COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES
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Environmental and Socio-Economic Impact of Artisanal and Small-Scale Placer Gold Mining at Dima. Gambella, Ethiopia.

BY: SELAM TARIKU

ADVISOR: Prof. SOLOMON TADESSE

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Addis Ababa, Ethiopia

Addis Ababa University
School of Earth Sciences Graduate program

Approval

This thesis entitled as: "**Environmental and Socio-Economic Impact of Artisanal and Small-Scale Placer Gold Mining at Dima. Gambella, Ethiopia"** by Selam Tariku for the partial fulfillment of the degree of Master of Science in Mining Geology compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

Advisor: Prof. Solomon Tadesse

Signature _____ Date _____

Examiner: Dr Worash Getaneh

Signature _____ Date _____

Examiner: Prof. Bekele Abebe

Signature _____ Date _____

Chairman:

Signature _____ Date _____

Declaration

I, the undersigned, declare that this thesis is my original work that have been carried out independently with the guidance and support of my advisor Prof. Solomon Tadesse. The matter embodied in this thesis has not been submitted earlier for award of any degree or diploma and that all sources of materials used for the thesis have been duly acknowledged.

Candidate: Selam Tariku

Signature _____ Date _____

@Addis Ababa University, School of Earth Sciences, Graduate Studies Program, June, 2021.

Abstract

Gold mining plays a significant economic role in the vicinity of Akobo River, Gambella, South-Western Ethiopia; yet the rudimentary nature of artisanal and small scale gold mining activities often caused extensive degradation and shocking environmental as well as social-conditions. The aim of this study is to emphasize the methods of production existing in artisanal and small-scale placer gold mining of the study area and examine environmental and socioeconomic impacts generated by these activities. The study adopted a multi-method approach that involved assessed the variability of physicochemical parameters in water along the Akobo River; collected data using a semi structured questionnaire, group discussions and one-to-one interviews; inspected the rate, extent and distribution of various land use and cover changes(LULC) in Dima district from 2000 to 2020 on the basis of Landsat 7 ETM satellite images downloaded in raw format from the USGS website (https://earthexplorer.usgs.gov/) and fieldwork. Facing a rapid expansion of artisanal and small-scale gold mining, governments, academia, green economy competitiveness, inter-institutional and multidisciplinary collaborations are urgently needed to overcome environmental and socio-economic challenges drawn from this sector in the study area.

Key words: Artisanal and Small scale gold mining, Environmental and Socioeconomic impacts, Physico-chemical parameters.

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Dedication

This paper is dedicated to my beloved family.

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Acronyms and Abbreviations

AGM	Artisanal Gold Mining
AS	Artisanal and Small-Scale
ASGM	Artisanal and Small-Scale Gold Mining
ASM	Artisanal and Small-Scale Mining
CCD	The United Nations Convention to Combat Desertification
DEM	Digital Elevation Model
EPA	Environmental Protection Authority
EC	Electrical Conductivity
ETM+	Enhanced Thematic Mapper Plus
GIS	Geographical Information System
GPS	Global Positioning System
GSE	Geological Survey of Ethiopia
Ha	Hectare
LULC	Land Use Land Cover
Mg/L	Milligram per Liter
MOM	Minister of Mines
NBE	National Bank of Ethiopia
NTU	Nephelometric Turbidity Units
SPSS	Statistical Package for Social Scientists
TDS	Total Dissolved Solid
USGS	United State Geological Survey
UTM	Universal Transverse Mercator
WB	World Bank
WHO	World Health Organization

Chapter One

Introduction

1.1 Background

In keeping with the Mining Operations Proclamation (N°678/2010) artisanal mining is defined as a mining operation carried out by individuals or small and micro enterprises which is mostly of manual nature and does not involve the engagement of employed workers. Similarly, in this proclamation article 35 defined that small scale mining is any mining operation of which the annual run-off mine ore does not exceed 100,000m^3 for placer operation. Artisanal and Small-Scale mining activities form an important part of the Ethiopian mining sector. Most ASM is carried out in remote areas, and at least a significant part of these activities are informal, the sector remains poorly understood (Mehari Girmay, 2018). Ethiopia has a long tradition of artisanal gold mining. The sector remains important and Minister of Mines (MOM, 2012) estimates that a total of about 1 million people are directly engaged in ASM in Ethiopia, about a third of which are concerned with gold mining.

Artisanal Mining in Ethiopia has been the basic mineral and rocks production and processing sectors throughout the older civilianization of the country from pre-Axumite kingdom to present time (Abebe Senbete, 2018). The most important extracted mineral in the country is gold. Gold has been produced from placer deposits for several thousand years, adopted from report of Ethiopia Extractive Industries Transparency Initiative (EEITI, 2014). Gold has been traditionally mined from placers for many years in disorganized manner in different areas of

the country; Most of the artisanal miners come from seasonally socially and economically marginalized communities; most miners work returning to their subsistence farms when agricultural work is required in order to supplement their insufficient incomes as said by Ministry of Mines, Petroleum and Natural Gas (MOM, 2016).

Gold could be mined from primary mineralized bodies like veins and disseminated deposits or from secondary (placer) deposits. Placer gold is known to occur in four different geographical regions of Ethiopia. These are the Adola area in Southern Ethiopia, in Benishangul and Wollega of Western Ethiopia, in the Akobo gold field of Southwestern Ethiopia, and also in the Mekele quadrangle of Northern Ethiopia Artisanal gold mining is being carried out in the South - Western part of the country which could be an indicator of potential placer deposits which could be large enough to be mined by a mechanized placer gold mining (Tamirat Worku, 2017).

1.2 Problem Statement

There is an overall agreement that although Artisanal and Small-Scale mining may become a source for the development of local entrepreneurship, and overall economic development. These kinds of mining activities can increase local purchasing power, increase demand for locally produced goods, contribute to foreign exchange earnings, reduce rural-urban migration and allow exploitation

of mineral deposits unviable for larger operators, it is also a sector which is associated with significant negative environmental impacts, and often with social conditions. An Artisanal Gold Mining activity in the study area is highly rudimentary and manual which lacks technological access, skills as well as legal framework. Rudimentary mining and processing techniques used in AGM often result in degraded environmental, safety, health and social conditions. The techniques and tools that have been used by artisanal miners for mining and processing of gold in Akobo domain were unsafe, inefficient and traditional. These traditional practices resulted in very low yields and high health risk and environmental damages. It is vital that measurements should be taken to control such problems. Thus, the main intention of this proposed research paper is thoroughly assess and identify the factors affecting artisanal and small-scale gold recovery and recommend possible solution to the identified problems.

1.3 Objective

1.3.1 General Objective

The general objective of the study is to emphasize the methods of production existing in artisanal and small-scale placer gold mining of the study area and examine environmental as well as socioeconomic impacts generated by these activities.

1.3.2 Specific Objectives

- To investigate and evaluate the equipment that the Artisanal miners used practices, recovery factors and efficiency in placer gold recovery.

- To determine whether and how artisanal and small scale placer gold mining impacted the environment and community structures.
- To evaluate Akobo river water footprints from surrounding artisanal and small scale placer gold mining activities.
- To detect change in land use and land cover in Dima Woreda from 2000-2020 G.C.
- To assess whether the Artisanal miners used Mercury for placer gold processing purpose or not; and examine how this mercury affect the environment if they use.
- To recommend possible remedy to be taken to minimize the environmental and socio-economic damage.

1.4 Research questions

- What type of mining and processing techniques that the Artisan miners adopted in Dima district?
- What have been the relationships between ASGM and environment?
- How ASGM affect the social activities in Dima district?
- Did ASGM sector in Dima district contribute to the local economy as expected?

1.5 Limitation of the study

In this research, there were limitations on availability of field water chemistry measurement instruments such as pH meter, EC meter and turbidity meter in the

department. It also difficult to acquire high-resolution satellite image related with the identified years.

1.6 Scope of the Study

This research deals with methods of production, environmental and socio-economic impact of ASGM in the locality of Gambella Regional state, Agnwa Zone, Chama and Merkes Kebeles of Dima Woreda from 2000-2020 G.C. So the main important thing here is that it focuses mainly on ASGM activities and their challenges with respect to the environment and socio-economic as well as opportunities. It does not take into consideration large-scale gold mining as a core of discussion.

In addition, placer gold mining is also a center of discussion in the entire paper. Accordingly, mining of primary gold deposits are not considered as an issue of this research. In line with this, environment and socio-economic issues analyzed from ASGM perspective.

1.7 Scheme of Presentations

Chapter 1
• Cover the general background, problem statement, objective (general and specific), research questions. • Demonstrate explanation on the limitation as well as scope of the study.
Chapter 2
• Overview literature reviews about Characteristics of Artisanal and Small-scale mining in the country as well as in the Dima district. • Different policies and legislation on Artisanal and Small-scale mining in the country also exist. • Highlights Environmental and Socio-Economic Impact of ASGM.
Chapter 3
• Describe the study Area, location and accessibility, geology (regional and local), climate, physiography and drainage.
Chapter 4
• Report the methodology adopted within the whole progress investigation. • Explain analytical tools and supporting materials.
Chapter 5
• Documented data analysis by using various analytical, experimental and computer Programmes regarding the methodology adopted. • Compile interpretation of results and final findings. • Address ASGM conditions in the study area. • Deals the mining and processing techniques that the Artisan miners adopted in the study area.
Chapter 6
• Layout the entire concluded and recommended research work within separate subheadings.

Table 1 Flow chart of the study

Chapter Two

Literature Review

2.1 Characteristics of Artisanal and Small-scale Gold mining in the country

Ministry of Mines, Petroleum and Natural Gas MOM (2016) reported gold occurrences are widespread in Ethiopia. Exploitation of placer gold reportedly dates back at least 3,500 years. Over the subsequent millennia, gold has been extracted nearly continuously to this day, although not always in large quantities.

Beyene Tadesse (2016) tries to investigate the total population involved in ASGM (legal and illegal) is numerous estimated around 1.24 million which shows the significance of the sector in terms of employment creation in Ethiopia.

Wall (2008) mentions globally, ASM employs many millions of people, with artisanal and small-scale gold mining employing 15 million people alone. It is believed to provide a livelihood for over 100 million, almost all of whom live in developing countries. There is no formal definition for ASM, but it is broadly understood to refer to mining activities that are labor–intensive and capital, mechanization and technology poor. Attempts to define ASM activities on the basis of human resources, production, capital and revenue have all proved impossible due to the wide variety of minerals mined and the heterogeneity within the sector.

According to World Bank WB (2014) report the productivity of ASM gold miners varies. However, in the mainly placer based gold deposits of western Ethiopia, surveys suggest that on average, one miner produces some 1-5g gold per month, depending upon whether the mining is conducted part- or- full time. The smuggling and illicit sales of gold to non-licensed buyers is reported to be rather widespread, and this has occurred in spite of the government policy of paying a 5% premium over the daily gold price. The reasons behind these illicit sales include a wish to avoid paying royalty (5%), and a belief that the price paid by illicit traders is higher than those being paid by the government. The amount of gold produced by ASM is reported to have increased dramatically in recent years: from a bit more than 400 kilo gram in 2008/2009, to in the excess of 8,000 kilo gram in 2011/2012.

Consistent with Tamirat Worku (2017) in Southwest Ethiopia Placer gold exploration activities in the Akobo goldfield, 310 km SW of Jima town, were initially carried out in 1934-1940 by COMINA and in the 1950s by the Department of Mines. Gold reserve estimates varied, but some were as high as 3000 kg. Earlier reserve estimates were upgraded in 1994 estimating 3600 kg at grades between 0.07 and 0.5 g/m3.

