banks
  - Increasing the risk of contamination to underlying aquifers due to removal of the natural filter medium

- **problems due to vibration**

Vibration, due to blasting, is transmitted through the ground and air pressure waves. It has the following effects:

- Shaking of buildings and people which cause damage and nuisance
- Propelling of rocks fragments in the air due to explosion which is dangerous to people and property both inside and outside the site
- Slight disturbance to the deep subsurface structure that may lead to modifications in water Courses

- **Problems on landscape**
  - Landscape changes and visual intrusion can result from quarrying activities. Landscapes are affected by:
  - Changes in land values, quarrying activities and shape, colors contrast, deforestation, waste dumps, product stockpiles, crushing or washing plants, haul roads, soil erosion and effects of displacing agricultural activities.

Note: non-Operational Quarries or abandoned sites cover an area of more than 67 hectares out of the total 328 hectares in the study area (refer table 4). According to some quarry developer respondents, the abandoning of such quarries has different reasons such as:

- The quarry has reached to the property limits, or
- The quarry was operating without a license and left without rehabilitation.

4.3. The current rehabilitation of quarry site in the study area

Rehabilitation has been of growing interest to science in recent times for the reasons stated at the reviewed literature part above. Several Journals have been dedicated to the subject and some authors have attempted to produce protocols for rehabilitation planning and management (Aronson et al. 1993; Hobbs and Harris 2001 and Martínez and López-Barrera 2008). The two major approaches to rehabilitation are to allow natural succession to occur, with minimal intervention, or more technical rehabilitation with landscaping, substrate amendments and planting. These approaches are determined by the environmental conditions of the area of interest, the level of degradation and the goals of the rehabilitation project.

Currently, only 2.4 percent of the study area rehabilitated with exotic plant species particularly *Acacia decurrens* and *Acacia saligna*. However there is no proper rehabilitation practice undergoing. The problems are identified as:

- Land instability (slope instability),
- lack of planting appropriate plant species that are acculturated to the site micro climate
- Absence of fencing
- Some of the plants that are planted on the site are frequently eaten by cattle,
- lack of soil conservation and
- Lack of appropriate improvement measures.

The following figure shows the current rehabilitation of the site.

Figure 13: Poor practice quarry rehabilitation efforts in the site

The table below shows the response obtained from the local residents on the tree species which were in the site before the site is licensed for quarrying activity.

Table 4: The lands cover background information of the study area

No.	Category	No. of respondents	rank
1	All covered with forest	13	3
2	Partially covered with forest	35	1
3	Covered with bush/shrub	8	4
4	Agriculture	29	2
5	Bare land / abundant area	6	5

The above table illustrates that the area was partially covered with forest, particularly the buffer or both sides of the river was covered with different species of forest and shrubs, such as *Acacia abyssinica, Croton macrostachyus, Carissa spinarum, Vernonia amygdalina, Ficus sycomorus, Millettia ferruginea, Ficus sur,etc.*were described by the respondents of the community. The majority respondent states that the vegetation covers were highly similar to the existing remnant natural wood land in the study area.

Figure 14: woody species found in the study area

The above figure shows plant species found in the study area. This was dominated by a species of Acacia abyssinica.

The current cobble stone and other quarry projects in the study area was an agricultural area. Moreover, as some respondent described the quarry project in the study area has long history and abandoned without any rehabilitation mechanism.

Figure 15: Abandoned /bare land in the study area

The left picture shows a quarry site owned by Berta construction Plc. This was started in 1986. This quarry is currently not operational and abandoned. While the picture in right side is a quarry site owned by BH trading, started its operation in 1987. However, the quarry has ceased its operation.

Figure 16: field photograph and Google earth image, 2013

The figure above revels the presence of bridges, access road, and employment opportunities available in the site. The map further shows the proximity of the quarry site to residential areas and water bodies, in addition the state of land degradation in the study area have been well illustrated.

4.4. Land use/ Land Cover of the study area

4.4.1. Existing land use land cover of the study area

The following results were obtained based on the data analysis. The land use and land cover percentage and the area coverage of each land category were derived from Addis Ababa base map and field survey. Thus it has resulted nine land use and land cover classes (see the following table and map).

Table 5: Existing Area Statistics and Percentage of LULC for each class

Land use/land cover	Area (ha)	Percentage (%)
Road	25.91	8
Residential	67.46	20.5
Active mining area	53.25	16.6
Cobble stone project site	44.85	14
Crusher plantation site	23.04	7.0
Abandoned quarry area and spoil heaps	67.89	21
Agriculture (farm land)	25.7	8
Grazing land	3.6	1.3
Tree Plantation area	7.73	2.5
Natural wood land	3.5	1.1
TOTAL	328.34	100

As shown in the table above the study area covers an area of 328.34 hectares, which comprise in hectare of road 25.91 (9.5%), residential 67.46 (20.5%), Active mining area 53.25 (16.6%), Cobble stone project site 44.85 (14 %) , crusher plantation site 23.04 (7%) , abandoned quarry area and spoil heaps 67.89 (21 %), farm land 25.7 (8%), grazing land 3.6 (1.3%), tree plantation area 7.73(2.5%) and natural wood

land 3.5 (1.1%) of the total land cover. Thus the majority of the study area is dominated by abandoned site and the area is degraded.

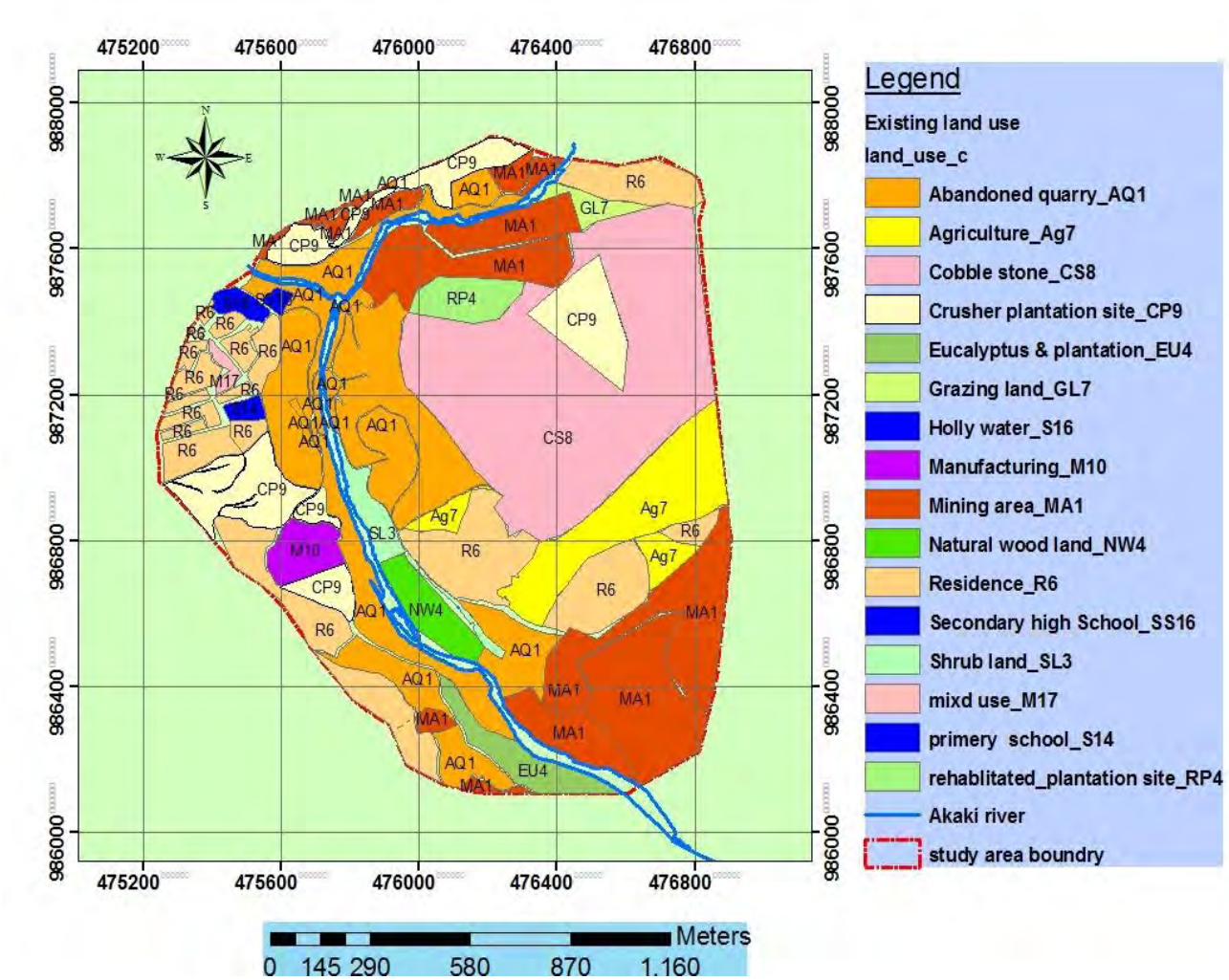


Figure 17: Existing land use map of the study area *(Source: field survey, 2013)*

The map clearly shows that the dominant land use of the study area is: abandoned quarry area & spoil heaps (unstable cliff) and active mining area which comprises basalt, selected material and cobble stone (ignimbrite) quarry site. Specifically, the area along the river side has been severely affected and the natural landscape disrupted mainly because of inadequate quarry planning and management practices of quarry development.

4.4.2. Land use land cover change of the study area

The land use and land cover percentage and the area coverage of each land category for each study year were derived from the two satellite images. Image classification of 1986 and 2012 has resulted five land uses and Land cover classes in the study area: Built-up, Agriculture, Forest, Grass Land and Bare Land.

The following table shows classification scheme for land use land cover of the study area. It was developed from the reclassification/regrouping of the existing land cover and land use classification system.

Table 6: Land covers Classification Scheme

Land cover class	Description
Built-up	Developed - Areas covered by considerable constructed materials (e.g. asphalt, concrete, buildings, etc) that can be for residential, commercial services, transportation, communications, industrial and commercial.
Agriculture land	Includes land used to grow field crop and non- cropped bare fields (Fallow land) that is land being tilled.
Bare land	Areas characterized by bare rock, bare lands (exposed soil and rock), Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface and abandoned quarry site.
Forest	Areas characterized by vegetation cover (It can be natural and plantation; tree canopy have considerable percent of the cover).
Grass land	This land cover includes grazing areas dominantly covered with grasses.

The following results were obtained based on the analyzed image, in 1986 agriculture was primarily practiced throughout the study area and it covers 46.64% followed by grass land and forest which accounts 25.03% and 14.62% respectively. While the bare land and Built-up covered smallest part of the study area.

The table below revealed that the land cover in two different times showed significant changes. Particularly, bare coverage was drastically changed from 8.65% in 1986 to 39.44% in 2012 that is almost five times the initial year. Thus these result made an evidence for data obtained from the residential response show that the current expansion of quarry projects and poor rehabilitation of the site was high.

Table 7: Area Statistics and Percentage of LULC for each year

Land Use Land cover Category	1986		2012	
	Area (m^2)	Area (%)	Area (Km^2)	Area (%)
Bare Land	283938.55	8.65	1294888.52	39.44
Forest	479968.44	14.62	207818.68	6.33
Agriculture	1531479.12	46.64	1134925.20	34.57
Grass Land	821745.73	25.03	430780.88	13.12
Built-up	166268.16	5.06	214986.71	6.55
Total	3283400.00	100.00	3283400.00	100.00

In addition, the classification result of 1986 that shows area covered by grass land and agricultural land was spread out at all sides of the study area and forest located in the northern, north eastern and south part of the study area. (Figure18).

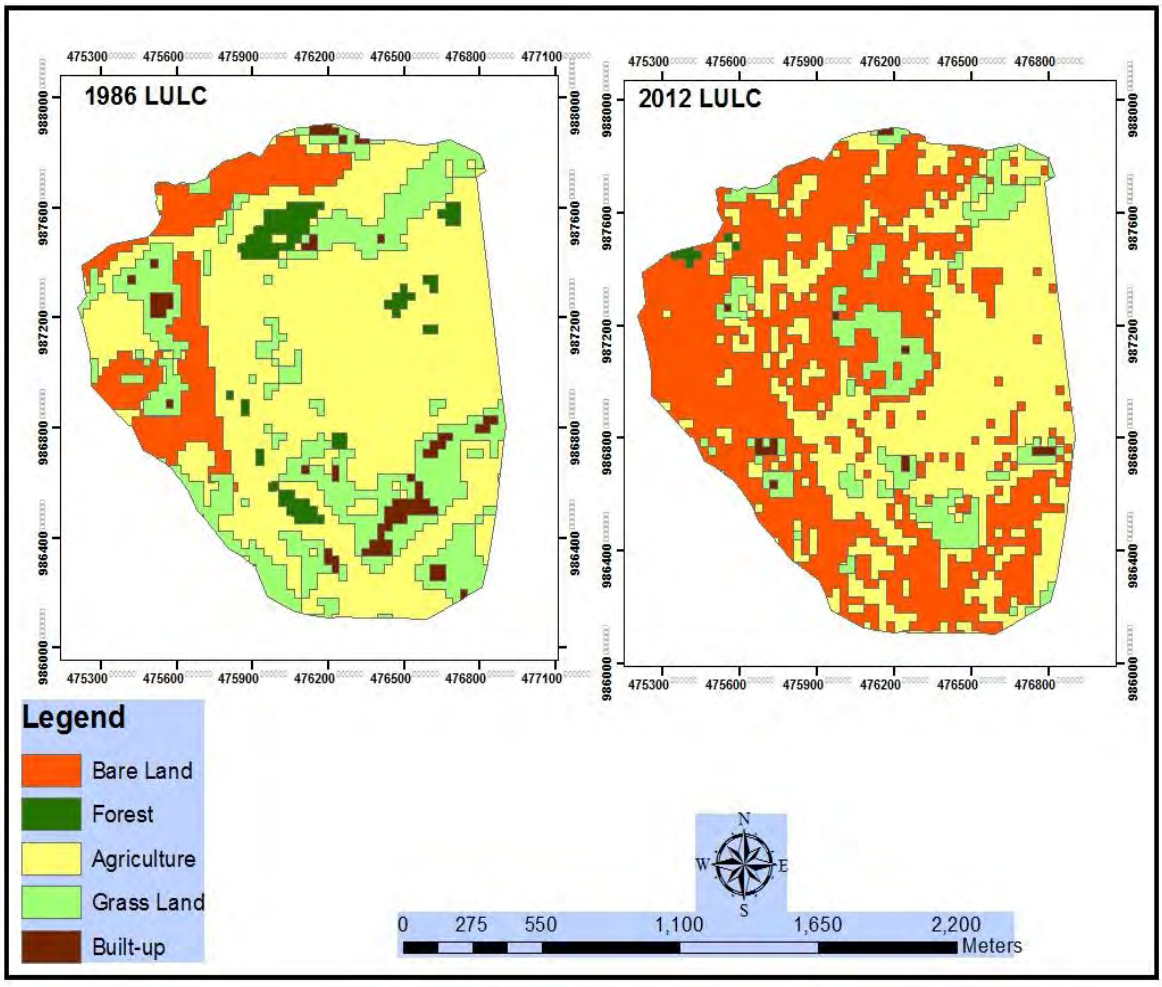


Figure 18: Land Use and Land Cover Change Map of 1986 &2012

In 2012, bare land was the largest LULC category in the study area. It accounted for 39.44% of the total land. Agriculture was the second largest category, covering 34.57%. Grass land was widely distributed, accounting for 13.12% of the land, while forest land and built-up covered 6.33% and 6.55%, respectively (Table 7). In general both bare land and built-up areas were increased. While the forest coverage, agriculture area and grass lands were diminished compared to 1986 area coverage.