2.2 Policies and legislation on Artisanal and Small-scale mining in the country

The pressure on the environment resulting from mining has been locally serious in some areas. Although tackling the problems requires coordination among several organizations, efforts in this regard are inadequate. Nonetheless, the following are among the regulatory instruments that have been issued and efforts that have been made by the government.

2.2.1 Constitution of the Federal Democratic Republic of Ethiopia (Proc. No. 1/1995)

One of the objectives of the Constitution of the Federal Democratic Republic of Ethiopia (Proclamation 1/1995) is ensuring a clean and healthy environment. It states that every citizen has the right to live in a healthy environment. Based on the Constitution, the Environmental Protection Authority (EPA), established to cater for environmental matters, which were enacted by the Federal Council of Peoples Representatives towards the end of 2002. The environmental guidelines seen as needed to implement these laws have been prepared or are under preparation by the EPA. Examples include guidelines designed to help in the implementation of environmental impact assessment in the agricultural, transport and industrial sectors.

2.2.2 Environmental Impact Assessment, Proclamation No. 299/2002

The Proclamation was enacted as Proclamation No. 299/2002 on 2nd of December 2002. The main reasons for enacting this proclamation are the following:

- Environmental Impact Assessment serves to bring about thoughtful development by predicting and mitigating the adverse environmental impacts that a proposed development activity is likely to cause as a result of its design, location, construction, operation, modification and cessation.
- A careful assessment and consideration of the likely environmental impacts of public documents prior to their approval provides an effective means of harmonizing and integrating environmental, economic, social and cultural considerations and aspirations into the decision-making process in a manner that promotes sustainable development.
- Implementation of the environmental rights and objectives enshrined in the Constitution requires the prediction and management of likely adverse environmental impacts, ways in which the benefits might be maximized, and the balancing of socio-economic benefits with environmental costs.
- Environmental impact assessment serves to bring about administrative transparency and accountability, as well as involve the public and, in particular, communities in development planning decisions which may affect them and their environment.

2.2.3 Environmental Pollution Control Proclamation 300/2002

This Proclamation was enacted as Proclamation No. 300/2002 on 2nd of December 2002. It was enacted to help realize the effective implementation of the environmental objectives and goals incorporated in the Environmental Policy. In addition, the Proclamation was enacted because:

- ✓ Some of the social and economic development endeavors may be capable of causing environmental impacts that might be detrimental to the development process itself;
- ✓ The protection of the environment in general and the safeguarding of human health and wellbeing, and the preserving of biota is the duty and responsibility of all; and
- ✓ It is essential to prevent or at least minimize to acceptable levels pollution resulting from economic development through appropriate measures.

The Proclamation consists of a number of articles on different issues such as pollution control, management of hazardous wastes, chemicals and radioactive substances, environmental standards, the rights and duties of environmental inspectors / and penalties etc.

2.2.4 Mining Proclamation No.52 of 1993

In line with the constitution, the Mining Proclamation provides that mineral resources within the territory of Ethiopia are the property of the government and of all the peoples of Ethiopia and that the government is the custodian of mineral

resources with duty to deploy them for the benefit and development of all Ethiopians.

The Mining Proclamation focuses on establishing the rules and procedures for a licensing system and includes key aspects of types of licenses, division between the federal government and regional states in the issuing of different types of licenses, rules and procedures for access to mineral rights, their termination, and rights and obligations of license holders.

2.2.5 Mining Operations Proclamation No 678/2010 amended under Operations Proclamation No 816/2016

The Mining Operations Proclamation governs all mining and related activities in the country. The proclamation does not encourage use of modern technology to be used in artisan mining in which technical and professional competence is not required. The proclamation directly targets provision of job opportunity to the youth that the license period is limited to a maximum of two years.

2.2.6 Child Labour Proclamation

Children typically work in mines to help their parents and to supplement family income in order to buy basic food and clothing items. Child labour is typically closely linked to poverty, and while the 1999 International Labour Organization (ILO) Convention 182 identified child labour in mines as one of the worst forms of child labour, it is unlikely to cease unless access to education improves and

alternative opportunities for income generation and poverty reduction exist in impoverished mineral-rich locations.

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2.2.7 International Agreements

Ethiopia has adopted and ratified several international conventions and agreements related to the environment. The major ones are:

2.2.7.1 Convention on Biological Diversity

The Convention was ratified by Ethiopia by Proclamation 98/94, on May 31, 1994. By Proclamation No. 362/2003, Ethiopia has ratified the Cartagena Protocol on Biosafety to the Convention on Biological Diversity. Various activities are being carried out towards the implementation of this convention. The following are some of them:

- ✓ A National Biodiversity Protection and Research Policy has been prepared;
- ✓ Prior to 1998, the Institute of Biodiversity Conservation and Research had been given the responsibility to conserve and carry out research on the country's plant, animal and micro-organism genetic resources, and it is active in fulfilling its mandate;
- ✓ A Biodiversity Protection and Conservation Support Project in important bird areas is being implemented since 1999 by the Ethiopian Wildlife Conservation and Development Organization;

- ✓ Biosafety framework, with the law being based on the Biosafety Model Law issued by the African Union, is being developed by the Environmental Protection Authority.

2.2.7.2 The United Nations Convention to Combat Desertification (CCD)

The objective of the Convention is to combat desertification and mitigate the effects of droughts in countries experiencing serious drought and/or desertification, particularly in Africa, Ethiopia has ratified the Convention through its Proclamation No. 80/1997. To implement the Convention, various activities are being carried out with the coordination of the Environmental Protection Authority.

2.2.7.3 The Basel Convention

The objective of the Basel Convention is to control and regulate the trans-boundary movement of hazardous wastes. The Bamako Convention of 1991 plays a similar role at the level of the African continent.

2.2.7.4 The Stockholm Convention

The objective of the Convention is to ban the use of Persistent Organic Pollutants (POPS). The Convention was ratified by Ethiopia by Proclamation No. 279/2002 in 2002. The Environment, Forest and Climate Change Commission (EFCCC) has the full mandate to implement the Convention at the national level. A project

to develop an appropriate system for the realization of the objectives of the Convention in Ethiopia is in progress.

2.3 ASGM and Environment in the country

Report from Ministry of Mines and Energy (MOM) (2009) shows the placer mining environment is extensively dug that there are physical land degradation, open tunnels and pits, deforestation etc which is becoming issue for the environment. The financial surety to reclaim and rehabilitate such destructed area is not likely to happen unless special programme is going to be undertaken by the government itself with other international partners.

2.3.1 Deforestation

When gold deposits are found in forests, they are frequently cut to give way for the digging of pits, for construction of residential or working premises, for fuel for cooking and in some cases for processing the ore and the manufacturing of hand tools. Unfortunately, replanting is rarely planned to make up for the trees that were cut down. The result is devegetation or deforestation along with Ministry of Mines, Petroleum and Natural Gas (MOM, 2016).

2.3.2 Water Pollution

As per Ministry of Mines, Petroleum and Natural Gas MOM (2016) the most significant impact a mine can have its potential effect on water quality and availability of water resources. Potential impacts on water resources include:

- ❖ Impacts of tailing impoundments, waste rock, heap leach, and dump leach facilities;
- ❖ Erosion of soils and mine wastes into surface waters; and
- ❖ Knock on impacts of mine dewatering.

Key questions that must be asked prior to commencing and throughout your mining operations include:

- ✓ Will the surface and groundwater supplies remain fit for human consumption based on the mining processes used?
- ✓ Will the quality of surface waters in the project area remain adequate to support native aquatic life and terrestrial wildlife?

2.3.3 Loss of Biodiversity

Impacts on wildlife can arise in the case of habitat loss or fragmentation due to the deforestation of the area for mining development. Moreover, with the influx of people to the mining site (caused by in-bound migration) predators such as dogs can increase in number, potentially threatening vulnerable species in the area as said by Ministry of Mines, Petroleum and Natural Gas (MOM, 2016).

2.4 ASGM and Social Conditions in the country

2.4.1 Health

Health impacts can be caused by the exposure of the community to increased level of hazardous and toxic chemicals or poisoning to crops and livestock. Ministry of Mines, Petroleum and Natural Gas MOM (2016) mentions poor management of the mine site can also lead to increased risk of accident. Migration can also increase the risk of communicable water borne diseases such as malaria and sexually transmitted infections including HIV/AIDS, and respiratory illnesses.

2.4.2 Safety issues

There are deteriorating safety conditions in mining areas (i.e. exposed to dust, poor ventilation and rock falls/ collapse. Study of Ministry of Mines MOM (2012) demonstrated that everything is done precariously in the district and death may occur. Poor environmental, health and safety mine site management can lead to increased risk of injury or death for miners and members of mining communities. For example, mining pits are often not filled following exploitation. This can lead to an increased risk of accidents, especially during the rainy season when the grasses grow and obscure the mine pit openings. The hazard can be acute for humans, livestock, and wildlife alike. Digging in pits can present a direct threat of pit collapse to miners, especially when timbering or stairs are not used to support the pits. In addition, aeration is often insufficient in

pits, especially where there is only one vertical shaft, which limits the supply of oxygen to the miners creating a risk of asphyxiation.

2.4.3 Child Labour

The International Labour Organization (ILO) estimates that nearly one million children between 5 and 7 years of age are engaged in small scale mining activities worldwide as conveyed by World Health Organization WHO (2016). It declared Children can be involved in virtually all stages of ASGM, ranging from ore extraction, to processing, and burning. Some children are also required to run errands, carry heavy equipment or materials, or deliver food and water to miners working deep within the mines. Children suffer disproportionately too; Child labour in mines damages not only young bodies and minds but also means that schooling is missed.

2.4.4 Gender Equity

According to Sofia Mohammed (2013) inform Mining is a demanding physical activity traditionally has been considered as a male activity. Women engaged in this Artisanal Mining in different regions of Ethiopia face many challenges in their participation to artisanal mining. Such as:

- Lack of formal education
- Time constraints- bear burden of household chores, nurturing children
- Lack of finance &technical skill to sustain or expand their business

- Limited access to credit facilities since they have no opportunity to own property
- Face discrimination under customary laws & traditions
- Lack of knowledge of identifying good mining sites- due to this they spend a lot of time.
- No capacity to buy equipments.
- High prevalence of HIV/AIDs
- For fear of robbery& safety issues they are compelled to sell their product to illegal buyers.

2.5 ASGM and Economic Conditions in the country

2.5.1 Contribution to the Microeconomy

Livelihood of the AS Miners- For the majority of the artisan miners (legal or illegal), mining is the backbone of their livelihood as give details by Ethiopia Extractive Industries Transparency Initiative (EEITI, 2016). Artisanal and small-scale mining activities are rapidly expanding because of gold's firmly rooted market value. Gold mining presents a unique opportunity for poor people since it generates 3-5 times the income from other livelihoods (John, 2013). In Ethiopia over 1,000,000 people are engaged in ASM. 5,000,000-7,000,000 people are indirectly depend on ASM for their livelihood (Sofia Mohammed, 2013).

Employment- Close to one million Ethiopians are employed in the artisanal mining sub-sector and support about five (5) million people (John, 2013). In terms of fluidity, employment numbers in ASM vary widely depending on, for example, the season, alternative livelihood opportunities and the price of

minerals. Total number employed, however, does not fully describe the potential value of ASM employment. Generally, artisanal mining has proved to be a primary source of employment for job seekers from various parts of the country who are relatively disadvantaged in the labour market (e.g. unskilled, low skilled, women, disabled, etc.) as reported by Centre for Development Studies (CDS, 2004).