4.4.3. Trend and Rate of Land Use and Land Cover Change

Analyzing the change at different times helps in determining the causal factors, the level of the change, impact of the change and the respective management techniques. The rate of change (difference in area between the final and the initial state of each land use and land cover category over the specified time period or number of years in each period) across the study period has also been analyzed based on the statistical data derived from the images (Table 8).

Table 8: Change in Extents and Rate of LULC

Land Use Land cover Category	Change 1986-2012		Annual rate of Change 1986-2012	
	Area (m^2)	Area (%)	Area (m^2)	Area (%)
Bare Land	1010949.97	30.79	38882.69	1.18
Forest	-272149.76	-8.29	-10467.30	-0.32
Agriculture	-396553.92	-12.08	-15252.07	-0.46
Grass Land	-390964.85	-11.91	-15037.11	-0.45
Built-up	48718.55	1.48	1873.79	0.06

The table above shows that bare land and agriculture land changed significantly; the former was increased in 101 hectares (1010949.97 m^2) with 3.9 ha (38882.69m^2)/yr (1.18%) rate of change, while the later one had decreased with 39.7 ha (396553.92m^2) by 1.5 ha (15252.07m^2) /yr (0.46 %) negative rate of change. The Forest coverage showed a major change that has declined with 1.1 ha (10467.3 m^2) per year (0.32%) negative rate of change. Built-up area showed very small expansion (4.9 ha) and the rate of increase over the period has been estimated as 0.2 ha (1873.79)/yr (0.06% per year) which is relatively the lowest rate of change. (Table 8 and figure 18).

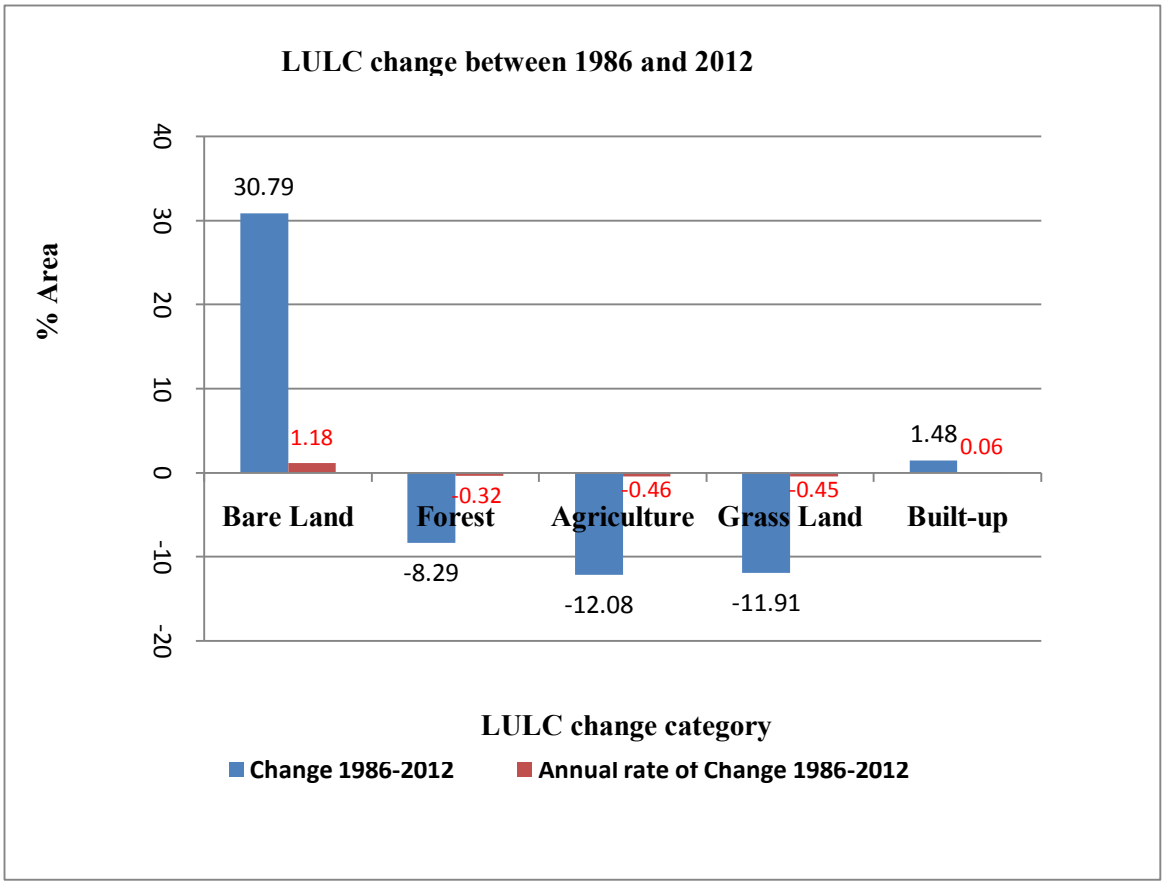


Figure 19: Land Use and Land Cover Change over the study period

Generally the trend and rate of land use and land cover between the 1986 and 2012 shows that a reduction in agriculture, grass land and forest, whereas the bare land has highly increased from 1986 to 2012 (Figure 19).

4.4.4. Land Use and Land Cover Dynamics

The matrix of change detection result shows results from one class change to another. This method is useful to understand how classified land covers have changed over time. Table 9 shows the land use land cover dynamics between 1986 and 2012. In the table the diagonal cells indicates the stable land classes' which were not changed to other classes between 1986 and 2012. But the off diagonal areas of each class indicate the changes of one class to the other by losing or gaining from the initial state. The column total of the table indicates the total area of that particular land use and land cover class of the initial state (1986); whereas the row total indicates the area of that particular land use land cover class of the final state (2012).

Table 9: Land Use Land Cover Change Transition Matrix

LULC Change Detection Statistics		Initial State Image in 1986 (m^2)					
		Bare Land	Forest	Agriculture	Grass Land	Built-up	Class Total
Final State Image in 2012 (m^2)	Bare Land	86363.13	268946.84	767149.91	122174.57	50253.63	1294888.52
	Forest	49893.85	77481.06	20047.91	42174.57	18221.63	207818.68
	Agriculture	48893.85	40496.84	700106.47	342174.57	3253.63	1134925.2
	Grass Land	55493.85	28046.84	17938.91	293047.44	36253.63	430780.88
	Built-up	43293.85	64996.84	26235.91	22174.57	58285.63	214986.71
	Class Total	283938.55	479968.44	1531479.12	821745.73	166268.16	3283400
	Class Changes	197575.4	402487.36	831372.64	528698.28	107982.52	

Based on the land use land cover transition statistics between 1986 and 2012, 767149.91 m^2 of agricultural land, 268946.84 m^2 of forest, 122174.57 m^2 of grass land, and 50253.63 m^2 built ups were converted to bare land. From 1986 to 2012, about 20047.91 m^2 of agricultural land was converted to forest, 17938.91 m^2 to grass land and 26235.91 m^2 to built- up. On the other hand agriculture gain from, forest 40496.84 m^2, grass land 342174.57 m^2, and bare lands 48893.85 m^2 and built up 3253.63m^2. While 700106.46 m^2 of the area of agriculture remains stable.

4.5. Vegetation survey

4.5.1. Number of species recorded in the sample plot

During vegetation survey different species were recorded in the sampled areas to judge the composition and related vegetation (woody species) qualities in the study area. The recorded species graphs to the four land category in the study area are given in Figures 20.

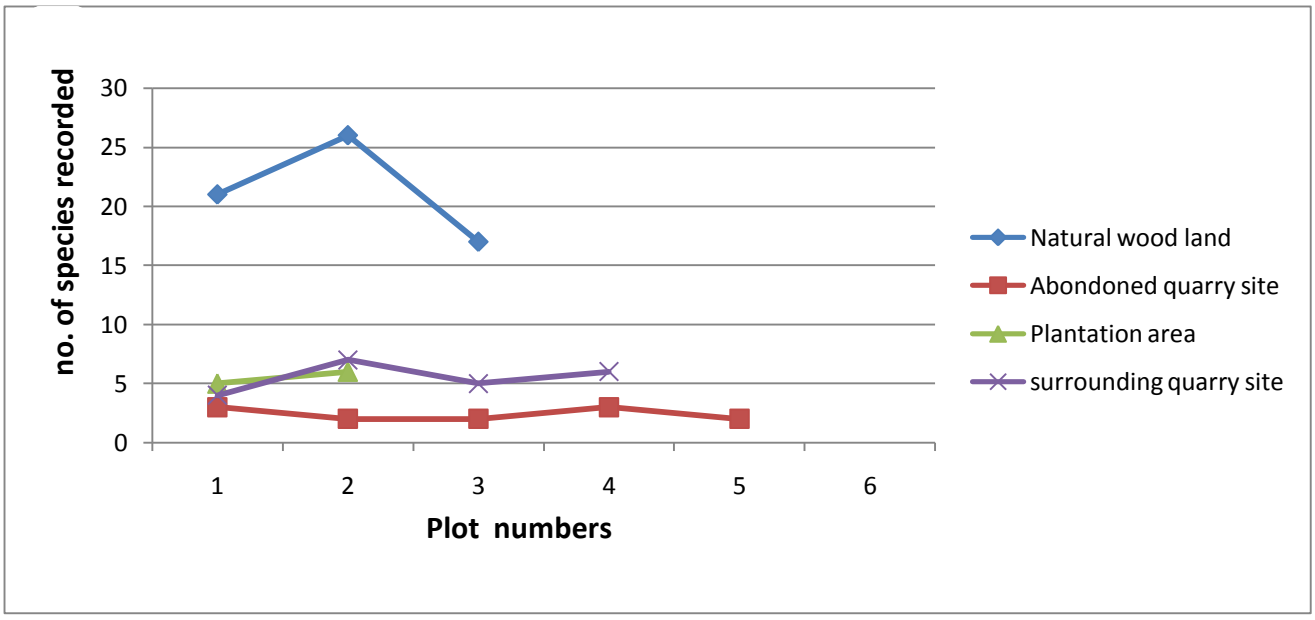


Figure 20: Number of woody plants (all trees and shrubs) for the different land uses types of the study area.

The above figure shows that a total of twelve quadrats were sampled across the four land categories i.e., three sample plots were taken in the natural wood land. At the middle of the remnant natural wood land had the highest diversity (about 26 types of species were recorded) (Annex C). This could be due to nature of the original vegetation and the relative lower anthropogenic impact allowing a more heterogeneous vegetation community than others. As the respondents explained it was very rich in species before the quarry work started. Also five sample plots were taken in the abandoned quarry site and had less woody species diversity than surrounding active quarry site. There were no trees in abandoned quarry site because it is degraded and difficult to survive or grow trees; however, there were an indicator of succession take place in the degraded site. As a result *rumex species* dominantly cover most parts of the abandoned quarry site in the study area. Moreover the four sample plots of the surrounding mining area have different scattered woody plants and show relatively high vegetation diversity next to the natural wood land. While only two sample plots were taken in the plantation area and the above graph show that the heterogeneity of the plantation were almost constant and dominated with exotic specious

(*Acacia decurrens* and *Acacia saligna*). The following picture shows different vegetation cover with different land uses of the study area.

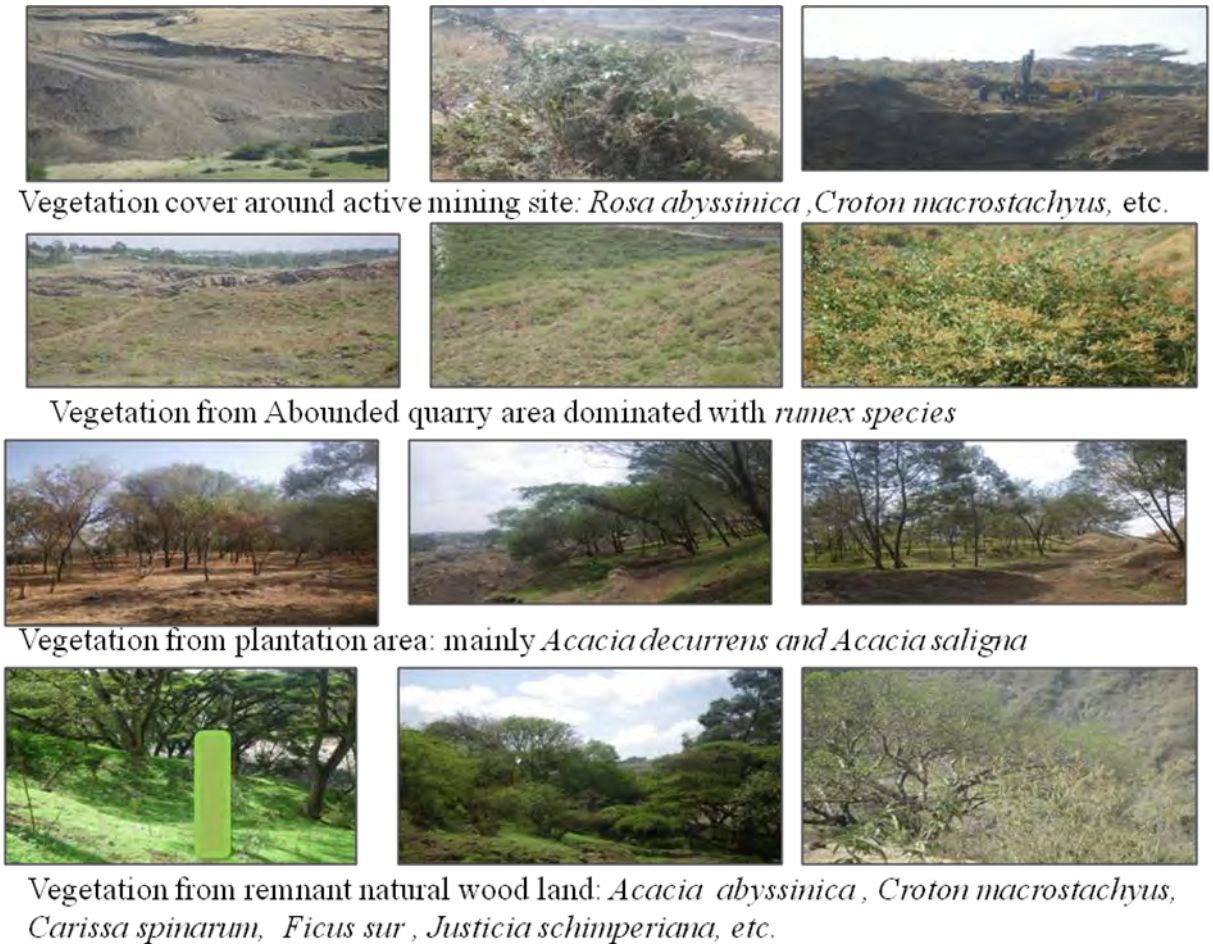


Figure 21: Different vegetation covers at different category in the study site

4.5.2. Diversity, evenness and similarity of Woody Species

As it can be seen in Table 9 and Annex D, the species diversity of woody plants of the natural wood land was greater than other sites. The high diversity values of natural wood land compared with other areas in the study site increase the opportunities of seed source conservation, particularly the woody species. Increase in the value of the indices (H') indicates more species diversity. While the (J) evenness value looks at the abundance distribution among the species occurring in a certain site. The higher the value of J, the more evenly distributed is the abundance among the species (Kent and Coker, 1992).