2.5.2 Contribution to the Macroeconomy

The ASGM sector has a significant contribution to the Ethiopian economy. Production and export of gold was just US$ 5 million in 2001 and rose to US$ 23.8 million in 2015. The World Bank Group WB (2014) also reported that the contribution of the mining sector was 10% of total foreign exchange earnings, and about 2/3 came from artisan mining.

On the word of John (2013) artisanal miners earn about 800 Birr (US$ 42.11) per gramme of gold. However, the value depends on the market and varies from time to time. On average, the mining sector contributes less than 5% of gross domestic product (GDP), of which the contribution of gold was more than 98 percent of the total mining exports.

Based on some assessment studies the gold being mined and produced by artisanal miners all over the country is estimated to be more than 3 tonnes (3000 kilo grams) per year. The regional administration collects royalty from the small scale and artisanal production. The total amount of royalty collected by each

region (nine regional states and two cities Administration) is in few tens of millions of Birr (up to three million US dollars) as per Ministry of Mines and Energy (MOM, 2009).

According to Ministry of Mines as mentioned by Ethiopia Extractive Industries Transparency Initiative MOM (2015, as cited in EEITI, 2016) the artisan miners contribute six to eight tons of gold every year and often generate, on average, US $ 300 million (Table 2). In 2011/12, the amount of gold purchased by the NBE reached 8,328 kg and this increased to 8,387 kg in the following year. Nevertheless, these figures slightly decreased in subsequent years and sharply dropped in 2014/15, perhaps due to the fall in global price of gold. As per the plan of the MoM, the mining sector is expected to generate 2 billion dollars by 2024.

Year	Amount of gold Purchased by the NBE (Kg)	Export (US $, in millions)
2010/11	7,296.30	322.46
2011/12	8,327.73	439.30
2012/13	8,386.84	430.60
2013/14	7,559.50	305.33
2014/15	5,548.38	211.00

Table 2 Artisan Gold Supplied to the NBE (National Bank of Ethiopia) and Export Earnings, 2010/11-2014/15

Source: Ministry of Mining, Dec. 2015

Minister of Mines, Petroleum and Natural Gas, Takele Uma said "Earnings from exports of minerals are showing a tremendous increase. Ethiopia's earned 90 million US dollars which is 15 million gram gold from Artisanal and small scale gold mineral export in the past ten - month of 2012 E.C. Two years ago, Ethiopia's gold export earnings were just $27m, down from its historic high performance – at $602m – recorded in 2012 E.C due to the fact that the government raised the price it pays to artisanal miners, who account for more than half of gold production" (https://www.theafricareport.com/56551/).

Chapter Three

General descriptions of the study area

3.1 Location and Accessibility of the study area

The study area is located in the Vicinity of Akobo River Banks at Chama and Merkes Kebeles, in Dima Woreda, Agnuwa Zone at Gambella Peoples National Regional State.The area is bounded by latitude of 164500 m N to166000 m N and longitude of 341000 m E to 344500 m E which is at 690 km south west of Addis Ababa. It is accessed along the main root of Addis Ababa - Weliso-Welkite-Jima-Bonga-Mizan-Biftu-Dima-Akobo River. The road from Addis Ababa to Dima is Asphalt. Dima Woreda and/or its town is the closest town for Akobo River which is accessed by motor cycles.

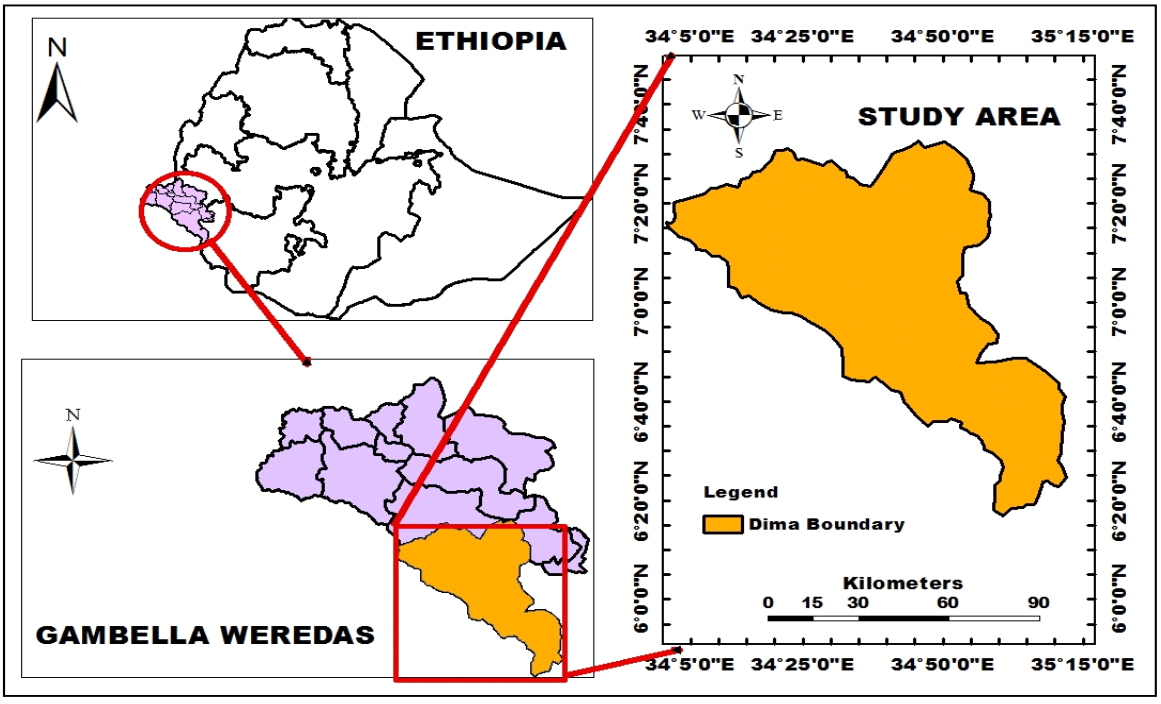

Figure 1 Location map of the area

3.2 Regional Geology

The main rock types of Ethiopia illustrated on the general are: the Precambrian metamorphic rocks with associated syn- to post-tectonic intrusions which form the Basement Complex; the late-Paleozoic to Mesozoic marine and continental sediments; the Cenozoic basic and felsic volcanics; and the volcano-sedimentary and volcano clastic rocks, associated with the Cenozoic volcanics, including Early Tertiary, Late Tertiary and Quaternary sediments. These rock assemblages represent 23%, 25%, 34% and 18% of the total surface area respectively (Solomon Tadesse et al., 2003).

Precambrian occurrences are being explored and exploited in the southern, western and northern greenstone belts of Ethiopia. Precambrian rocks are the most important repositories for gold deposits. The western greenstone belt stretches more than 600 kilometers from Akobo-SW Ethiopia, and its average width varies from 50 to 200 kilometers. The belt comprises region of Gambella include gold prospects at Akobo. The Akobo narrow greenstone sub-belt is a high potential target for gold exploration (http://www.gse.gov.et).

Gambella area are characterized by three geologic domains. The Baro and Geba domains from the western Ethiopian shield consist of heterogeneous ortho- and para-gneisses and migmatites while the Birbir domain consists of lower amphibolite facies rocks with abundant intrusive and meta-intrusive rocks of mafic and intermediate composition. There is an abrupt increase in metamorphic grade across the domain boundaries. The Birbir domain is tectonically bounded

to the east and west, respectively, by the gneissic Geba and Baro domains (Teklewold Ayalew, 1988).

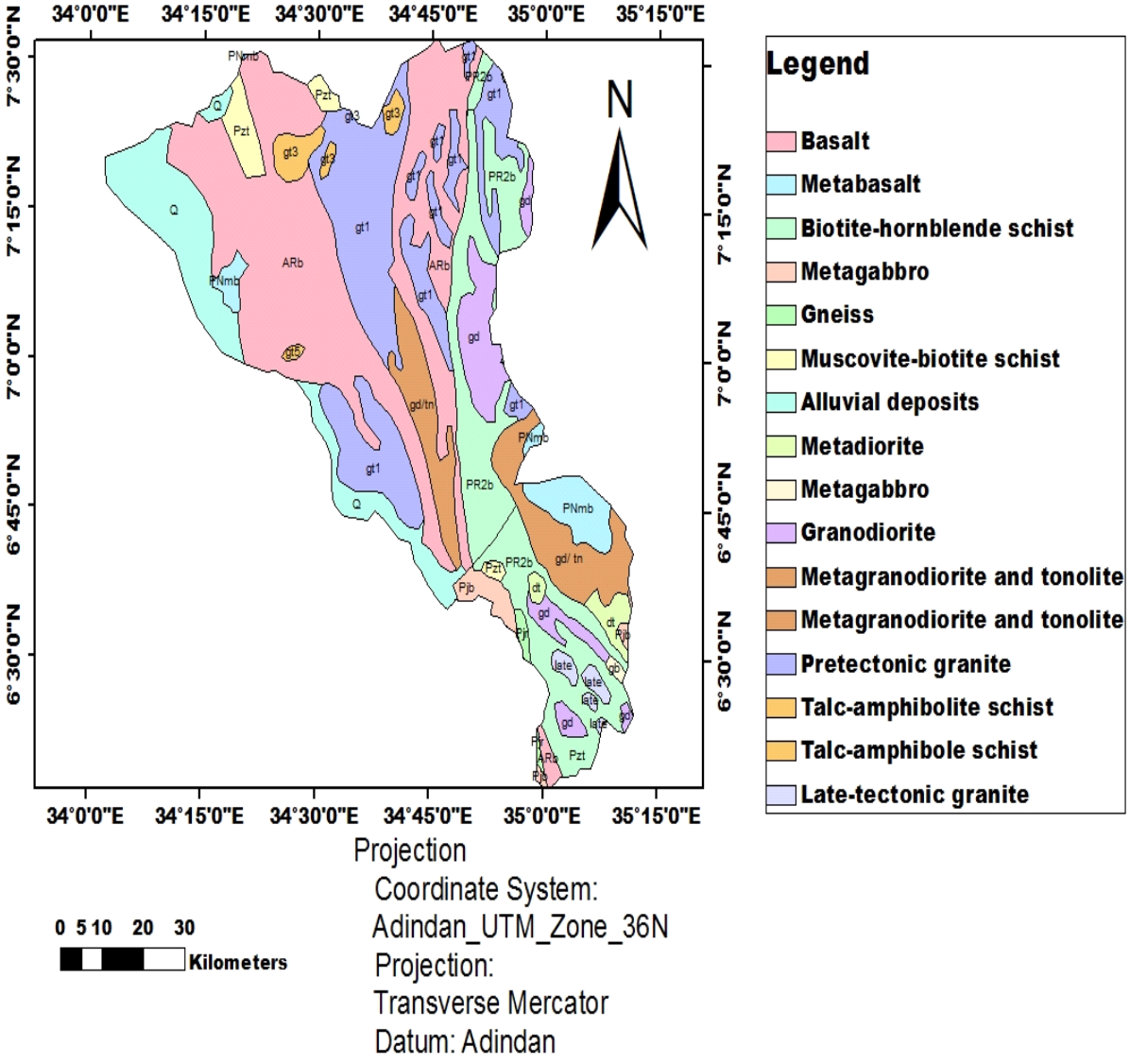

Figure 2 Regional geology of the study area clipped from Basalfew Zenebe et al., 2018 (GSE)

3.3 Local Geology

As mentioned by Tamirat Worku, Akobo's geological setting comprises mafic schists, meta-ultramafic rocks, meta-sedimentary schists, and undifferentiated schists and gneisses. Sansheng Buliding Materials Plc SBMPlc (2020) stated that the Akobo river in particular is covered by Precambrian rock of Akobo Domain which is represented by Gneiss and schist of undivided sedimentary and volcanic, Mafic schist of predominantly volcanic origin, minor Metagraywack, Gabrro, diorite and metamorphosed equivalent, Pre-tectonic and/or Syntectonic Granodiorite and Tonalite and Sandstone, minor conglomerate and siltstone. Alluvial deposit covers on either side of the river banks which is coved by soil.

3.3.1 Mafic Schist

The mafic schist unit is outcropping in central part of the study area and it is generally dark; fine to medium grain. This unit is constituted by Hornblende, Feldspar, Biotite and some Quartz. The general foliation of the rock is $N30^0W$ to $N45^0W$ and dips 50^0 to 65^0 South-West on the word of SBMPlc (2020).

3.3.2 Felsic Schist

The felsic schist is exposed in the south eastern part of the study area. This rock unit is characterized by fine to medium grained texture and light grey in color. According to SBMPlc (2020) it is composed of quartz, mica and feldspar

minerals. The rock is well foliated with orientation of N30^{0}W – N40^{0}W foliation and dip 65^0 to 70^0 SW.

Figure 3 Field exposure of Felsic Schist Outcrops

3.3.3 Meta granite

The Meta granite rock unit exhibits coarse grain texture and light grey color which is exposed in the south western part of the study area. As stated by SBMPlc (2020), it is locally strongly deformed grade to gneiss and dominated by the assemblages of the minerals like quartz, alkali feldspar and plagioclase. The general foliation of this rock is N 60^0 W and dip 65^0 to 70^0 South-West.

Figure 4 Field exposure of Meta granite Outcrops

3.3.4 Ultramafic

Here the ultramafic lithologic unit is found in the eastern part of the area and represents by coarse grain. Consistent with SBMPlc (2020), it grades to serpentinite that is mainly constituted by proximity, serpentine, and some tremolite. This geologic formation exhibits massive outcrop forming small hills.

3.3.5 Quaternary Deposits

The alluvial deposits are localised in places along Akobo River and extensively covered by thick soil. This Quaternary deposits characterized by deposits of sand, gravel, and other detrital or residual material containing a valuable mineral that

has accumulated through weathering and mechanical concentration. The exposure of these deposits in the study area is targets for AS gold mining operations.

3.4 Climate and Wildlife

The climate condition of the study area is characterised by arid to semi-arid with the current average maximum temperature of 40.4^{0}C midday and 16.6^{0}C at night stated by national meteorological agency of Ethiopia. The area gets high rain from June to October with maximum average annual rainfall of 400 mm (http://en.climate-data.org/location/1651/).

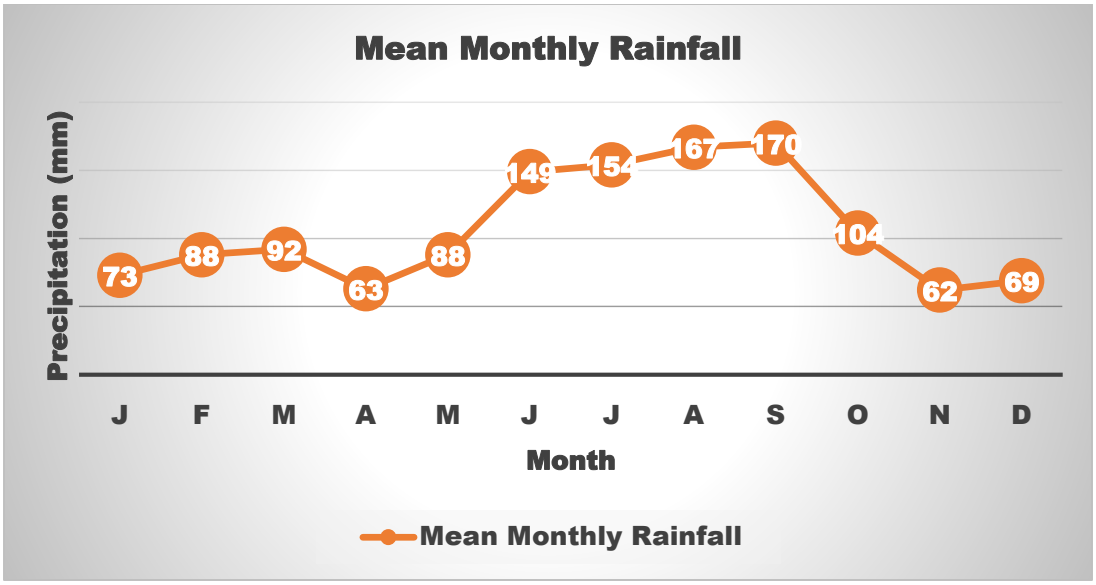

Figure 5 Mean monthly rainfall of the area

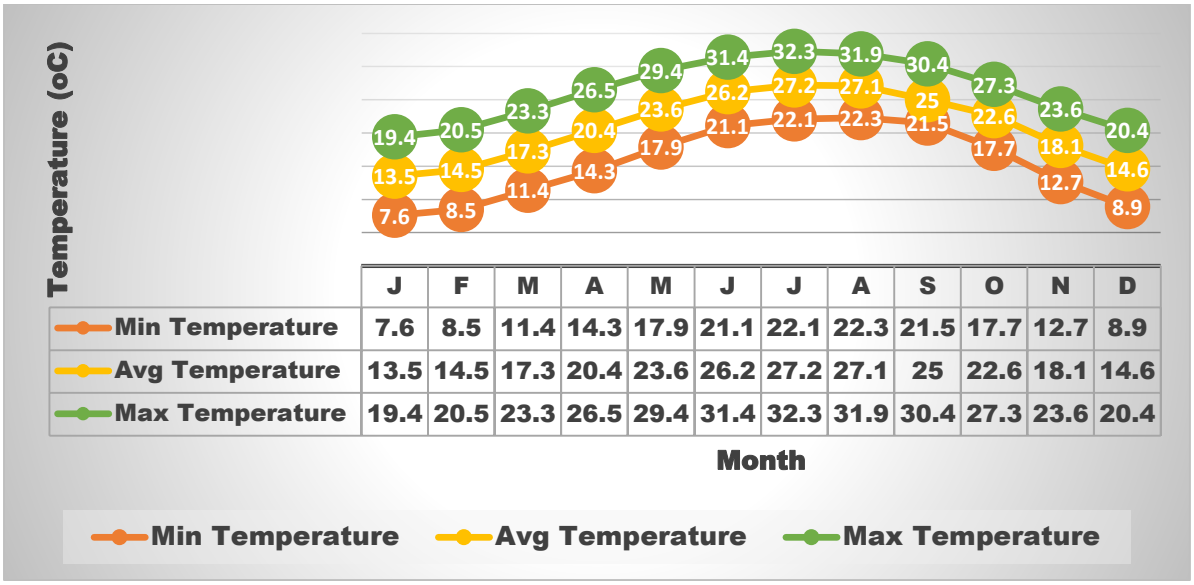

Figure 6 Minimum, Average and Maximum temperature of the study area

The vegetations that existing in the study area include savanna trees, scattered trees and shrubs grown during the rainy season and also reed grasses are occurred. Wildlife species live here are predators like Lion, leopard and Hyena, birds, vertebrates like reptiles (Snake, Python and Lizard), mammals suchlike Monkey in which the Red monkey is endemic to Ethiopia, aquatic animals such as fishes and crocodile. (Source: Discussion with the communities, February 2021).

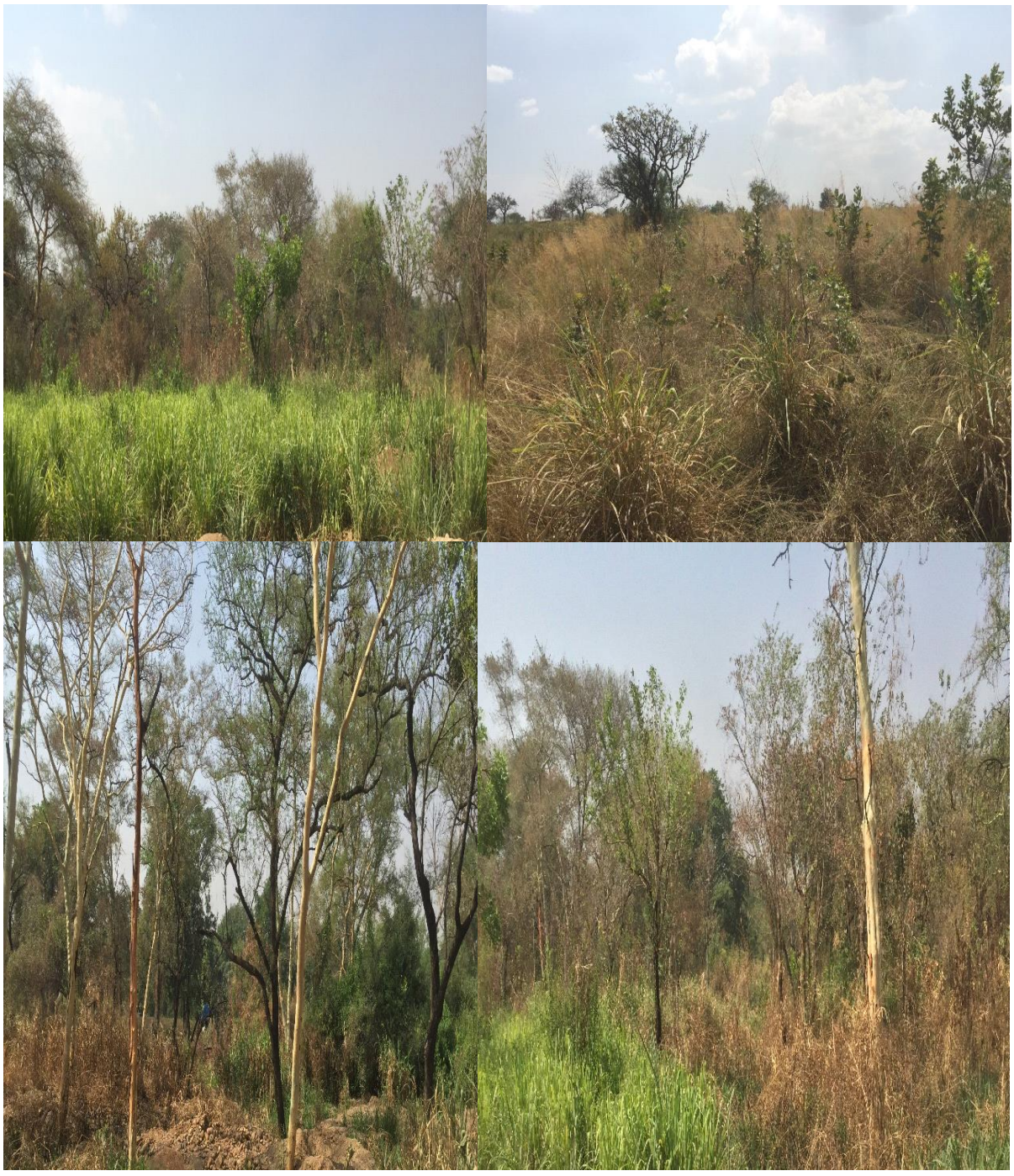

Figure 7 Images of different flora species in the area

3.5 Physiography and Drainage

The topography of the area is differentiated by rugged terrains of Gura Ferda in the north, Shoa Gimira in the East, Maji in the south and flat morphology in the west of South Sudan border. The altitude of the Dima District ranges from 412 meter to 2063 meter above sea level. Akobo River runs from east to west and forming dendritic drainage patterns whereby it's joining tributaries draining from north to south and from south to north.