Table 9: Shannon-Wiener indices of diversity and evenness of woody species in the different land category

No.	Land category in the study area	H'	J
1	Natural wood land	2.751	0.844
2	Surrounding mining area	2.395	0.999
3	Abandoned quarry area	0.662	0.369
4	Plantation area	0.894	0.556

The above table reveled that natural wood land has higher diversity of woody species than others land category with relatively lower evenly distributions of woody species than the vegetation found in the surrounding of the mining area. The woody species recorded in the surrounding mining area show higher diversity index next to the natural wood land. Moreover, more evenly distribution values of woody species were recorded than other sites. However, these species found in the surrounding area of the mining area will be cleared and disturbed through the expansion of mining operation in the area.

Similarity

The species of the four different land categories were also compared according to Sörensen (1948) and the method considers presence/absence of species. When all species are taken, the species compositions of natural wood land were different from the other land category. *Natural wood land* was more different from their corresponding *plantation area* than *abandoned quarry* area. *Surrounding mining area* had 94.73% and 30.77% species in common with *natural wood land* and *abandoned quarry* area respectively (Table 10).

Table 10: Species similarity indices of the different land use types, when all species are used for comparison

No.	Land category in the study area	Sörensen (1948)
1	Natural wood land vs. Surrounding mining area	94.73
2	Abandoned quarry area vs. Natural wood land	33.33
3	Plantation area vs. Natural wood land	24
4	Surrounding mining area vs. Abandoned quarry area	30.77

4.5.3. Species composition and abundance of woody plants

A total of 33 species of woody plants of both trees and shrubs were recorded in the study area. Seventy nine percent of the species were found only in the remnant natural wood land, six percent of the species were found in the abandoned quarry site, nine percent of the species were found in the surrounding quarry site, while about six species were recorded in the plantation area.

Table 11: Woody vegetation presence/absence by vegetation type for all sample plot data combined.

No.	Species name	category	NWL	No.	AQ	No.	SQ	No.	PA	No.
1	*Acacia abyssinica*	tree	1	22	0	-	1	2	1	1
2	*Croton macrostachyus*	tree	1	35	0	-	1	1	0	-
3	*Ricinus communis*	shrub	1	4	1	2	0	-	0	-
4	*Carissa spinarum*	shrub	1	14	0	-	1	3	1	3
5	*Euclea racemosa*	Shrub	1	43	1	1	1	4	0	-
6	*Opuntia ficus-indica*	Shrub	1	7	0	-	0	-	0	-
7	*Euphorbia abyssinica*	tree	1	3	0	-	0	-	0	-
8	*Entada abyssinica*	shrub	1	12	0	-	1	1	0	-
9	*Rumex sps.*	Shrub	1	8	1	39	1	5	0	-
10	*Justicia schimperiana*	Shrub	1	3	0	-	1	2	0	-
11	*Grewia villosa*	Shrub	1	19	0	-	0	-	0	-
12	*Carissa spinarum*	Tree	1	5	0	-	1	3	1	2
13	*Vernonia amygdalina*	tree	1	8	0	-	1	2	0	-
14	*Capparis tomentosa*	Shrub	1	4	0	-	0	-	0	-
15	*Casuarina equisetifolia*	tree	1	2	0	-	0	-	0	-

16	*Senna didymobotrya*	Shrub	1	6	1	2	1	4	0	-
17	*Buddleia polystachya*	tree	1	2	0	-	0	-	0	-
18	*Ficus sycomorus*	tree	1	10	0	-	0	-	0	-
19	*Maesa lanceolata*	Shrub	1	3	0	-	1	1	0	-
20	*Ficus sur*	tree	1	2	0	-	0	-	0	-
21	*Millettia ferruginea*	tree	1	1	0	-	0	-	0	-
22	*Grevillea robusta*	tree	1	3	0	-	0	-	0	-
23	*Ficus carica*	tree	1	3	0	-	0	-	0	-
24	*Phoenix reclinata*	palm	1	2	0	-	0	-	0	-
25	*Acacia decurrens*	tree	0	-	0	-	0	-	1	72
26	*Croton macrostachyus*	Shrub	0	-	0	-	1	2	1	1
27	*Eucalyptus camaldulensis*	tree	0	-	0	-	1	4	0	-
28	*Acacia saligna*	tree	0	-	0	-	0	-	1	59
29	*Rosa abyssinica*	Shrub	0	-	0	-	1	1	0	-
30	*Aloe vera*	Succulent shrubby	1	3	0	-	1	2	0	-
31	*Premna schimperi*	shrub	1	2	0	-	0	-	0	-
32	*Acacia lahai*	shrub	0	-	1	1	0	-	0	-
33	*Combretum collinum*	Shrub	0	-	1	1	0	-	0	-
Total				226		46		37		138

Note: 1 = species present, 0 = species absent. While, NWL=Natural wood land, AQ= Abandoned quarry site, SMQ= Surrounding quarry site and PA= Plantation area.

The abundance of woody plants of both trees and shrubs was highly varied over the four land use types (figure 22). The remnant natural wood land area has the highest abundance with 226 plants (50.5% of the total). The plots surrounding the quarry sites had 37 plants (8.3 % of the total), the abandoned quarry and spoil heaps area had 46 plants (10.3 % of total), and the planted area survey recorded only 138 plants (30.9 % of total abundance).

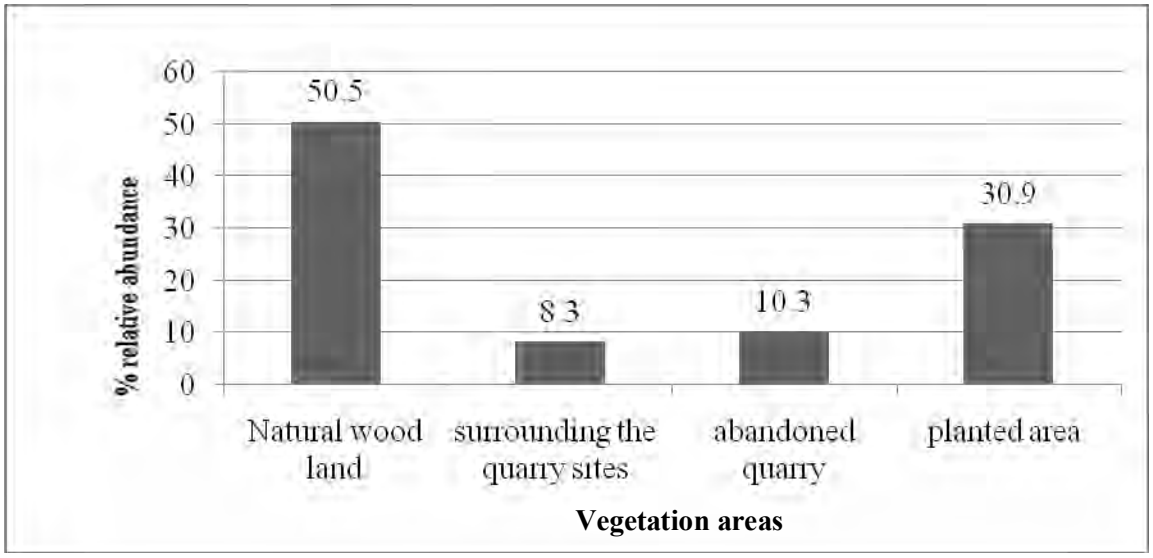


Figure 22: Total % relative abundance of all woody species across the vegetation types (calculated as the total abundance of all species in each vegetation type show as a percentage of the combined total for all vegetation types).

This shows a clear distinction between the four areas. The natural wood land clearly dominates with over 50% of the abundance of individual woody species. Similarly plantation area had 30.9% of individual woody species with dominant species of *Acacia decurrens* and *Acacia saligna* (Table 11). While the abundance of woody species from other land category types drop off rapidly.

4.6. Evaluation of the current situation in quarry management

4.6.1. Weaknesses related to sustainable quarry management

According to field observation and information obtained from key informants the mining area in 'Worku-sefer' faces many barriers related to the goals of biophysical integrity, social vitality and economic sufficiency as do other mining areas around the city. These barriers include the non-approval of the quarry master plan, continuing biophysical degradation from abandoned mines and current practices, economic challenges, limited enforcement capacity and social inequity.

- **Abandoned mines and problems**

As is the case around 'Worku –Sefer' with abandoned quarry sites, one of the major problems is accountability. Determining as to whom responsible for the cleanup is a serious barrier to any remediation attempts. The fact that government quarry developer take no responsibility for damage done is a significant barrier to restoration. The difficulty in holding any one responsible for environmental damage represents a large gap among the necessary preconditions for a sustainable mining region, as remediation is required in order to advance toward a sustainable future.

- **Economic challenges**

Mining sector or industry requires high investment capacity to utilize the resource wisely and efficiently. Issues surrounding the problem of remediation derive from the lack of appropriate technology utilization. The tight economic situation also makes it difficult for the industry to invest in cleaner more appropriate technologies, which again, further hinder progress towards a more sustainable mining culture.

- **Barriers to regulatory enforcement**

The barrier to more sustainable mining in the study area is the limited capacity of regulating bodies to carry out their duties. With only a staff of four in AAEPA, the workload for the concerned office overwhelms the capacity of the available staff. The office is hampered in its ability to carry out many environmental responsibilities, including quarry site inspection. The limited capacity to carry out the mandate has led to a lack of enforcement of environmental regulations creating a large barrier to sustainable mining industry in the area.

- **Quarry closure and rehabilitation problems**

One of the main barriers in Addis Ababa in general and 'Worku-sefer' quarry projects in particular is lack of the proper technical, financial, law enforcement mechanism with respect to quarry rehabilitation and closure legislation. Furthermore, as many quarry developer respondents explained, investors lack instruction and guidance from the government regarding quarry closure and end point criteria for rehabilitation.

4.6.2. Opportunities

As the case in the rest of the world, changes are taking place in government and industry to address environmental impacts of quarry management. These changes can be noted in academic institutions, environmental and labor legislation and regulations as well as changing corporate and civic culture.

- **Academic institution**

The strongest opportunity for effecting environmental change lies with the academic institutions located in the region. Academic commitment to research in minerals production, environmental management, and social and economic development provides new insights and support projects geared at improving the sustainability of mining practices in the region.

- **Environmental legislation and regulation**

In spite of a lack of proper enforcement and implementation, the existence of environmental legislation at the government level appears sound. In addition, the strong governmental support for environment creates a good opportunity to improve the regulatory and enforcement systems.

CHAPTER V

5. Environmental planning solutions for rehabilitation of abandoned quarry site in the study area

5.1. Alternatives for rehabilitation

Quarrying is only a temporary use of land that can last up to several decades. However, the question remains as to what will happen to the site following its exploitation. Addressed prior to extraction, the answer to this question determines not only the method for site rehabilitation but that for the quarrying operation itself. Therefore, prior to any rehabilitation work begins and even any extraction work, the after-use of a site needs to be proposed by the quarry operator and approved by the competent regulatory agency.

There are many different after-uses into which a quarry site can be rehabilitated. According to Surrey County Council (SCC, 2002), these after-uses have been categorized into five broad categories: recreational and leisure, nature conservation, agriculture, development, and other beneficial uses. The choice of alternatives however, is not a straight forward process. It involves careful consideration of various factors including not only the characteristics of the quarry and its surroundings, but also factors such as the economic feasibility of the selected alternative, local land-use schemes, as well as public opinion. Moreover, the long-term implementation of the use, as well as the entity responsible for the long-term site management and finance should be identified.

Moreover, it is possible to integrate more than one after-use within the same site. This is more common for larger extraction sites. Such multi-use or zoned sites are typically larger in size. They are also typically more complex to plan for but have the potential to better suit the existing land-use patterns and surrounding landscape. For example, the nature conservation after-use typically compliments an informal recreational usage such as picnic areas.

5.2. Restoration mechanism of the study area

Currently almost 21% (more than 67 hectares) of the study area is abandoned quarry. However there is no any proper rehabilitation practice undergoing. Thus this quarry can provide special opportunities for restoration. The often extreme conditions that result from the extraction process allow a creative approach not possible on other sites to a large extent that the environment must be created before restoration takes place. Therefore, landscaping, soil management and additions, organic matter application and plant species selections can be the techniques of quarry rehabilitation in the study area.

- **Landscaping**

Landscaping involves the shaping of the abandoned quarry site under rehabilitation for a number of purposes. Landscaping can be done to re-contour the site and blend it with the surrounding terrain for predominantly aesthetic reasons. It can also be done to reduce slope angle which can aid water and propagate capture and retention, control erosion and reduce leaching of any soil amendments.