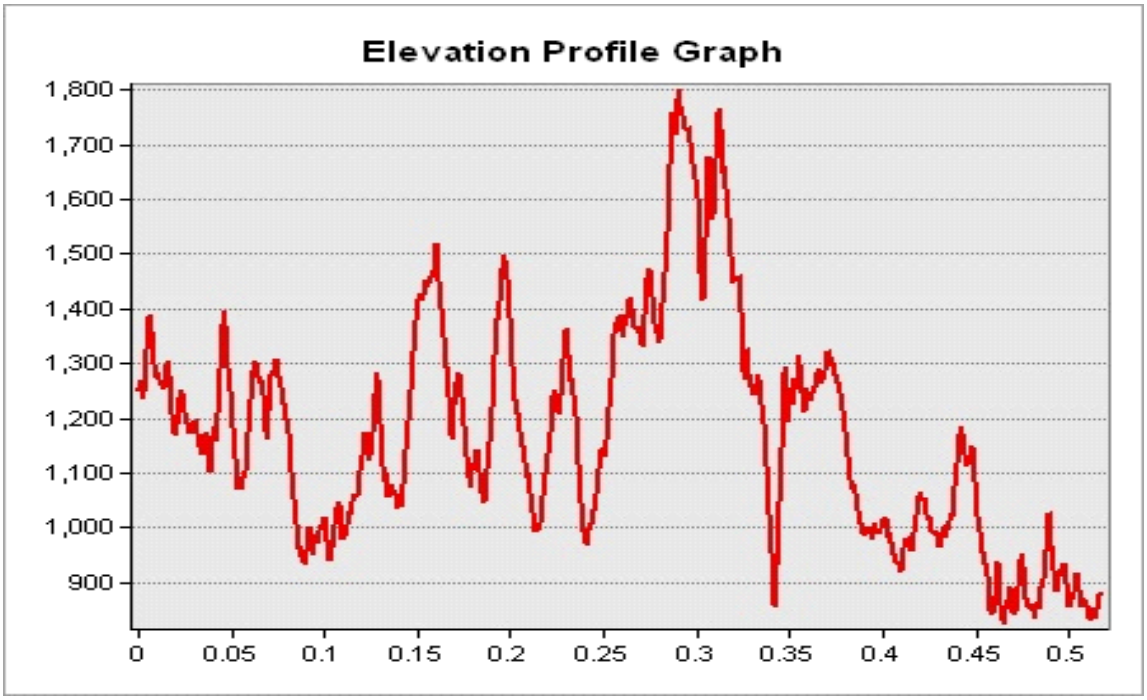

Figure 8 Graph showing Elevation Profile of the district (x-coordinate shows distance in mile and y-coordinate shows elevation value in meter).

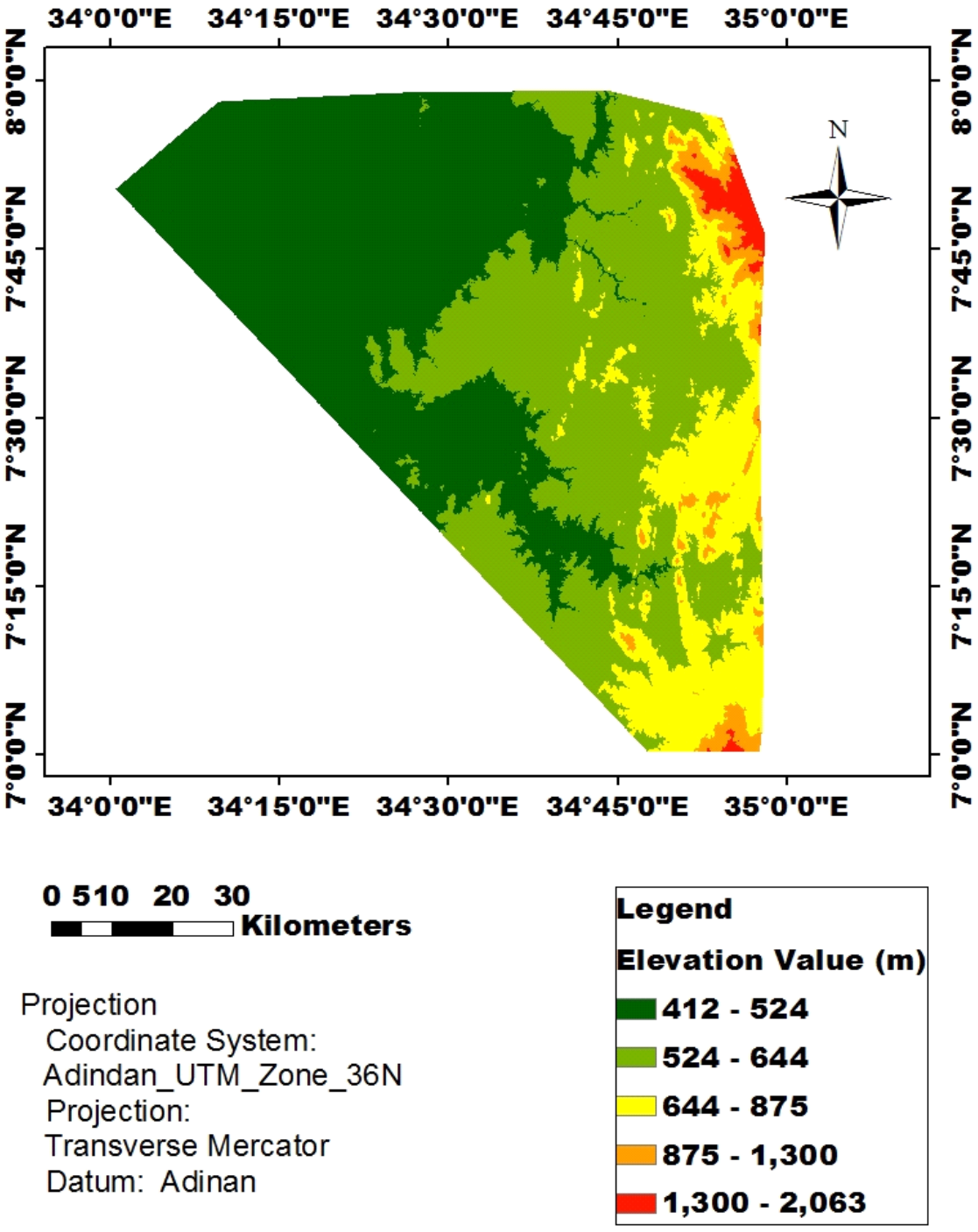

Figure 9 Physiographic map of Dima area

3.6 Water Resource

The ‘Akobo River’ is situated in the South-Western part of Ethiopia, frontier with South Sudan in west direction. It has gentle slope and contains much water in the months of abundant rainfall from June to October. The AS gold mining activities within and around the river have been carried out in the study area since the past years to till. The Akobo River is main source of drinking water and sanitary for communities populated near to the river within the study area.

Figure 10 Partial view of Akobo River

3.7 Settlement and Land Use

'Agnuwa', 'Surma' and 'Amhara' tribes are the dominant ethnic groups that were in the study area. The inhabitants are dependent on Agriculture of Maize, Sorghum, Pepper, Almond and the like for their livelihoods. AS placer gold mining activities also done following the Akobo River. Regarding to the socioeconomic baseline survey, mining operation by migrants from other regional states is foremost in the district.

Figure 11 Field photograph of Pepper land use

Chapter Four

Methods and Materials

4.1 Methods

The physical observation, river water sampling, questionnaire and interview data's are used to enhance the knowledge of mining method and processing techniques, types of equipment used, and associated environmental & socio-economic challenges of Artisanal & Small-Scale Gold Mining in the study area. To successfully accomplish the above objectives, different methods had been carried out before, during and after the field works.

4.2 Pre-field work

The pre-field work is launched by Searching and documenting relevant literatures (i.e. published and unpublished papers MSc. and PhD thesis, journals, articles, etc.), secondary and other existing data's sourced from scientific databases, including Web of Science, and media articles about socioeconomic and environmental challenges of ASGM related with the study area. Moreover, the literatures were helpful in developing semi-open questionnaire.

4.2.1 Respondents Sampling and Sample size Determination

Since there are different methods to determine the sample size of respondents from total population, the researcher used a form of non-probability sampling (Noushmehr, H.et al., 2010). To consume time and resource, the researcher

follow Israel's (1992) formula to determine the representative sample size in the district (Israel, 1992).

$$n = \frac{N}{1+N(e)2}$$

Where, n= sample size

e = the precision level with 95% of confidence level i.e. 0.1

N= Total population in the study site

Based on the 2007 Census conducted by the Central Statistical Agency (CSA), Dima Woreda has a total of 20,815 population. Using Israel's formula for sample size calculation, a representative sample of 100 respondents was calculated as shown below.

$$n = \frac{20815}{1 + 20815(0.1)2}$$

$$n = \frac{20815}{209.15}$$

$$n = 99.52 \sim 100$$

4.3 During field work

4.3.1 Physical observation

Field observation on mining and processing methods had been performing to get full picture of the socio-economic condition of the ASGM, production process,

environmental aspects, challenges and opportunities. The observation mainly focused by researcher was ‘’what are the artisan miners doing?’’, ‘’how the artisan miners doing?’’ and ‘’why the artisan miners do it?” .Physical observation was conducted to delineate the training classes with the aid of a Global Positioning System (GPS**)** making identification of features on the downloaded satellite images easy and aid for completing ground truth that derive different training sets in quality assessment of the entire satellite image classification.

4.3.2 Questionnaires, interviews and group discussion

Both qualitative and quantitative data were collect. The qualitative data collected through semi-structured interviews. It was conducted with artisan & small-scale miners and relevant stakeholders in addition to open discussions. The discussion comprised production process of placer gold, their ideas; attitude and problems of working in the mines; craves and future ambitions. While the quantitative data was collected from semi- open questionnaire (Appendix A-5) with rigorous and precise questions that have put out a good picture of the circumstance on the ground. The questionnaire was divide into three parts; economic, social and environment so as to cut across all aspects that support objective of the study.

4.3.3 River water sampling

The criteria of selecting river water sampling points in the study area were based on the population density, areas of AS placer gold mining activities, and the river catchment areas. As deliberate before potential AS placer gold mining activities

were take place on Akobo River, it was essential to assess the water quality in these areas where the river flows and crosses the AS placer gold mining.

Figure 12 River Water Sampling

The samples were collected in 1-liter polyethylene (PE) bottles. Before sampling, all the bottles were washed thoroughly with distilled water. A total of six water samples were collected from different sampling sites. Site 1 was located in the upper part of the river alongside village of Merkes since this site shows the river water quality before the water passes through the mining area and attribution of domestic wastes; Site 2 was located in the vicinity of AS placer gold mining activities area about 200 meters away from upstream; Site 3 was located in the place of AS placer gold mining in order to record and assess the effects of the mining activity on water quality; Site 4 was located in the merge of sewage water after panning pursuit in to river about 30 meters apart from mine station; Site 5 was located in the entrance of water that was takeoff from the river for ground sluicing purpose by water pump generator, the distance between them was approximately 600 meters; and Site 6 was located 500 meters downstream of the river near to village of Chama to evaluate the river water quality in the downstream of the mining site and comparing with the other sites.