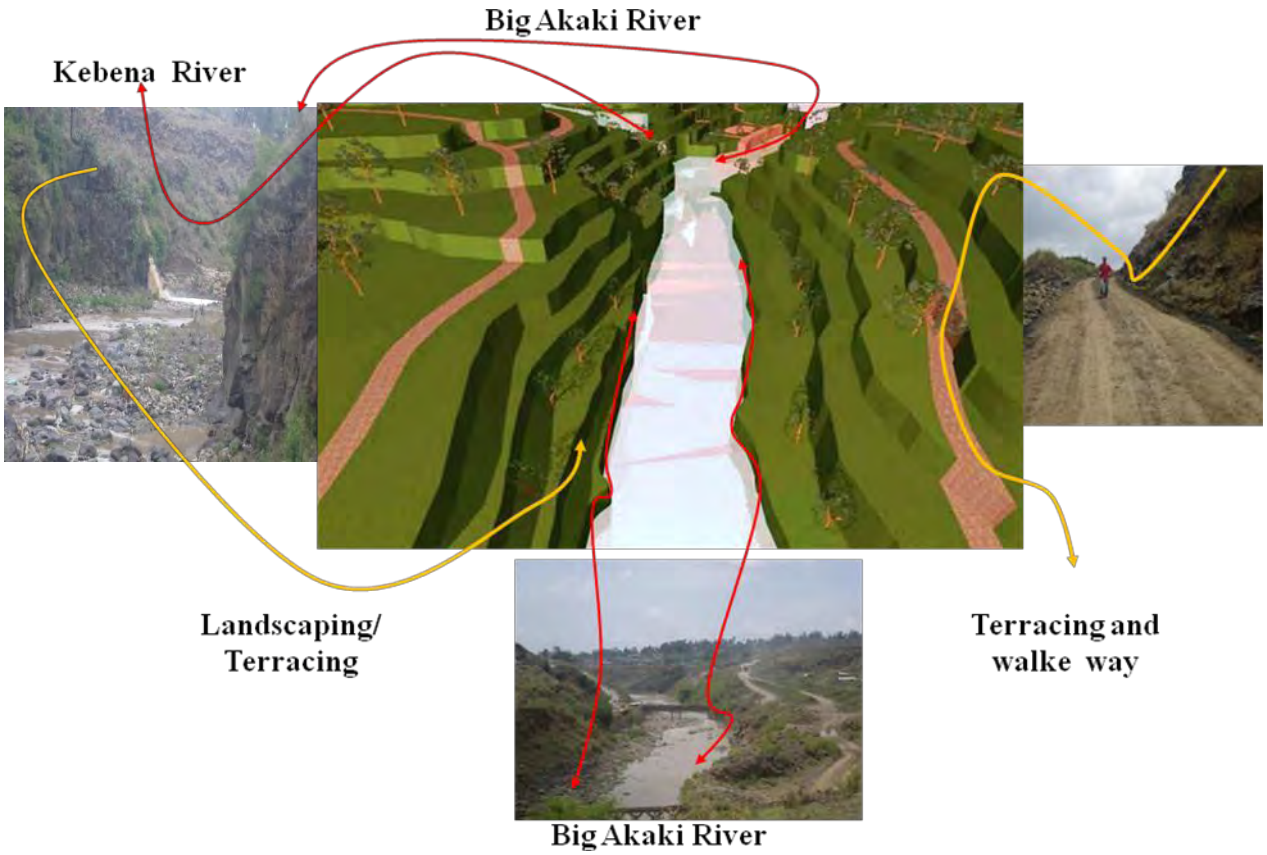


Figure 23: Landscaping / terracing of river side in the study area.

❖ **Refilling and leveling of the abandoned quarry site**

Now a day extensive infrastructure development projects are under way in Addis Ababa most of which need to remove top soil from the site. Hence this is a good opportunity to refill the abandoned site of 'Worku-Sefer' with top soil materials. However, commonly three problems may occur when the soil is filled. These are soil compaction, soil fertility and lack of organic matter. These conditions often occur simultaneously. Soil compaction can result in reduced water penetration and lack of oxygen. It creates adverse conditions for roots and seriously limits plant growth. To rehabilitate the site it requires aeration or cracking of soil to improve its physical structure. In addition to these, before refilling of the site, cut off drain should be constructed at the top of the excavated site to protect soil erosion and pollution of the nearby river from such loss of organic debris by erosion. Then the excavated site should be refilled by soil and leveled by dozer to compact it and to alter the landform of the excavated site.

Furthermore, the quarry operator should improve the plan of the extractions of material by adding the stripping of over burden material (top soil) from the active mining site to the abandoned quarry sites in the study area.

Figure 24: the stripped overburden material from the active mining site used to refilling the abandoned quarry site in the study area

Then phased rehabilitation should follow a logical sequence, preferably working through the site and finishing back at the site entrance. In addition, the processing crusher plantation and storage areas should be positioned on the last areas to be restored.

- The re-routing of haul roads should be avoided to reduce additional site disturbance. In addition, it is preferable that the haul roads not cross-unstripped or restored soils.
- The areas selected for phased rehabilitation should as far as possible reflect the different soil units to be handled.
- Site planning should aim at increasing the areas with vegetation cover prior to extraction and during rehabilitation since soils are best conserved in that manner rather than in storage.

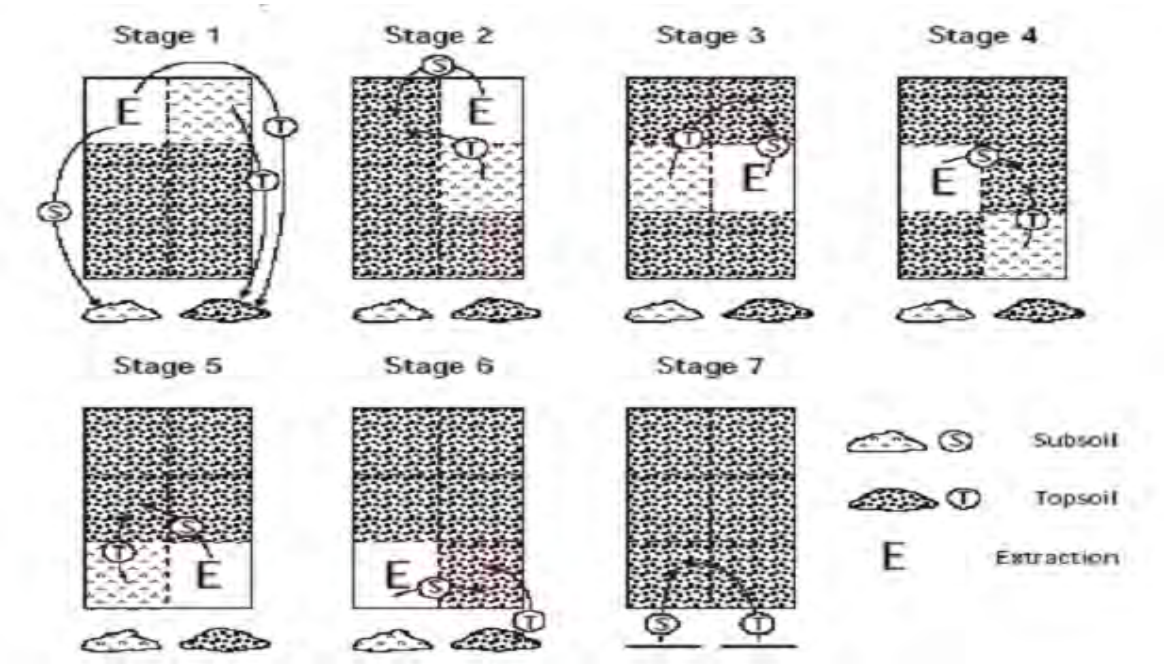


Figure 25 Principle scheme of progressive restoration (Adapted from SCC, 2002)

- Cut-off drain (diversion ditches)

In order to minimize soil erosion by runoff, a cut off drain should be constructed at the top of the active and the abandoned quarry site in the study area to intercept surface run-off and convey water from the upper parts of the area to the natural outlet or artificial water way.

Diversion ditches can be constructed across slopes to reduce the length of slope exposed to erosion, intercept flow at the top of slopes or to convey storm water at the slope base. It is necessary to temporarily place straw-bale check dams at 15 to 30 meters intervals in the ditches for erosion protection. The ditches should be seeded and mulched or sodded for long-term erosion protection. In addition it should be stabilized with riprap and other combination of mechanical methods. A diversion ditch should preferably be constructed before the land below it is terraced, and the construction should start from the outlet end. The soil from the ditch should be placed on the downward side to form an embankment.

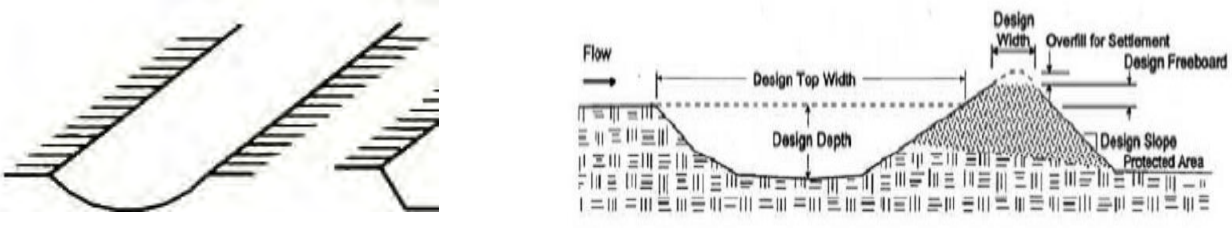


Figure.26.Diversion ditches

❖ **Stone check-dams**

In the study area particularly at the plantation area and the abandoned quarry sites, the three types of soil erosion (sheet soil erosion, formation of rill soil erosion and developed gulley) were identified. Therefore, stone check dam construction in the site enables to stabilize rill and gully erosions problems.

A check-dam is a control structure built across the floor of a gully, a waterway or a drainage channel at predetermined intervals. The purpose of a check-dam built in a gully is to trap soil moving with run-off water in the gully. Such soil trapping and accumulation above the check-dam leads to a reduction of the gradient between the check-dams and thus reduces the speed of the water. Eventually check-dams can stabilize gullies and protect them from further expansion. A check-dam should have a spillway, keys and an apron, as indicated in Figure 27.

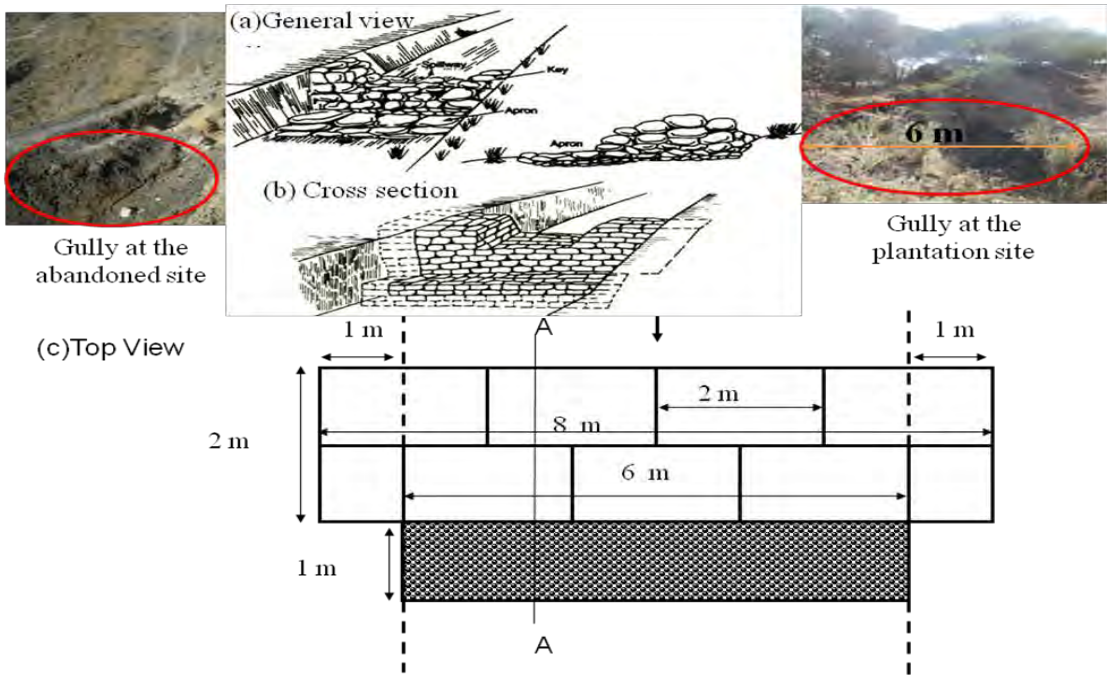


Figure.27: Check-dam extends into the gully side for increased stability and resistance against erosion

Note: The width of the spillway should be the same as the gully bottom, while the vertical interval between check-dams should be equal to the height of the check-dam.

❖ **Soil management and organic matter application**

Soil compaction is a significant problem within the study area and is a barrier to plant establishment and growth. One method of reducing this problem is the applications of soil and water conservation and improvement mechanisms. Another is soil ripping which can benefit plant establishment and growth. Particularly planting leguminous plants help to improve the soil structure. Furthermore, the problems of soil depth, structure, fertility and water holding capacity in the study area can all be reduced with the addition of organic matter to the soil, such as: compost or manure.

This study strongly recommends preparing compost in the study area. Composting is the natural process of decomposition of locally available organic waste like grass, leaves, crop residues, cow dung and kitchen household waste and other organic matter for quick decomposition that yields manure or compost, which is very rich in nutrients. Compost, also called humus, is a soil conditioner and a very good fertilizer. The product you end up with is a rich, odorless, soil-like substance that can be added to gardens to help plants grow.