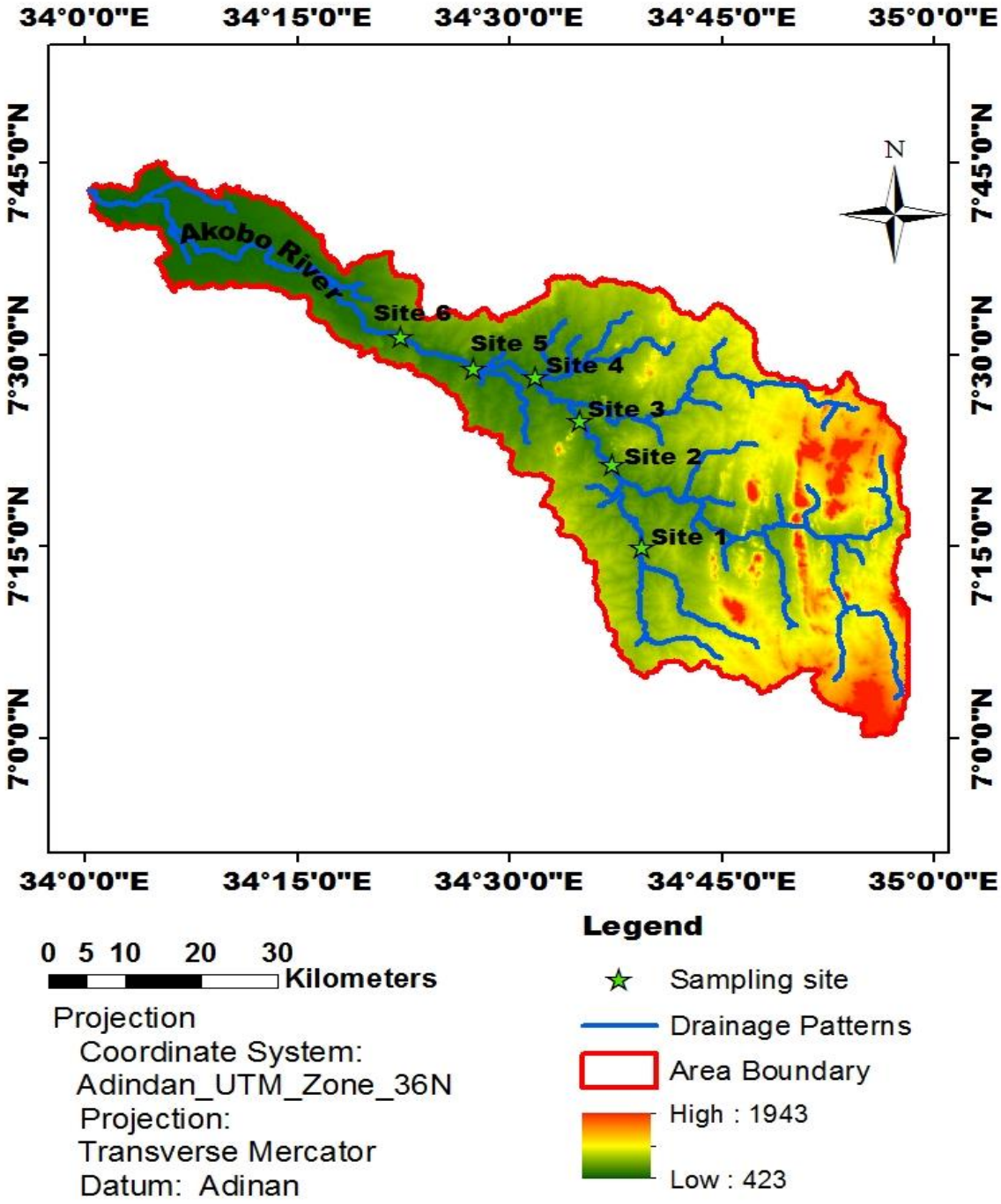

Figure 13 Map showing river water sampling stations

4.4 Post field work

4.4.1 Impact of ASGM on Akobo River water

Artisanal and small-scale gold mining work typically on placer deposits created through weathering of upstream auriferous rock formations and then transported downstream. The water turns brown due to panning of gold which is discharged mine waste into downstream. The principal physico-chemical analyses undertaken on Akobo River include analyses for PH, Electrical Conductivity, Alkalinity, Total Dissolved Solid, Turbidity, Total Hardness, Sodium, Potassium, Total Iron, Manganese, Calcium, Magnesium, Carbonate, Bicarbonate, Chloride, Nitrate, Fluoride and Phosphate.

4.4.2 Classification of Land use land covers and change detection

This study investigated the land use and land cover change in the Dima District from 2000 to 2020. The change can be detected using multi-spectral Landsat 7 Enhanced Thematic Mapper (ETM) satellite images of 30 m resolution for the years 2000, 2006, 2016 and 2020 were attained through the United States Geological Survey (USGS). All of the raw images were accompanied in the same season and less than 10% of cloud cover in view of the fact that they were acquired during the dry period that avoid investigating dried up vegetation. The ETM+ image was georeferenced to the UTM (Universal Transverse Mercator) map projection (Zone 36), Adindan datum and WGS_1984 ellipsoid. Digital Image Processing is largely concerned with four basic operations: Pre-processing, Classification, Change detection and Accuracy assessment.

- **Pre-processing -** Just before the images came to analysis, radiometric and geometric corrections (rectified and geo-referenced) carried out on the raw images restoration concerned with the correction and calibration of images in order to achieve as faithful a representation of the earth surface as possible (Lillesand et al., 2004). Geometric correction includes correcting the errors resulting from tilting of the platform on which the sensor is mounted in order to produce a planimetrically correct image and registration of the images with ground points. Radiometric correction involves the transformation of DN (Digital Number) values into top of atmosphere and ground reflectance values. These was implemented by modifying the misaligned Landsat 7 ETM image based on x and y coordinates of a geometrically correct reference raster. As part of the phase, a series of bands compositions of RGB (Red, Green and Blue) filters on Landsat 7 ETM in False Color were produced. For visual analysis, color composites (natural colour image) generation ranges from eight spectral bands make fullest use of the capabilities of the human eye. The Landsat-7 images used to create a mosaic were produced using Band 5(mid infrared applied to the red filter), Band 4(near infrared applied to the green filter) and Band 3(red applied to the blue filter) spectral bands and filters. The raster images for the respective years were mosaiced to size using coordinates of the district and clipped out the sections within the study area for image classification.

- **Classification -** After pre-processed, it involved selecting a sample of pixels from the image and using it to establish thresholds to delineate

specific land covers on the ground. Each pixel within an image has a uniform colour and the colour of a pixel results from the average reflectivity of objects on the surface corresponding to the ground resolution of the image used. Then develop a statistical characterization of the reflectances for each information class. Once a statistical characterization has been achieved for each information class, the image is then classified by examining the reflectances for each pixel and making a decision about which of the signatures it resembles most. As remarked previously, from all bands compositions carried out, the corresponding to false color composition of RGB: 543 was chosen for the classification process for land cover since this presented a strong contrast between different land uses and coverings. On this band combination the samplings to separate the coverings of the study area were carried out. Apparently, multi-spectral Landsat imagery of each year classified into five classes (Cultivated Land, Forests, Artisanal Mining, Built Up and Grasslands) using supervised classification (maximum likelihood classification method). The main reason for undertaking an image classification is to convert the image's information on the spectral response of the Earth's surface into a thematic map depicting classes of interest such as land cover. The delineation of training classes were conducted based on reference data of Google Earth information, field review with the aid of a Global Positioning System as well as interviews with elders. Land use –Land cover maps for 2000, 2006, 2016 and 2020 were derived by independent supervised classification of the Landsat images, using a Gaussian maximum-likelihood classifier.

- **Change detection** - Following classification of imagery from the individual years, a multi-date post-classification comparison change detection analysis of this paper was undertaken to determine the change between four time periods, 2000–2006, 2006–2016, 2016–2020, and 2000–2020 for a particular land cover, by providing quantitative information on spatial and temporal distribution. The classified images assembled by using the overlay tool in ArcGIS 10.3 to rate land use land cover dynamics of the district, identifying the nature of the change, measuring the areal extent of the change and then a complete matrix of categorical change was figure out (Hassan et al., 2016). During change-detection analysis, the researcher offered four aspects of change detection that are important when monitoring naturally occurring or human-induced incidents: detecting the changes that have occurred, recognizing the characteristics of the change, computing the areal range of the change, and assessing the spatial pattern of the change (Macleod & Congalton, 1998). Analyzing land-use and land-cover conversion allows different combinations of changes to be revealed, thus providing further information concerning the nature of change.

- **Accuracy assessment** - The assessment of the accuracy of the final images produced is a vital step to measure the quality of thematic maps produced and required by users, typically to help evaluate the fitness of a map for a particular purpose. Accuracy assessment of land use land cover maps of the area arise from Landsat 7 ETM by contrasting the land cover results with Google Earth Pro and ground truthing. Finally, accuracy reports of each land cover data in terms of overall accuracy (the percentage of

correctly classified pixels out of all pixels sampled for all classes), producer's accuracy (the percentage of a particular LULC type on the ground is correctly classified in the map), user's accuracy (the percentage of a class on the map that matches the corresponding class on the ground), and kappa coefficient or index (the degree of matching between reference data set and classification) have been generated. The error matrix (confusion matrix) produced used to identify particular cover types for which errors are in excess of that desired. The information in the matrix about which covers are being mistakenly included in a particular class (errors of commission) and those that are being mistakenly excluded (errors of omission) from that class can be used to refine the classification approach.

4.4.3 Data Analysis

All data including both those from literatures and collected through field work were analyzed & interpreted together. Environmental, social and economic ramification of AS placer gold mining were analyzed descriptively and statistically using Statistical Package for Social Scientists (SPSS version 25) to rank the impact they formed and subjectively coded. The outcomes are discussed in form of maps, pie-charts and statistical tables.