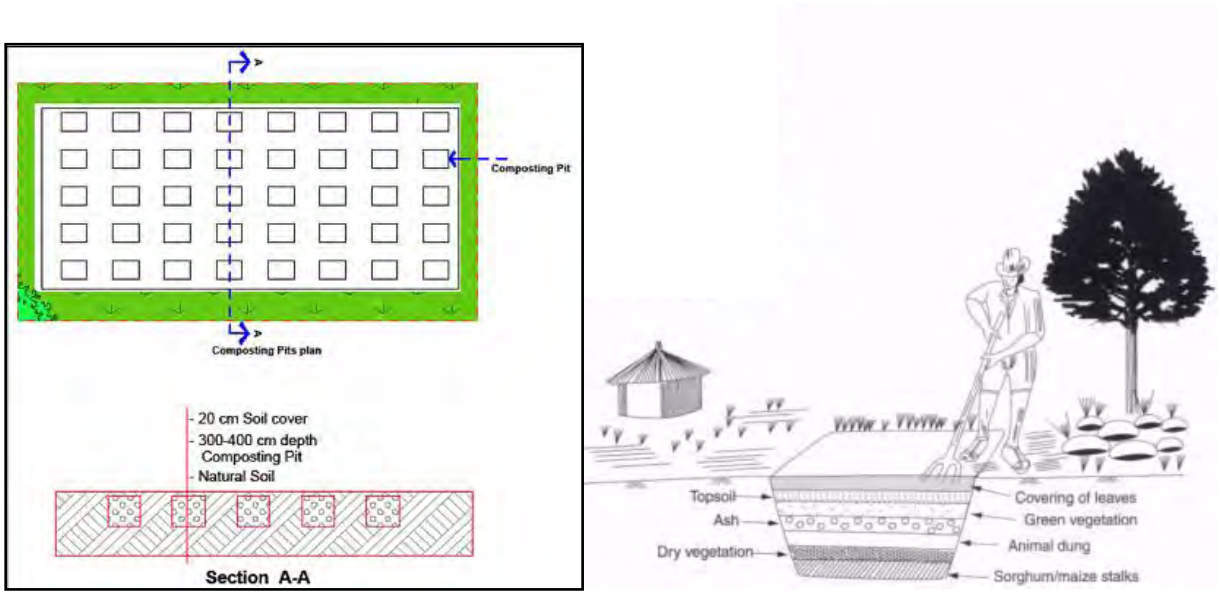


Figure 28: composting pit design and three dimensional view of the pit in the study area

❖ **Plantation and species selection**

The ultimate aim of the restoration is to establish a sustainable vegetation cover on abandoned mine sites. After exploiting the materials in green areas, Addis Ababa structural plan allows to plant indigenous species. The type of vegetation depends on the goals of the restoration project and is usually one of two options. One is to produce an economically valuable species often multipurpose tree, such as eucalyptus and acacia species which are used for construction material and fire wood. These should be planted on the

land proposed for agriculture land use. The second is to produce a vegetative assemblage of environmental value (Annex E) and it should be planted at the proposed green area. A crucial factor to the success of establishing vegetation is to identify suitable species for the area. Hence, the combined plantations of legume plant species with native plants increase the success of quarry rehabilitation in the study area. Native plants are often tolerant of the local environmental conditions. The tree planting shall in quarry focuses on creating wind break, providing cover, and improving microclimate, soil characteristics, and prefer species which have the characteristics of nitrogen fixing which can ameliorate soil condition. Moreover selecting native species that are tolerant to difficult growing condition is preferable. There for, after the vegetation (woody species) surveyed and analyzed, 24 woody species were identified and recommended for the rehabilitation of the study area (Annex E).

5.2.1. Protection of River Banks

The function of riverbank protection is to avoid bank erosion, which is caused by current attack. Effect of erosion is collapsing of riverbank, causing movement of my study area river channel. The movement is both vertical and horizontal, arise meandering, braiding, or move and changing of river path. Bank protections that are commonly used are made from masonry or concrete, this type is expensive and not natural or not environmental friendly. Because, riverbank stability has an influence on channel form, vegetation growth and habitat of bank-living species, eco-hydraulics solves the river problem with environment and ecology approach.

Bank protection measures, which are matching with the environmental friendly of eco-hydraulic, must be:

• Using natural materials which can be found around which is low cost.

• Labor intensive and lessening unemployment to condition of our country.

• Can provide habitat for water body lives and crops.

Some low-cost river bank protection methods that are recommended for the study area are: stone rip rap (beaching) and dikes,groins and revetments.

❖ **Stone rip-rap or beaching**

Lining the river banks with some stone is feasible if local source of rock is available. The pits in stones and the nooks and crannies between them increase the amount of area for colonization by aquatic insects. Plants can take root between the rocks and rocks ledges can be used as resting and roosting sites by waterfowl. Stone is a relatively permanent option if the stones used are sufficiently large that they do not wash away during high flows. More angular stones will interlock and thus more stable. Placing a layer of fine gravel or stone under the larger rip-rap material will help to prevent erosion of finer bank materials from beneath the rocks. To avoid undermining at the toe of the rip-rap, stone aprons can be used which extends well out into the riverbed. An extra pile of rocks can be added to the edge of the apron which fall in and continue protecting the bed if it degrades.

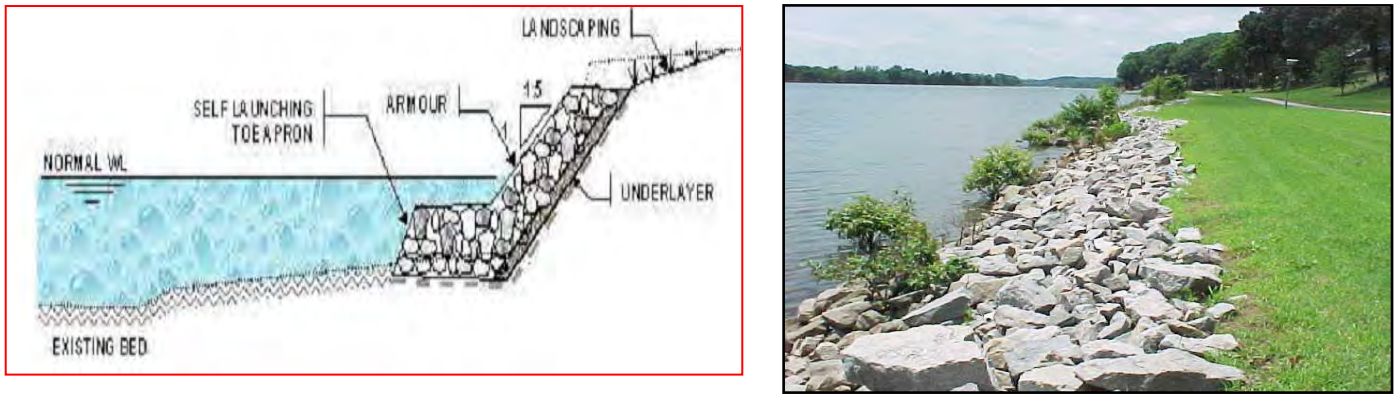


Figure29. Stone rip raping (Adapted from Tweed River Estuary Management Plan 2009)

❖ **Dikes, groins or revetments**

These structures extend out from a river bank into the flow figure. They are used to reduce the speed or change the direction of the stream's current and thus reduces the erosion force on the banks. They are many designs, to timber planks or logs bolted to posts. With proper design silt will be deposited in the quieter water between the groins. Vegetation can be planted in these silt beds which will eventually form floodplain benches. Normally, a series of groins are used along a bank.

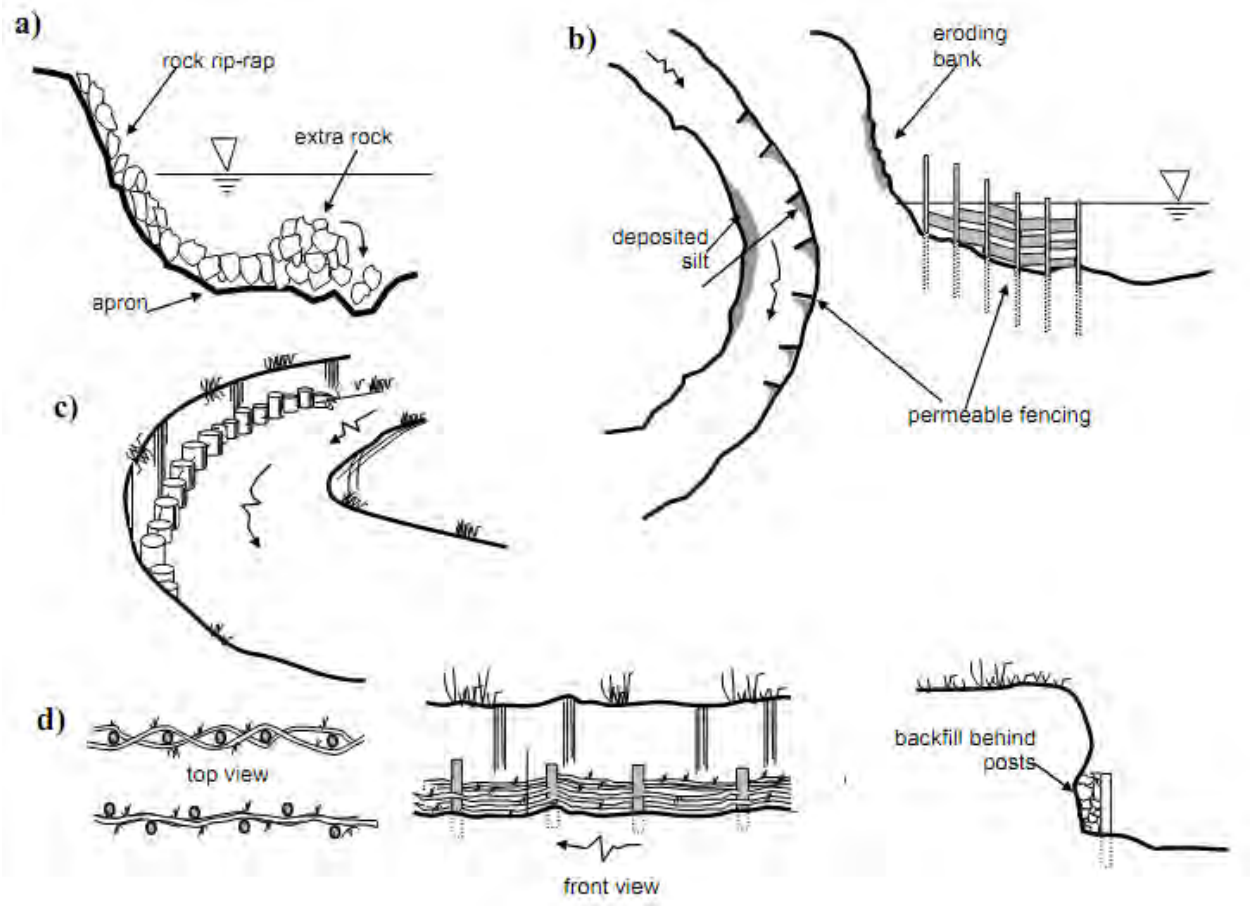


Figure 30: Bank-protection measures: (a) stone rip-rap, (b) dikes *or groynes ,(c)* vertical timber posts, and (d) wicker spilling *(Adapted from Gordon, McMahon and Finlayson 1992)*

5.3. Green area development proposals

5.3.1. SWOT analysis of the study area

SWOT analysis is the in-depth analysis of the strength and weakness of a particular site and they describe the internal issues of the site while the opportunities and threats are issues which have positive or adverse effect on the site imposed by external issues.

Table 12: SWOT analysis of the study area

Strength	**Opportunities.**
• Availability of infrastructure development (road, electricity, bridge, etc). • Existence of investors • Presence of attractive landscape elements (water body, landform, natural wood land) • Wide open space available for development. • The master plan allocated up to 100m buffer zone in the study area • Availability of seed source from the remnant natural wood land in the study area	• The establishment of environmental protection authority and agencies at different tiers of government. • IT technology to access best practice on quarry rehabilitation • Private sector initiation to involve in quarry rehabilitation development. • Endorsement of environmental policies by the Regional and Federal government. • The availability of professionals concerning the environment.
Weakness.	**Threats.**
• No appropriate use of overburden materials and lost through erosion • Disposal of solid and liquid waste on the site • The presence of degraded landscape. • Vulnerable water bodies (Kebena and Great Akaki river) • Informal settlements in the study area. • Poor rehabilitation practice and vegetation cover	• Increasing global warming and climate change • Pollution of upper river catchment. • The prevalence of flooding in the catchment.

5.3.2. Land use proposal in the study area

The structural plan of Addis Ababa is prepared to serve for 10 years from 2001-2010 and recently its performance is under evaluation. The structural plan has allocated river buffer zone in the study area for the green areas.

According to public consultation of the local residents almost 85% of the people want the area to be changed in to recreational use. In addition, during the study all the nearby area was assessed and no recreational facilities are available in the vicinity where the resident or others use. Furthermore, urban dwellers near the selected quarries for rehabilitation lack recreation facilities like garden with retail services and open space. Moreover, the structural plan of Addis Ababa has proposed the study area under green area (figure 31). Therefore, it is advisory to transform the abandoned quarries along the river bank to recreation facility and park administered by legal authority or NGOs.

The need for parks and recreation areas and facilities can be related to rapid urban expansion. Social benefits of recreation activities are increased health of dwellers and the curtailment of social disorders have long been recognized. In addition, there are many economic benefits from a public park and recreation system, such as making the area served a more desirable place in which to live, and designate the tourist, recreation equipment and services industries. The rehabilitation of the quarry can contribute a lot for environmental change problem. Moreover, the land use change of abandoned quarry area to recreational site can launch a region wide initiative to encourage healthful outdoor physical activity.

Generally with steady trend toward greater urbanization, parks and recreation centers are essential rehabilitation systems to provide the physical race and surroundings which will give people opportunities for participating in the many types of active or passive recreation activities which are not possible in the average home environment. In addition, public parks and recreation areas provide the conservation of natural scenic areas, other resources and economic importance.

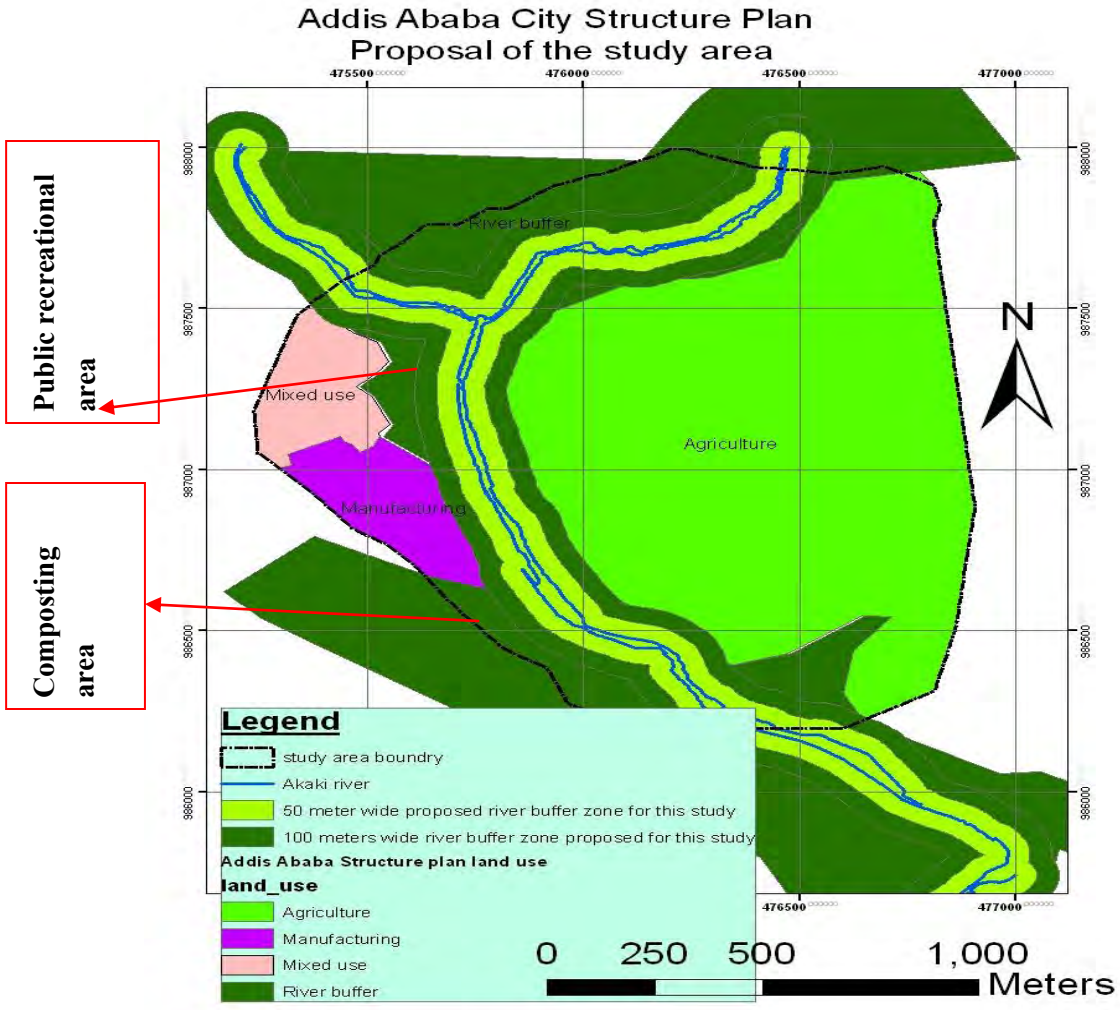


Figure 31: Land use proposal in the study area

5.3.3. River buffers and recreational development proposal

As part of the Environmental planning buffer for river is crucial component. Hence, the structural plan has proposed up to 100 meter buffer for the Big Akaki Rivers which are found in the study area.

The map above reveals river buffer and social and municipal services had been proposed at the study area on the structural plan of Addis Ababa city. The social and municipal services incorporate recreational areas and services. The 50 m buffer of vegetation prevents the river from runoff, pollutants and sediment, and protects properties from floods and erosion. Here buffer is provided to protect the flood plain and at the same time create shelter belts to facilitate the flow of wind in the site. Therefore, deep rooted trees, shrubs and grasses should be planted in this buffer area. *Carissa spinarum, Aloe vera,* vetiver grass, etc are used for this purpose. It is a tropical clumping grass that is sterile, fast-growing and that does not tiller to the side. The culms above root crown are dense and very stiff, while the roots are fine, dense and deep (3 m). When planted on the contour of sloping land, a vetiver hedge anchors the soil profile three meters

deep by increasing shear resistance of the soil by 40 percent and prevents landslides (Journey, W. 2003). While, the 100 meter buffer zone should be covered with a vegetation of grass and shade trees including *Acacia abyssinica, Casuarina cunninghamiana, Millettia ferruginea, Jacaranda mimosifolia, phoenix reclanata,* etc. These shade trees should be planted in a space of 2.5m x 2.5m between each other.

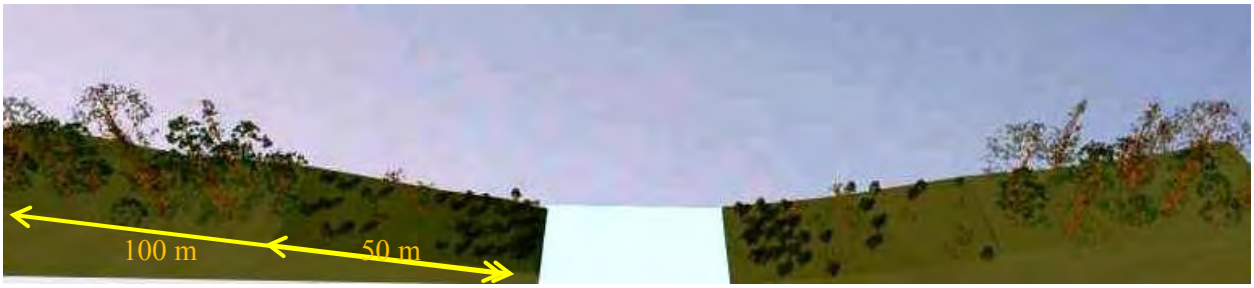


Figure 32: Proposed river buffer plantation in the study area

These buffer zone mainly used for recreational, walk way, seating area and play ground. Hence, sitting areas have been proposed to create a sense of relief and admiration of the natural setting in the area at the same time it will provide a place to rest and see.

Picnic open space activities are located adjacent to the river side so that park users can have good impression on the natural scenic views of the river (fig 33).

Furthermore, green area development for the study area is goods and services depend on strong connectivity between location and user. Others, such as wildlife habitat, may depend on the interconnectedness of the component parts of the green space for example recreation. Here, it is important that there is suitable access from zones of environment into the green space, and it is increasingly important that accessibility to river side walkway and connect to the outer and the inner green structure. With its focus on networking and the connectivity of green spaces it can aid movement through landscape. Green area development can alter the flow patterns of water through the catchment can fracture hydrological and ecological connectivity, which can then have an impact on the freshwater ecology which relies on high quality flowing water for its survival.

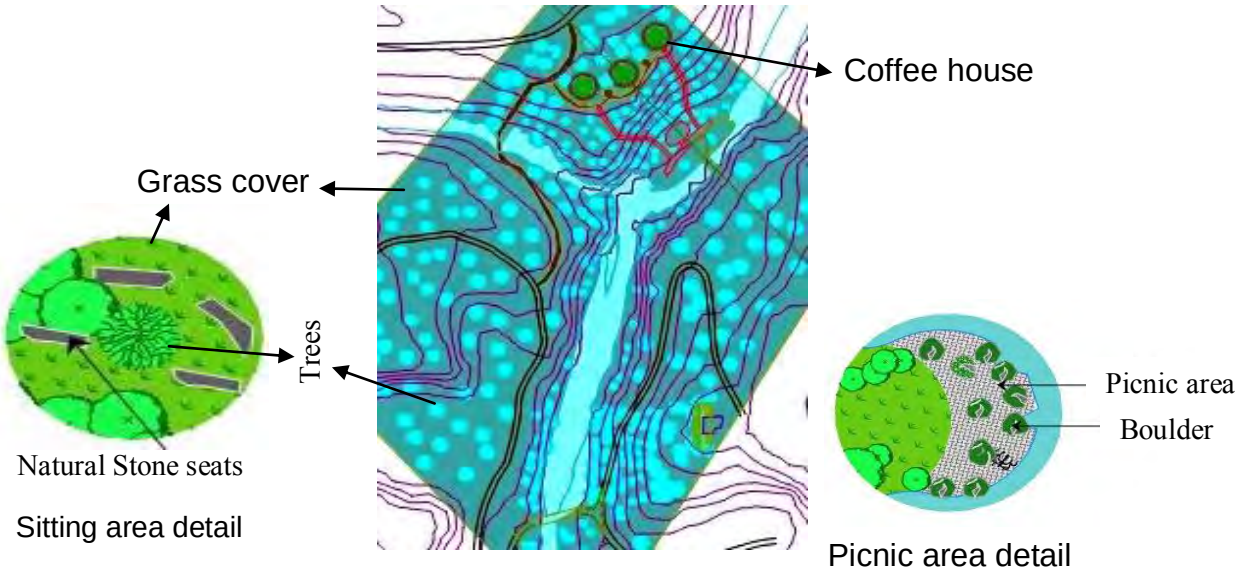


Figure33: plan of public recreational park in the study area

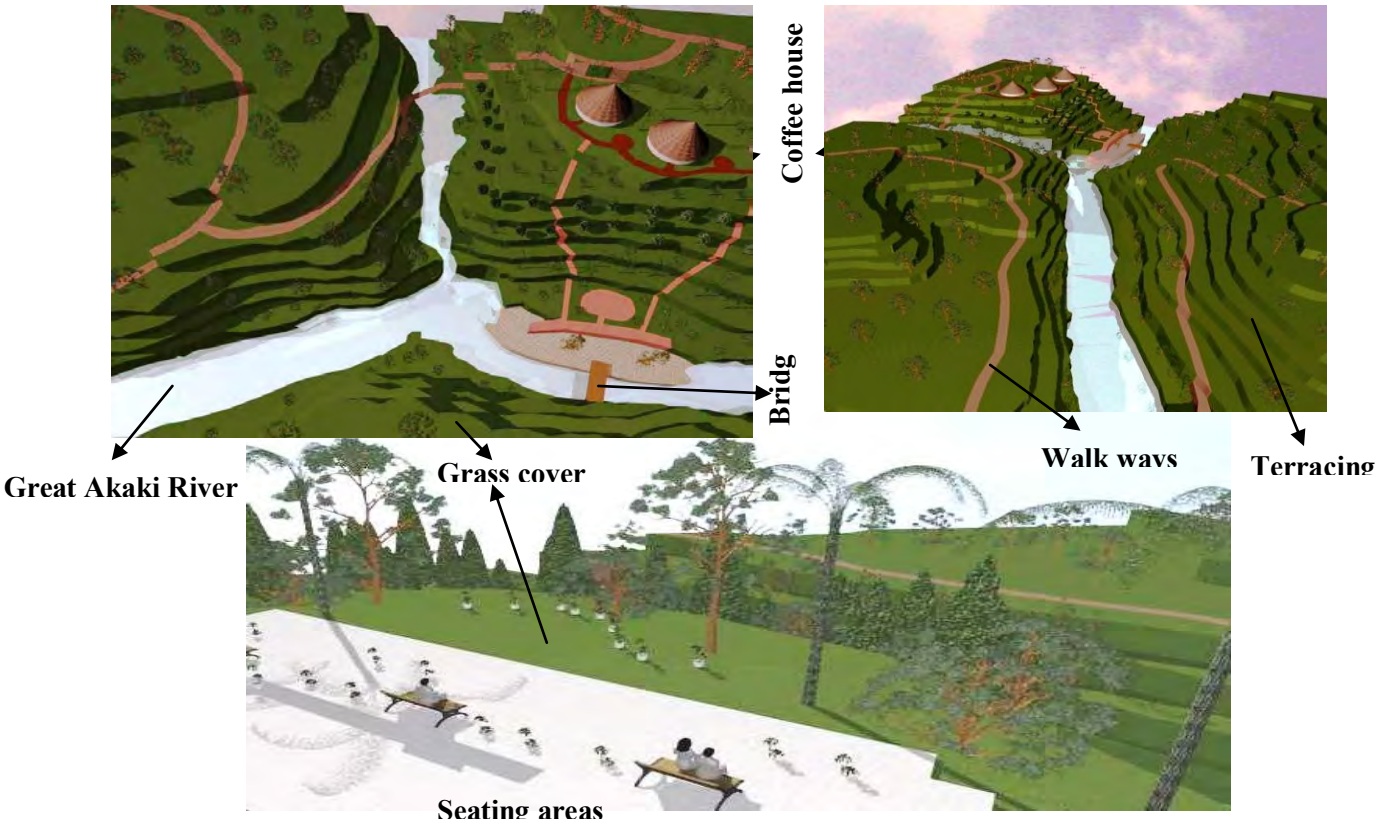
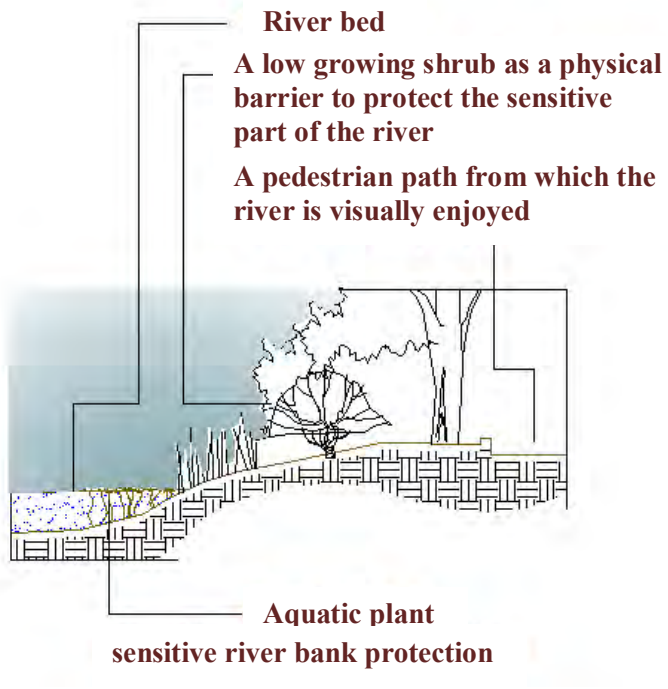


Figure 34: 3 D view of public recreational park in the study area

The design includes all facilities such like children play ground, indoors and out door games, coffee shops, seating area ,walkway with terracing etc.

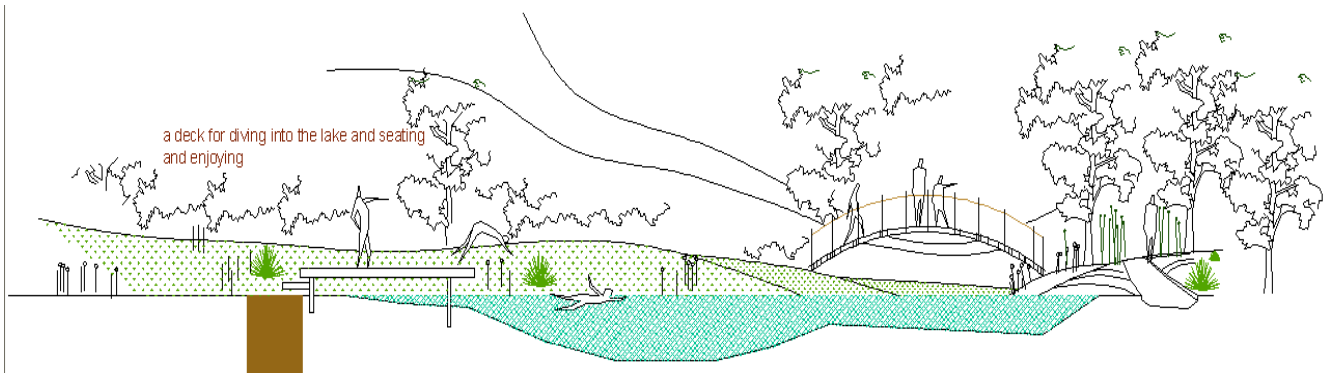
5.3.4. River side recreation

The river side development plays different roles for one thing it will protect the river from pollution and it will be a better habitat for the aquatic flora and fauna.



On the other hand it will be an ideal place to enjoy with water and nature. It will also be a place to interact with the society. In addition to recreation and habitat protection the river side development will also give excellent opportunity for crop cultivation. Water from the river will be diverted to the adjacent farm land. This will enable the river side development to play ecological, social and economical role.

The river bank development connects the neighboring different residential blocks. It can easily be accessed from the different directions by the paths which are coming from these residential blocks. At the opposite of the residential block passes a path which is part of the green frame circulation and the interaction of this path with the river is controlled by different design approaches. The road is designed in such a way that at one point it will come very close to the river and at another it will be far from the river. This will decrease the probable harm done to the sensitive parts of the river.