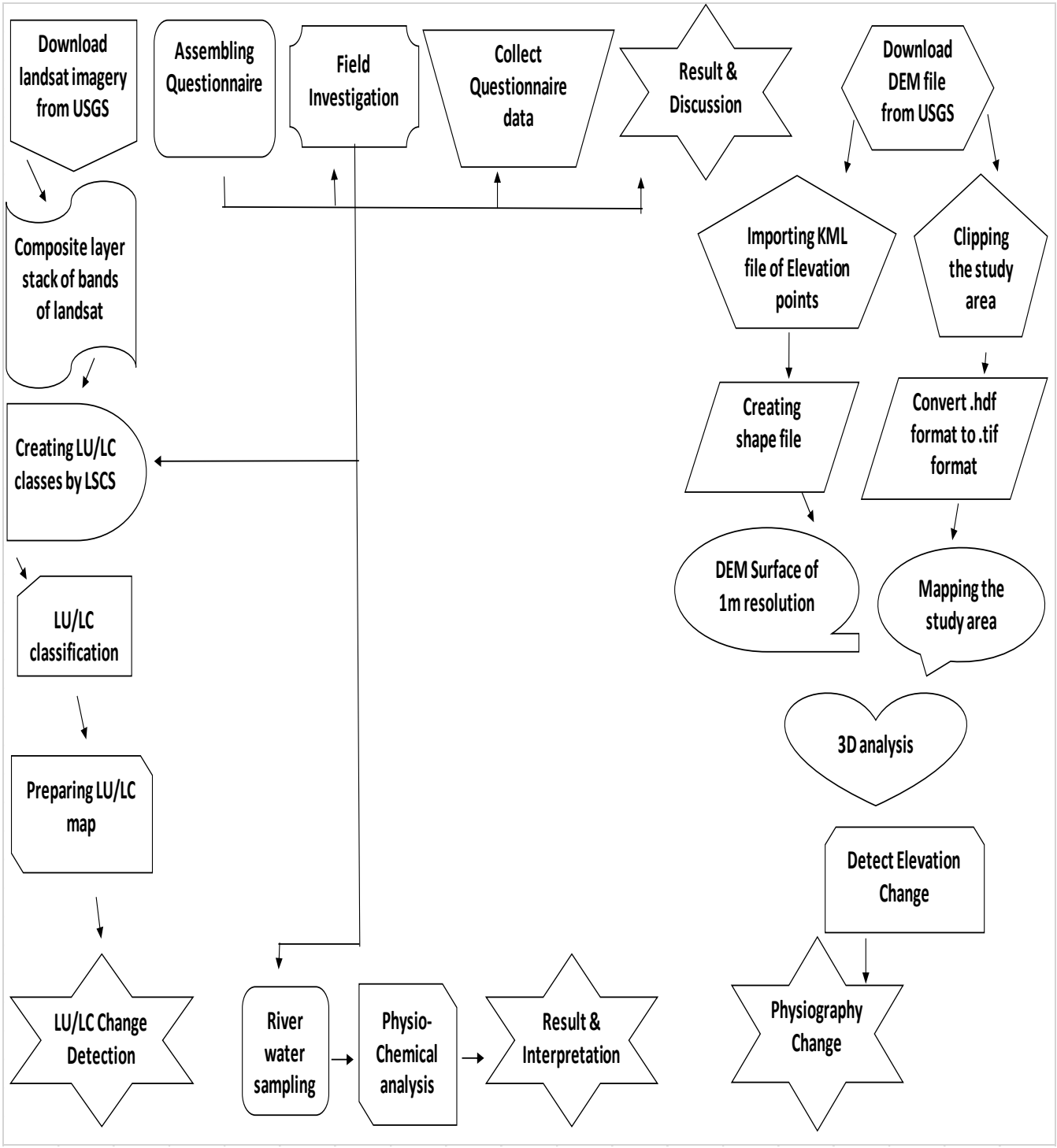

Figure 14 The methodology workflow

4.5 Materials

To meet the objectives of the study, various softwares & materials were used. Among these:

- Arc GIS 10.3 for the processing, analysis and integration of spatial data.
- Google earth platform utilizing the time-slider function to view archival imagery of an area. The directional tool was also employed when analyzing imagery at different angles.
- ERDAS Imagine 10 used for imagery data processing including multi spectral analysis; a supervised classification; and determining the accuracy of the image classification.
- A multi item structured closed-ended questionnaires.
- Landsat 7 ETM satellite images of the years 2000, 2006, 2016 and 2020 with 30m resolution.
- Digital Elevation Map (30m resolution).
- Microsoft Excel 2013 for statistical analyze of the generated datasets.
- Geological field-kits like GPS (Global Positioning System), Note book, Digital Photo Camera, Sample bag, Distilled water, 1-liter polyethylene (PE) bottles, Topographical map of the study area by 1:50,000; Geological map of Dime and south west part of Maji area by 1:250,000 and 1:100,000 respectively; etc.

Chapter Five

Result and Discussion

5.1 Placer Gold Mining and Processing in Dima District

The Akobo narrow greenstone sub - belt is a high potential target for gold exploration. Placer gold has long been considered a prime source of income as agriculture and domestic animal raising for local people. Systematic placer gold exploration and prospecting activities have been carried out in different parts of the country. Akobo Basin is one of the significant localities of placer gold that has traditionally been mined, which were recently studied by the Geological Survey of Ethiopia (GSE) (http://www.gse.gov.et).

Activities of ASGM in Dima district is a labour intensive and utilize rudimentary technology. In Artisan miners, there is a lack of geological knowledge and basic principles in resource management. Most of the AS placer gold miners worked in groups and divide responsibilities among themselves due to difficulty of the processes. They live in small huts without any formal kitchen and latrine.

Figure 15 Life of the artisanal miners at Dima

Among the miners, there are schoolchildren Panners panning alone or with their relatives. The environmental and socio-economic impacts of greatest concern around AS placer gold mining in the vicinity of Akobo River were neglected.

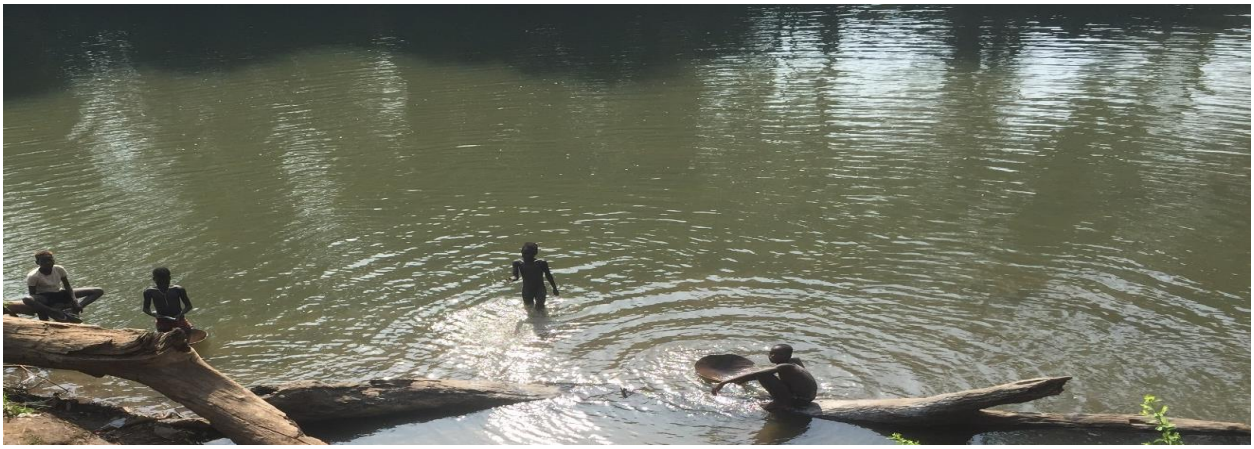

Figure 16 Child labour in Dima

Placer gold mining is the process of mining of alluvial deposits for gold mineral. The techniques and processes by which placer gold can be extracted from soil, river and by ground sluicing with water not under pressure in Dima District. The following points provides information on the equipment and methods in the study area used to recover gold in three different types of operation.

5.1.1 Gold in Soils

Main steps in ASGM from soil include: (I) clearing the land (II) digging; (III) transporting gold rich soil and water; (IV) recovering gold by panning; and (V) selling gold.

(I) Clearing the land - When gold miners had established new gold mining sites, they aggressively cleared flora species. The process is done by removing surface vegetation, dirt, and if necessary, layers of top soil in order to reach ore deposits closer to the earth's surface. Mining is practiced, here and there and as such no restriction is made in cross boundary movement of the miners. Therefore, the artisan mining communities do localization of the gold resource simply through "trial and error" method. Artisanal gold mining was intimately associated with deforestation across the study sites. The observations of the researcher were eye evidenced that extensive land units were converted to useless land which were cultivated or grazing land before due to unmanaged mining practice. Observing dried and root exposed indigenous big trees were very common in the mining sites.

Figure 17 Partial view of cleared land at gold mining sites.

(II) Digging - Artisan miners dug holes up to the depths of 3m to the vertical and 20m to the horizontal dimensions using rudimentary tools such as picks, shovels and metal bars of selected gold location randomly by following black sands. When the holes go deeper, they used light battery and rope tighten with plastic container to hoick fine sediments with a capacity of 15-20 kg to the surface.

Figure 18 Mining sites showing digging different holes

(III) Transporting gold rich soil and water - After excavation, the gold gravel soil is either brought to the nearby river (Akobo River) in terry clothes or storing water sources around the area for panning or sluicing to recover the gold.

Figure 19 Transporting of gold by terry clothes

(IV) Recovering gold by panning – To recover the gold, the pan made with plate submerged under water and mix the finely crushed sediment material by hand. Then, swirling the pan smoothly with a circular motion to concentrate the materials. Timely, the lighter materials of large pebbles were removed by hand and this panning activity became exit when the heaviest material remained at the bottom by tilted the plate pan. The remained material shows glittering appearance and once they got a point or two points of gold simultaneously, the artisan miners put it in a safe small plastic container or another plate pan the whole day.

Figure 20 Panning Activity in the study area

(V) Selling gold - Finally, sold the collecting gold directly to either the local enterprise or black market (intermediate traders) without any purification and amalgamation. Resources flow to the informal market from producers through the illegal traders. The major reason why producers prefer to sell their mineral to the informal traders is to avoid government's claim for royalty.

The price of gold is often regulated by the National Bank for the defined quality standards, with a 5% premium on top of the current gold price. Although miners' access to gold price information is better these days than any other time, miners still do not have full information about the prices with the quality standards of the gold mineral. Therefore, the ultimate price makers are again the local traders.

Figure 21 The final gold for marketing

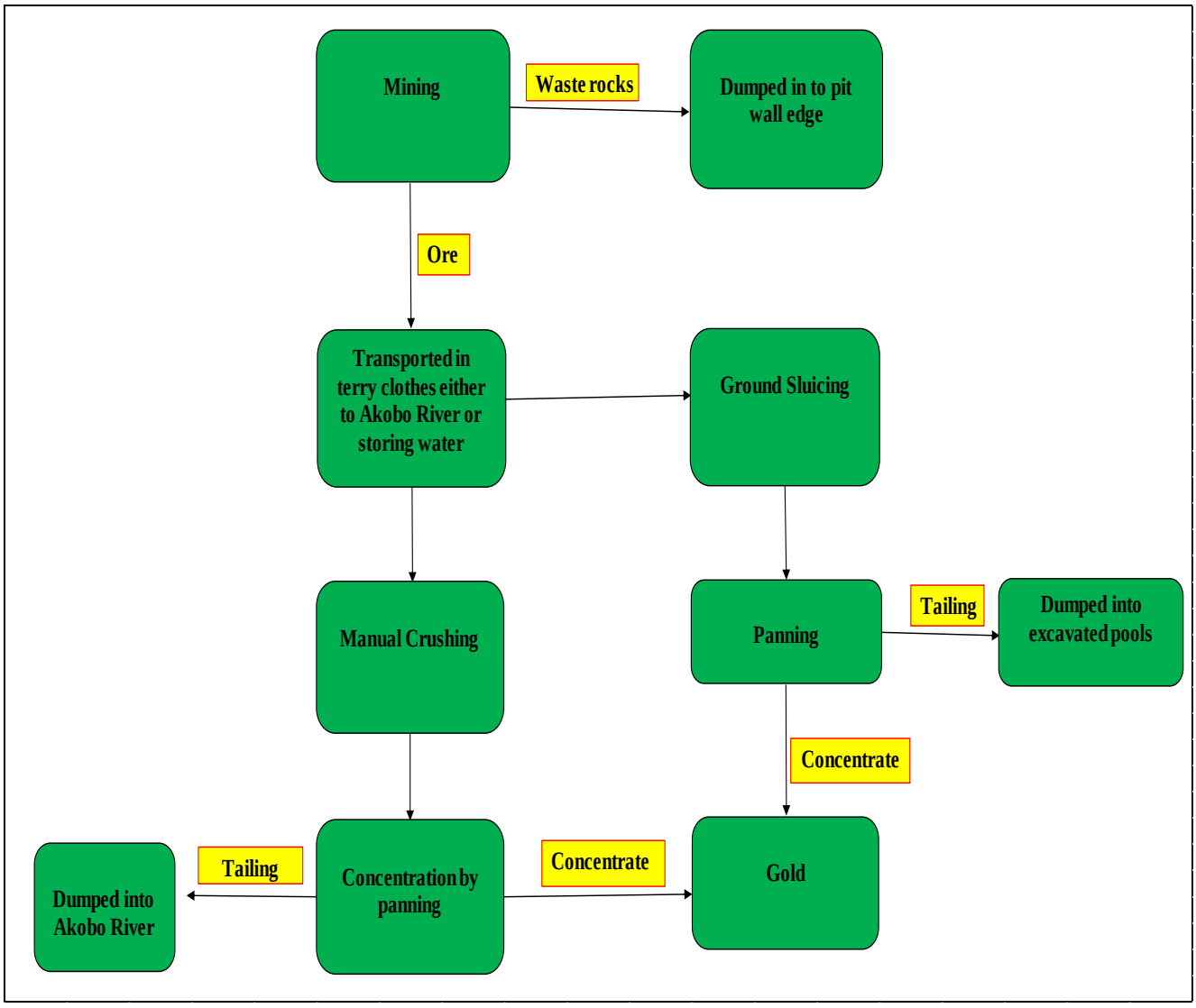

Figure 22 Flow sheet of Mining and Processing operations in Dima

5.1.2 Gold in Rivers

The extraction process from deposited sediments of the river occur in wide riverbed where the river is not so deep that the river water level decreases. Exploration of the riverbeds is effected by suction dredges that suck the gravels from the bottom of the river and then proceed with visual inspection. Artisan

miners extract alluvial sediment deposited matters from the bottom of a river by using spade and put it on the plate pan. Then, fill the pan with water and carefully remove rocks and pebbles by hand, checking them before discarding. The pan may be periodically lifted from the water and shaken vigorously with the same circular motion to help concentrate materials. Panning continues until only the heaviest material remains. Gold may be observed by gently swirling the concentrate into a crescent in the bottom of the pan.