In addition it increases the excitement. At some point where the path is close to the river we can have a design which gives a visual access to the river but forbids physical access.

The course of the river will be altered to certain extent so as to increase the distance taken in order to decrease the speed of the water. This will minimize the risk of erosion and flood hazard. Along the river it is also proposed to have a node in which water will be feed by the river to form a mini lake. Because it is not faced directly to the running water direction, the lake will be safe for swimming and playing around.

CHAPTER VI

6. CONCLUSION AND RECOMMENDATION

In this chapter the finding of the study about the problems, operation and management of quarry rehabilitation in "Worku Sefer" are summarized. Recommendations for sustainable quarry rehabilitation planning are forwarded based on the finding. In addition to these, further research areas are also suggested in this section.

6.1. Conclusion

As mentioned in problem justification the study supports that the current quarry operation and managements have bring various problems in the study area: excavated sites are abandoned and wasteland, the resource is not well utilized, the overburden materials stripped are not properly kept and protected for future rehabilitation, soil erosion & land degradation, diversion of natural river water flow, poor practice of rehabilitation and deforestation of the indigenous trees in the study site were identified. The quarry operation is characterized by poor mining plan, lack of ecological considerations, inadequate quarrying process and rehabilitation planning, technical and policy enforcement barriers, etc.

Information gathered from the local residents revealed that the area under study was covered by forest and was the habitat of various wild lives such as birds, hyenas, rabbit and other.

Currently, only 2.4 percent of the study area is rehabilitated with exotic plant species. Particularly, *Acacia decurrens* and *Acacia saligna* are the dominant species in the plantation site. However, there are lacks of proper rehabilitation practices. The problems included: lack of land stability and landscaping or reshaping of slopes, lack of planting appropriate plant species that are acculturated to the site micro climate, absence of fencing, some of the plants that are planted on the site are frequently eaten by cattle, lack of soil conservation and lack of appropriate site improvement measures.

The study made on woody species survey revealed that there were a total of 33 woody species recorded in the study area. However, more than seventy nine percent of the species are only found in a small area of the natural wood land, which is 3.5 hectares, covers only 1.1 percent of the total study area.

Furthermore, the land use land cover change analysis revealed that the land cover in two different times showed significant changes. Particularly, bare coverage was drastically changed from 8.65% in 1986 to 39.44% in 2012 that is almost five times the initial year. Thus these result made an evidence for the current expansion of quarry projects and poor rehabilitation of the sites and it is the consequence for the

current land degradation in the study area. In 1986 agriculture was primarily practiced throughout the study area and it covers 46.64% followed by grass land and forest which accounts 25.03% and 14.62% respectively. While the bare land and built-up area covered smallest part of the study area. While in 2012 bare land was the largest LULC category in the study area. Generally the trend and rate of land use and land cover between 1986 and 2012 shows a reduction in agriculture, grass land and forest area, whereas an increase in bare land area.

Generally both active and abandoned quarry sites were studied in this paper. The current quarry operations are accelerating degradation of the land in the study area. Thus the land will need progressive and final restoration when all of the activity is closed. Furthermore; landscaping, soil management, organic matter application, soil and water conservation measures and plantation of selected species can be the techniques used for quarry rehabilitation in the study area. Almost all abandoned quarry sites were along the river bank and currently the resources are depleted. Thus it is proposed to change in to recreational use. Hence, the study investigated and identified different useful woody species to " Worku- Sefer" quarry rehabilitation project based on beneficial use for the environment and their preferred agro climatic zone.

6.2. Recommendations

The following key measures are recommended to curb the problem of sustainable quarry rehabilitation and lack of quarry management and respond to the increasing demand for greenery in the study area:

- The main barriers that hinder the development and implementation of quarry rehabilitation program in the study area were lack of awareness. Therefore, meaningful awareness creation program should be made by the concerned body to quarry developers, quarry operators and the community at large.

- The existing indigenous vegetation in the study area was deforested by the current expansions of quarrying activity. So that, the remnant natural wood land site should be protected and conserved: used as a source of seed for rehabilitation of the degraded site in Worku-Sefer quarry projects.

- The quarry development should have a river buffer zone for quarrying operation in the study area up to 100m distance of the river. The effectiveness of distance as a means of control varies with topography and local environmental sensitivity.

- Some quarry developers in the study area are exploiting construction materials without undergoing EIA and rehabilitation program. Even though some quarry developers in the study area have submitted EIA document to the concerned body, no one has implemented it and rather it is theoretical. Hence before any construction work, a proper site investigation and earthwork must be done first during EIA study and quarry operation should be conducted within a strict planning system and the issues of safety, visual appearance, environmental protection and the future use of the site will be investigated and incorporated into the quarry design before EIA application is submitted.

- The government quarry developer organization particularly AACRA and CRBC Addis Engineering PLC found in the study area should submit EIA study before starting operation and all quarry developer should be adapting the progressive /side by side rehabilitation strategy.

- The current quarry rehabilitation practice in the study area was faced various problems and covered by exotic plant species, which has low diversity of species. Hence rehabilitation of sites should preserve or enhance the overall quality of the environment after quarrying has ceased and, where appropriate, make contributions to improved habitats and biodiversity.

- In order to obtain relevant results, it is necessary to evaluate both the success of the rehabilitation and the survival of the different species. Monitoring rodent damage may indicate the need for remedial measures or additional planting.

- The other barriers that hinder the rehabilitation of abandoned quarry site in the study area were lack of accountability and responsibility of the quarry developer. So that law enforcement strategy should be designed and develop the polluter pay system, the proponent should forced by law to establish bench mark with concrete to demark its boundary and responsible to properly rehabilitate its excavated site.

- Some quarry developers in the study area have long history (greater than 26 years) and still owned the area with non operational and abandoned. Thus quarry licensing should be time bounded and monitored & evaluated there activity by the concerned body.

- The poor coordination and communication among AAEPA, Subcity and Woreda EPO should be strengthen for common goal, ensure environmentally friendly quarrying operation

Finally it is suggested that the sustainability of quarry rehabilitation in the study area does not solely on studying on vegetation, management of quarry operation and environmental issues. It further relays on the socio economic, geological & geotechnical properties of foundation and back fill issues with landscape design for both river side park development and after use of the current active mining site in the study area. Hence, this paper suggests that further study shall be made on the socio economic issues, geological & geotechnical properties of the foundation of the study area and back fill material. Moreover, the suggestion on sustainable landscape design for various alternative uses of the rehabilitated quarry is still opened.

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Annexes

Annex A: Addis Ababa Environmental Protection Authority guidelines of Environmental Impact Assessment Report of Quarrying Project

1. Introduction

This section will have importance in providing background information about the proposal and indicating how the report is structured. It is important that the 'context' of the study report should make clear especially the following: -

- Background information that can be used for the study in context;
- Objectives of the EIA
- Benefits of the project
- Methodologies employed.

2. Description of the project site

- Location and Accessibility of the project area
- Landscape i.e. slope, creek, etc
- Climate & Natural resources (river, forest land other vegetation) existing in and around the project site and their distance from the quarry
- The previous and existing land use of the quarry site and its surroundings: Agriculture, residential, industrial and forest, etc.

3. Geology, Reserve Evaluation and life span of the project area

Regional Geology

Local Geology

Reserve Estimation

Life-Span of the deposit

4. Resource requirement

- Human resource
- Machinery

- Capital expenditures
- Pre-production costs
- Depreciation and Amortization

5. Legal and administrative requirements related to mining/quarrying

6. Environmental Impacts of the project:

- Positive impacts of the projects

Note: Take a commitment to participate youth and women in your project activities i.e number of youth and women who will be benefited from your project.

- Negative Impacts of the mining

✓ Land degradation, erosion, surface irregularity, pits, etc by quarrying

✓ Dust created during crushing and transporting

✓ Noise caused by mining (blasting, crushing, and transporting)

✓ Vibration caused by explosion/blasting

✓ Any other problem that could affect the neighborhoods and the surrounding

✓ Natural resource

7. Mitigation measures to minimize the negative impacts

- Options to minimize the negative impacts that could affect the neighborhoods and the surrounding natural resource
- Management plan to rehabilitate the degraded quarry site
- Physical activities scheduled monthly/annually
- Estimated cost for the rehabilitation activity (monthly/annually)

8. List of study team members name, qualification, experiences, etc

Annex B: Questionnaires

Profile of the questionnaires

As discussed in the methodology part of this paper, one of data collection approach is to prepare questionnaires and distribute to systematically selected households, Quarry owners, government organizations: AAEPA, Bole and Akaki kality sub cities of environmental protection office and Woreda 05 &10, in order to identify problem of quarry planning, existing situation and practice of quarry rehabilitation and environmental problems caused by extraction of construction materials in the study area. Hence the Questionnaires are designed to collect data regarding the extraction of construction materials with poor rehabilitation and their associated problems on the environment and community. The questioners are grouped in to three major sections. The section and their area of identification are the following

1. Section one is related to the existing situation and practice of extraction of construction materials and their associated problem

2. Section two focuses on the considerations of environmental problems caused by poor design of extracting construction material

3. Section three raises issues related to different barriers that hinder the development and implementation of a sustainable quarry rehabilitation program

Part I

Question to be filed by Project owner's and their employees

Dear respondent, this questionnaire is designed for the purpose of conducting a study on quarry rehabilitation planning. The information you will give is used for academic purposes for the partial fulfillment of Master of Science degree in Environmental Planning and Landscape Design, Ethiopian institute of Architecture Building Construction and City Development (EiABC), Addis Ababa University. The information has a great role for the success of this research. So, you are kindly requested to take a few minutes and provide accurate information as much as possible. Thank you for your cooperation.

Direction

You don't need to write your name or anything that identify you

Please give your response for the following questioners either by writing your answer in the space provided or by putting "✓" or "×" in the box provided for multiple choice questions.

If your answer or ideas are not listed in the choices, you can specify on blank space provided

1. Respondent's background

Sex Male ☐ Female ☐

Educational back ground

A/ < 10 ☐ B/ 10+1 ☐ C/ 10+2 ☐ D/ 12 Complete☐ E/ Diploma ☐

F/ First degree ☐ G/ Master Degree & above ☐

2. Please specify the type of your organization?

A/ Government organization ☐ b/ Private ☐ C/ other please specify----------

3. How long have you been working in this organization?

A/ below 3 years ☐ B/ 3-5 years ☐ c/ > 5 ☐

4. What is your position in this organization?

---

5. When did the project start its operation in this site?

A/ bellow one year ☐ B/ 1-5 years ☐ C/ 5-10 years ☐ D/ >10 years ☐

6. What type of construction materials are you producing?

A/ Basalt ☐ B/ Selected material ☐ C/ Ignimbrite ☐ D/ if other please specify ----------

7. How are you managing the over burdened materials?

---

8. What are the benefits/adverse effects of the over burden materials on the surrounding ecosystem?

The benefits

Adverse effects ----------

---

9. What efforts did your organization make to reduce the negative effects of over burden materials?

---

10. Are there any problems your organization faced in achieving its objectives?

A/ Yes B/ No

If your answer to Question No. 11 is 'yes' what do you think the cause for the problem

---

---

11. Is there any EIA study carried out before you start your operation?

A/Yes ☐ B/ No ☐

If 'yes' how are you implementing the adaptation or mitigation measures on the site?

……

……

If your answer is 'no' please state your reasons

……

……

12. What mechanism are you using to reduce the impacts of the quarry on your employee, the nearby residents and ecosystem in and around the site?

---

13. How are you protecting the river in the site?

---

14. Is there part of the quarry site which you stopped quarrying?

A/Yes ☐ B/ No ☐

If 'yes' why you stopped quarrying on this specific location?

---

15. Is there any rehabilitation efforts carried out so far on the completed/abandoned/stopped portion of the quarry site?

A/Yes ☐ B/ No ☐

If 'yes' what are the components of the rehabilitation plan? ---

---

---

16. Who prepared the rehabilitation plan?

If 'no' what is the reason for not having the rehabilitation plan?---

---

---

17. What are the barriers that hindered your activities?

---

18. What is your future intent for the site after you finished your operation or the site reached its optimum utilization?

---

19. If you have any comments regarding the current quarrying, rehabilitation operation and the barriers that hinders the development and implementation of a sustainable quarry rehabilitation program, please list in the space provided

---

Part II

Questionnaire prepared for the community to identify the past land use, existing/current situation of the area and their problem and their need of future land use type.

1. How long did you live in this area?

A/ Less than 5 years B/ 5-10 years C/ More than 10 years

2. Are you living in this area before the quarry projects starts?

A/ Yes ☐ B/ No ☐

If 'yes', what did the site looked like?

A/ All covered with forest ☐ B/ partially covered with forest ☐

C/ Covered with bush/shrubs ☐ D/ It was bare land ☐

E/ If other land cover, please State----------

3. Do you remember the vegetation type, particularly woody specious in the area?

A/ yes ☐ B/ No ☐

If you yes please list some of them ----------

---

4. What do you say about the current situation of the quarry area?

---

5. . What problems did the quarry site brought on the environment and local residents?

---

6. What measure are taken to avoid/reduce the impact of the problems

---

---

7. What solution do you suggest to solve the above mentioned problem?

---

8. To what type of land use do you want the quarry site to be rehabilitated?

---

9. What do you think about the participations expected from the following bodies for fulfilling the type of land use you proposed in no 8 above?

A/ Local community:

B/ Government bodies:

C / Quarrying Company:

D/ Teaching and research institutes:

E/ If others please specify:

Part III

Questionnaire prepared for government organization

1. What are the social and environmental mandate of your organization with respect to quarrying and its development?

---

2. What are the stakeholders in the quarry development?

---

3. Is there a level of interaction between or among concerned organization and departments about quarry planning and management?

A/Yes ☐ B/No ☐

If ‘yes’, how the relationship can be explained? ----------

If ‘no’ state the reason?----------

---

4. What are the procedures set out to get quarrying license?

A/Yes ☐ B/ No ☐

5. Are quarry developers expected to provide EIA document before commencing quarrying?

A/Yes ☐ B/ No ☐

If ‘yes’ what are the issues that need to be incorporate on the EIA report?

---

6. How are you monitoring proper application of EIA on the quarry site?

---

7. Do you monitor the operation of quarry sites on the site?

A/Yes ☐ B/ No ☐

If yes, how often? ----------

8. Did you so far observed some problems during quarry operation?

A/ Yes ☐ B/ No ☐

If ‘yes’ what problems did you observe?

On the river----------

On the landscape ----------

On the surrounding vegetation ----------

On the nearby residents----------

Employee of the developer----------

---

9. Is there all quarry projects are subjected to EIA study before starting?

A/ yes ☐ B/ no ☐

If no, please state the reason and list some example ----------

---

---

10. Is there any quarry rehabilitation document submitted by the developer?

A/Yes ☐ B/ No ☐

If 'yes' what are the activities included for future rehabilitation of the site? ----------

---

If 'no' why they did not submit the rehabilitation plan? ----------

---

---

11. Is there any awareness created about quarry rehabilitation for quarry companies?

A/Yes ☐ B/ No ☐

If you 'yes' for how many times? ----------

If you say 'no' state the reason?----------

---

12. What are the themes of the training? ----------

---

13. What changes do the training brought about on quarry management? ----------
---

---

14. What is your general comment about quarry operation and problem of proper rehabilitation around great Akaki river, 'Worku-sefer' quarry projects" ?----------
---

---

15. To what type of land use do you think the 'Worku-sefer' quarry site to be rehabilitated?

---

16. What do you think about the participations expected from the following bodies for fulfilling the type of land use you proposed in no 13 above?

A/ Local community:

B/ Government bodies:

C / Quarrying Company:

D/ Teaching and research institutes:

E/ If others please specify:

Thank you so much!!!

Annex C: Plants (Woody species) recorded in the four land category

- *Woody species recorded in the natural wood land Plots (3)*

No.	Vernacular name of species	Scientific name	Origen	Category	Number of individual species
1	Bazra girare	*Acacia abyssinica*	Indigenous	tree	22
2	Besana	*Croton macrostachyus*	Indigenous	tree	35
3	Gulo	*Ricinus communis*	Indigenous	shrub	4
4	Agame	*Carissa spinarum*	Indigenous	shrub	14
5	Dedeho	*Euclea racemosa*	Indigenous	Shrub	43
6	Cactus	*Opuntia ficus-indica*	unknown	Shrub	7
7	Kulkual	*Euphorbia abyssinica*	Indigenous	tree	3
8	Kentefa	*Entada abyssinica*	Indigenous	shrub	12
9	Embacho	*Rumex sps.*	Unknown	Shrub	8
10	Sensele	*Justicia schimperiana*	Indigenous	Shrub	3
11	Lenequata	*Grewia villosa*	Indigenous	Shrub	19
12	Agame	*Carissa spinarum*	Indigenous	Tree	5
13	Grawa	*Vernonia amygdalina*	Indigenous	tree	8
14	Gumero	*Capparis*	Indigenous	Shrub	4

		tomentosa			
15	Sheweshewie	*Casuarina equisetifolia*	Exotic	tree	2
16	Asene meka	*Senna didymobotrya*	Indigenous	Shrub	6
17	Anefar	*Buddleia polystachya*	Indigenous	tree	2
18	Bamba,shola	*Ficus sycomorus*	Indigenous	tree	10
19	Kelawa,yeregna qolo	*Maesa lanceolata*	Indigenous	Shrub	3
20	Shola	*Ficus sur*	Indigenous	tree	2
21	Berbera	*Millettia ferruginea*	Indigenous	tree	1
22	Grevillea	*Grevillea robusta*	Exotic	tree	3
23	Beles	*Ficus carica*	Indigenous	tree	3
24	zembaba	*Phoenix reclinata*	indigenous	palm	2
25	Eret	*Aloe vera*	Unknown	Succulent	3
26	Chocho	*Premna schimperi*	Indigenous	shrub	2
Totals of individual species					226

- *Woody species recorded in the abandoned quarry plots (5)*

No.	Vernacular name of species	Scientific name	Origen	Category	Number of individual species
1	Embacho	*Rumex sps.*	Unknown	Shrub	39
2	Gulo	*Ricinus communis*	Indigenous	shrub	2
3	Dedeho	*Euclea racemosa*	Indigenous	Shrub	1
4	Cheba	*Acacia lahai*	Indigenous	shrub	1
5	Asene meka	*Senna didymobotrya*	Indigenous	Shrub	2
6	Tinjuet	*Combretum collinum*	Indigenous	shrub	1
Totals of individual species					46

- *Woody species recorded at the surrounding quarry site (4 plots)*

No.	Vernacular name of species	Scientific name	Origen	Category	Number of individual species
1	Bazra girare	*Acacia abyssinica*	Indigenous	tree	2
2	Bisana	*Croton macrostachyus*	Indigenous	Shrub	1
3	Agame	*Carissa spinarum*	Indigenous	Shrub	3
4	Dedeho	*Euclea racemosa*	Indigenous	shrub	4
5	Key bahir zaf	*Eucalyptus camaldulensis*	Exotic	tree	6

6	Embacho	*Rumex sps.*	Unknown	shrub	5
7	Sensele	*Justicia schimperiana*	Indigenous	shrub	2
8	Agame	*Carissa spinarum*	Indigenous	tree	2
9	Gerawa	*Vernonia amygdalina*	Indigenous	shrub	2
10	Asene meka	*Senna didymobotrya*	Indigenous	shrub	4
11	Bisana	*Croton macrostachyus*	Indigenous	tree	3
12	Qega	*Rosa abyssinica*	Indigenous	Shrubs	1
13	Eriet	*Aloe vera*	Unknown	Succulent shrubby	2
Totals of individual species					37

- *Woody species recorded in the plantation site (2 plots)*

No.	Vernacular name of species	Scientific name	Origen	Category	Number of individual species
1	Mimosa	*Acacia decurrens*	Exotic	tree	72
2	Saligna	*Acacia saligna*	Exotic	Small tree	59
3	Agam	*Carissa spinarum*	Indigenous	tree	2
4	Agam	*Carissa spinarum*	Indigenous	shrub	3
5	Bazera gerare	*Acacia abyssinica*	Indigenous	tree	1
6	Besana	*Croton macrostachyus*	Indigenous	tree	1
Totals of individual species					138

Annex D: Shannon-Wiener indices of diversity and evenness of woody species in the different land categories

- *Shannon-Wiener indices of diversity and evenness of woody species in the natural wood land*

No.	Species name	No.of Sps.	pi	ln(pi)	pi*ln(pi)
1	*Acacia abyssinica*	22	0.097345133	-2.329492546	-0.226764761
2	*Croton macrostachyus*	35	0.154867257	-1.865186938	-0.288856384
3	*Ricinus communis*	4	0.017699115	-4.034240638	-0.071402489
4	*Carissa spinarum*	14	0.061946903	-2.78147767	-0.172303926
5	*Euclea racemosa*	43	0.190265487	-1.659334884	-0.315714159
6	*Opuntia ficus-indica*	7	0.030973451	-3.47462485	-0.107621124
7	*Euphorbia abyssinica*	3	0.013274336	-4.321922711	-0.057370655
8	*Entada abyssinica*	12	0.053097345	-2.935628349	-0.155874072
9	*Rumex sps.*	8	0.03539823	-3.341093458	-0.118268795
10	*Justicia schimperiana*	3	0.013274336	-4.321922711	-0.057370655
11	*Grewia villosa*	19	0.084070796	-2.47609602	-0.208167365
12	*Carissa spinarum*	5	0.022123894	-3.811097087	-0.084316307
13	*Vernonia amygdalina*	8	0.03539823	-3.341093458	-0.118268795
14	*Capparis tomentosa*	4	0.017699115	-4.034240638	-0.071402489
15	*Casuarina equisetifolia*	2	0.008849558	-4.727387819	-0.04183529
16	*Senna didymobotrya*	6	0.026548673	-3.62877553	-0.096339173
17	*Buddleia polystachya*	2	0.008849558	-4.727387819	-0.04183529
18	*Ficus sycomorus*	10	0.044247788	-3.117949906	-0.137962385

19	*Maesa lanceolata*	3	0.013274336	-4.321922711	-0.057370655
20	*Ficus sur*	2	0.008849558	-4.727387819	-0.04183529
21	*Millettia ferruginea*	1	0.004424779	-5.420534999	-0.023984668
22	*Grevillea robusta*	3	0.013274336	-4.321922711	-0.057370655
23	*Ficus carica*	3	0.013274336	-4.321922711	-0.057370655
24	*Phoenix reclinata*	2	0.008849558	-4.727387819	-0.04183529
25	*Aloe vera*	3	0.013274336	-4.321922711	-0.057370655
26	*Premna schimperi*	2	0.008849558	-4.727387819	-0.04183529
Total		226	1		-2.750647278
H= Σ(pi*ln(pi))-					2.750647278
J=H/lns					0.844249778

- *Shannon-Wiener indices of diversity and evenness of woody species in the surrounding quarry site*

No.	Species name	No.of Sps.	pi	ln(pi)	pi*ln(pi)
1	*Acacia abyssinica*	2	0.054054054	-2.917770732	-0.157717337
2	*Croton macrostachyus*	4	0.108108108	-2.224623552	-0.240499843
3	*Carissa spinarum*	5	0.135135135	-2.00148	-0.27047027
4	*Euclea racemosa*	4	0.108108108	-2.224623552	-0.240499843
5	*Eucalyptus camaldulensis*	6	0.162162162	-1.819158443	-0.294998666
6	*Rumex sps.*	5	0.135135135	-2.00148	-0.27047027

7	*Justicia schimperiana*	2	0.054054054	-2.917770732	-0.157717337
8	*Vernonia amygdalina*	2	0.054054054	-2.917770732	-0.157717337
9	*Senna didymobotrya*	4	0.108108108	-2.224623552	-0.240499843
10	*Rosa abyssinica*	1	0.027027027	-3.610917913	-0.097592376
11	*Aloe vera*	2	0.054054054	-2.917770732	-0.157717337
Total		37	1		-2.285900461
H=Σ(pi*ln(pi))*-1					2.285900461
J=H/lns					0.953294536

- *Shannon-Wiener indices of diversity and evenness of woody species in the abandoned quarry site*

No.	Species name	No.of Sps.	pi	ln(pi)	pi*ln(pi)
1	*Ricinus communis*	2	0.043478261	-3.135494216	-0.136325835
2	*Euclea racemosa*	1	0.02173913	-3.828641396	-0.083231335
3	*Rumex sps.*	39	0.847826087	-0.16507975	-0.139958919
4	*Senna didymobotrya*	2	0.043478261	-3.135494216	-0.136325835
5	*Acacia lahai*	1	0.02173913	-3.828641396	-0.083231335
6	*Combretum collinum*	1	0.02173913	-3.828641396	-0.083231335

Total	46	1		-0.662304594
H=Σ(pi*ln(pi))-1				0.662304594
J=H/lns				0.369639232

- *Shannon-Wiener indices of diversity and evenness of woody species in the plantation area*

No.	Species name	No.	pi	ln(pi)	pi*ln(pi)
1	*Acacia abyssinica*	1	0.00724638	-4.927253685	-0.035704737
2	*Carissa spinarum*	5	0.03623188	-3.317815773	-0.120210716
3	*Acacia decurrens*	72	0.52173913	-0.650587566	-0.339436991
4	*Croton macrostachyus*	1	0.00724638	-4.927253685	-0.035704737
5	*Acacia saligna*	59	0.42753623	-0.849716241	-0.36328448
Total		138	1		-0.894341661
H=Σ(pi*ln(pi))*-1					0.894341661
J=H/lns					0.555685717

Annex E. Recommended tree and shrubs for abandoned quarry rehabilitation use of 'Worku-Sefer' quarry

No.	Scientific name	Vernacular name of species	Origen	Environmental use						Notes
				shade	ornamental	Nitrogen fixation	Soil conservation	Soil Improvements	Windbreak	
1	*Acacia abyssinica*	Bazra girare	Indigenous	✓	-	✓	✓	✓	-	A large flat-topped shade tree to 20 m when mature
2	*Acacia decurrens*	Mimosa	Exotic	✓	✓	✓	✓	-	✓	A beautiful tree or shrub with strong up right growth
3	*Acacia lahai*	Cheba	Indigenous	✓	-	✓	-	-	-	A very flat toped tree to 15 m
4	*Acacia mearnsii*	Mimosa	Exotic	-	✓	✓	✓	-	✓	An unarmed shrub or tree, 2-15m
5	*Acacia melanoxylon*	Omedla	Exotic	✓	✓	-	-	-	✓	A tall conical timber tree growth up to 35m

6	*Acacia saligna*	Saligna	Exotic	✓	✓	✓	✓	✓	✓	A shrub or leafy tree to 10m
7	*Aloe vera*	Eret	Unknown	-	✓	-	✓	-	-	More or less succulent shrubby perennial with very short stem
8	*Cajanus cajan*	Yergib ater,Yewof ater	Exotic			✓	✓	✓	✓	A slender shrub 2-5m, annual or perennial, becomes woody with age
9	*Carissa spinarum*	Agame	Indigenous	-	✓	-	✓	-	-	A spiny shrub or small tree
10	*Casuarina cunninghamiana*	Shewshewe or Arzelibanos	Exotic	✓	✓	✓	✓	✓	✓	An evergreen tree to 20 m, pyramidal in shape, shady crown
11	*Casuarina equisetifolia*	Sheweshewie	Exotic	✓	✓	✓	✓	✓	✓	A tree to 20 m with "weeping" foliage

12	*Cordial africana*	Wanza	Indigenous	✓	✓	-	✓	-	-	A much-branched deciduous tree with rounded crown
13	*Croton macrostachyus*	Besana	Indigenous	-	-	-	✓	-	-	A deciduous tree, crown rounded
14	*Entada abyssinica*	Kentefa	Indigenous	✓	-	✓	-	-	-	A deciduous tree without thorns,3-10m,dense.leafy,spreading crown, flat or rounded
15	*Erythrina abyssinica*	Korch	Indigenous		✓	✓	✓			A deciduous tree with a short trunk, thick spreading branches, rounded crown,6-12m
16	*Euclea racemosa*	Dedeho	Indigenous	-	✓	-	-	-	-	A shrub or small tree 3-4m
17	*Ficus sycomorus*	Bamba,shola	Indigenous	✓	✓	-	✓	✓	✓	A large semi-deciduous spreading tree to

										25m
18	*Ficus sur*	Shola	Indigenous	✓	-	-	-	-	-	A large tree often strongly buttressed to 30 m and up to 150 cm in diameter
19	*Grevillea robusta*	Grevillea	Exotic	✓	✓	-	✓	-	✓	A semi-deciduous tree to 20m or more with a straight trunk and angular branches
20	*Jacaranda mimosifolia*	Yetemenja zaf	Exotic	✓	✓	-	-	-	✓	A deciduous tree up to 20m with spreading branches
21	*Millettia ferruginea*	Berbera	Indigenous	✓	✓	✓	-	-	-	A large shady tree to 35m
22	*Phoenix reclinata*	zembaba	indigenous	-	✓	-	✓	-	-	The mature palm trunk reach 10m,slender and

										often bent over
23	*Prunus africana*	Tikur inchet	indigenous	✓	-	-	-	-	✓	An evergreen tree to 40m
24	*Vernonia amygdalina*	Grawa	Indigenous	-	✓	-	-	✓	-	A single-stemmed shrub to 3m, sometimes a tree to 10m with a wide bole