Figure 23 Recover of Gold from Akobo River

5.1.3 Ground Sluicing

With Ground Sluicing method, the gold bearing materials are shoveled into ground channel where they are washed and transported by stream of water provided by motor pumps from Akobo River. Riffles are made of rocks, and are commonly fastened to a rack that is wedged into the sluice so that the lighter materials wash away by gravity using inclination of outcrop and with the help of

water. For cleanup, clear water is run through the sluice until the riffles are clear of gravel. A pan or plastic jar is placed at the discharge end to prevent loss of concentrate. The gold and other heaviest materials remain at the bottom of the ground channel and removed them by hand. Then Pan the collected concentrate and dumped into a suitable container. The method of extraction used in the small-scale mining of placer gold in Dima district is semi-mechanized but final recovery is accomplished manually, which is panning.

Figure 24 Ground sluicing for gold recovery

5.2 Efficiency of Placer Gold Recovery Equipments and Methods

There are a number of factors that must be considered when designing an efficiency of placer gold recovery.

- **Cost versus recovery-** Overall, panes are widely used due to their low cost and availability and also sluices entail a minimal initial investment. Estimating volume of production of gold mineral by the artisan miners is very complicated due to lack of historical records and suspicions by many miners to give information. As it is very hard to know how much an individual produces, here rough estimation for gold production/year is made using the following simple formula:

  Total gold production/year = Average gold produced by an individual per month (kg) × number of months worked in a year × total population involved in the artisan gold mining.

  Mining is practiced during the day and sometimes during the night with the help of flashlights. On average, every body works eight hrs/day and 26 days in a month. But due to frequent holidays the number of working days falls to as low as 21 to 23 days/month.

  In the study area, Mining is not a regular and permanent activity for the majority of the artisan miners. Only few miners are operating throughout the year estimated just at 20% of the total miners (which is about 200 individual). Some work only for three months, others for six months and a few for nine months. This discrepancy happens because of the operation is tiresome and boring and hence people want to take break; It is a risky activity and hence the probability of earning enough is low, and so risk averters drop quickly; and for some people, mining is an additional source of income, supplementary to farming.

Artisan miners were afraid to report their actual income on a monthly basis mainly as most of them are informally producing and selling gold mineral and are afraid of the legal consequences of not paying royalties to the government. Therefore, the income at individual level was roughly estimated. However, to make a good estimation of the figure, smart cross-cutting interviews were carried out with large number of discussants at the field with mining practitioners, and local collectors. Individual level estimation of an average monthly income from artisan mining was done for the study areas, taking the prevailing prices at the respective mining sites.

Accordingly, the number of effective time allocated for artisan mining for all is roughly estimated at six months. Total population involved in ASGM is estimated to be 1,000 (1 thousand) as indicated in respective kebele administrators. By using the above formula, the result of the analysis shows that a total of about 34.5 kg of gold per year was produced in the area. These obsolete technologies and traditional practices in the district resulting in very low yield.

❖ **Size distribution of the gold-** The major flaw of these gravity separation method is that very fine gold is lost in processing. Ground sluices work on the principle that in water a larger particle will drop faster; therefore, the sediment will contain coarse particles while the water above it will contain smaller particles still in suspension. Subsequent separation of the sediment and water therefore allows particles to be separated by size. However, differences in

particle density results in small dense particles having similar settling characteristics to larger light particles. Therefore, a certain amount of Very fine particles of gold are misplaced during the separation process, and this can be a source of inefficiency in subsequent processes. This inefficiency can result in tailings containing a significant amount of gold.

Fine gold particles are associated with the coarse fractions, usually unliberated from the silicate gangue, while in the fine fractions, fine gold is not trapped or recovered by the rudimentary concentration methods. Most gravity concentration methods used in artisanal mining are not continuous i.e., they must be stopped to discharge the concentrate. Miners working with alluvial ores control their activities based on how ‘‘yellow is the concentrate’’. This is a very common mistake. High gold grade in concentrates do not reflect high gold recoveries. Usually, the relationship is the opposite. Figure 25 below shows a hypothetical graph that exemplifies the antagonistic behavior of gold recovery and concentrate grade. A large mass of concentrate implies that the gold grade is low but the recovery is high and vice versa.

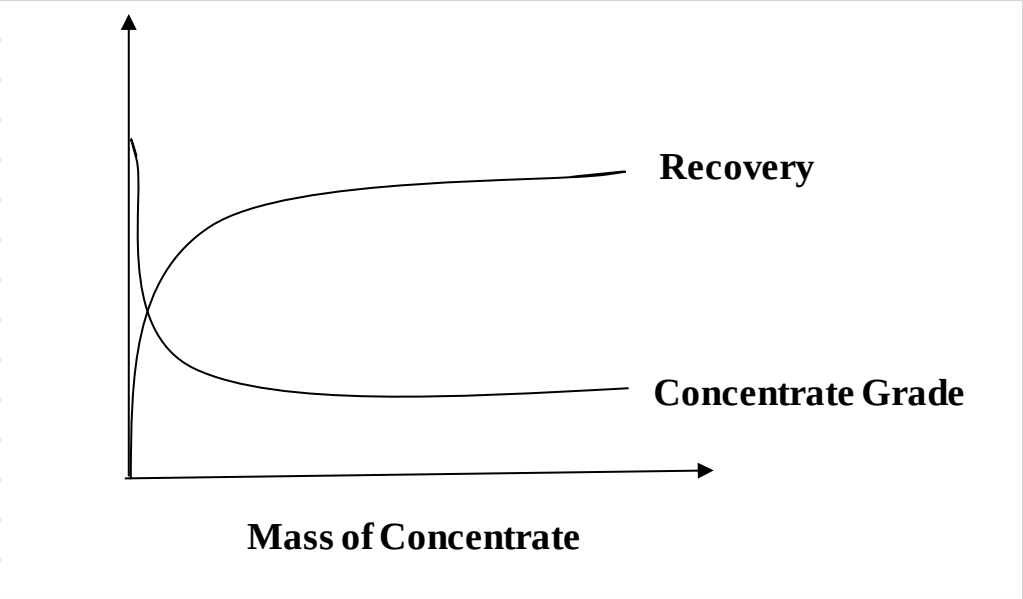

Figure 25 Hypothetical relationship between mass of concentrate, gold grade and gold recovery.

❖ **Processing capacity of the equipment-** Panning was widely used as a primary recovery method in the area of mining. However, the process is extremely limited, as only coarse gold is recovered, while very fine particles are usually washed away with the gravel. Only small amounts of gravel can be processed, even by the most experienced panners. The pans usually have relatively low capacities and may limit the total amount of ore that can be processed.

Within sluices, heavy particles sink to the bottom of a stream of water while lighter particles tend to be carried downstream and discharged. A rough surface at the bottom of ground, can trap the gold and other heavy particles. Like a ball rolling down a hill, flow and momentum increase with distance, making the trapping mechanism less effective further down the sluice,

particularly for fine gold. For this reason most gold is caught in the first meter of simple sluices.

- **Character of wash water -** For efficient sluice gold recovery operation, a sluice needs large amounts of clean water for frequent cleaning up in order to minimizing fine gold losses. Enough water should be added to the feed to build up a sand bed in the bottom of the ground sluice. For maximum recovery, the flow should be turbulent, yet not the sand bed, improving gold recovery. This study shows that recovery increases with the frequency of cleanups by is reassembling the sluice and processing more material; reducing the speed of the slurry flow, and decreasing the size of the feed.

5.3 River water experimental analysis

PH of the sampled river water were analysed using potentiometric test method. PH values of all water samples measured were ranging from 6.49 to 7.07 show that these water samples are neutral. Alkalinity is the measure of hydroxide and carbonate ion concentration in water sample. The alkalinity of Akobo River due to carbonates (CO_3^{2-}) was more or less nil.

Electrical conductivity is the measure of the extent to which water conducts electricity and is related to the presence of dissolved ions in water samples carries the electric current through water. The conductivity of the river water samples were measured by using potentiometric test method. Higher Electrical conductivity value (324 – 349 µS/cm) indicating the presence of high amount of

dissolved inorganic substances in their ionized form. This high level of conductivity along the Akobo River may be attributed to the proliferation of AS placer gold mining activities in the area. It believed that high mineral contents found in river water which resulted in higher conductivity value. This could be due to the time of contact with sediments and soils which is much longer and the exposure of mine tailings that leaching is more pronounced. Potassium is alkali metal which is highly reactive with water and has high electrical conductivities.

Total Dissolved Solids (TDS) are the concentration of substances including inorganic matters and not much organic matter in a dissolved state water. Higher concentrations of TDS (174.8 - 191 mg/l) indicate turbidity of the river by affecting the aesthetic value and their basis can be from dissolution or weathering of the rocks and soil, AS placer gold mining runoff and discharge of waste water from panning. These dissolved solids are capable of moving with the water. TDS indicates the general nature of salinity of water such as higher value will have salty taste. Sodium ion is permeating in water, owing to the high solubility of its salts and the abundance of sodium containing mineral deposits.

Turbidity can be a surrogate measure for suspended materials influence the clarity of water in the Akobo River, and it is often measured in Turbidimetric test method. Since sampling were carried out during dry season, relatively little turbid water (85 NTU) has been sampled in the upstream part of the river. It is indicating low river energy which leads sediments easily settle to the bottom of the river. This is a result of hardly little precipitation from the catchment to cause

meaningful runoff to promote water erosion. This follows that there is no extra sediment added into the river from itself or from the catchment. High readings of turbidity (130 NTU) occur in the area surrounded by gold panning activities along the river. It can be linked to high sediment load being carried into the river in form of gold rich soil by the gold panners as they separate the gold mineral from the soil. AS placer gold mining techniques consume, process, and released riverbed and consolidated riverbank sediments. Coarse sediments and intercalated rock dislodged from banks and beds are redistributed as in situ tailing piles, while finely divided suspended matters: clay, silt, and carbon elements suspend in the water column to be redeposited downstream. As mentioned earlier, there were AS placer gold mining near the Akobo River which produce ground channel to downstream. These ground channel can be composed of dense sand-size soil particles that are deposited by the flow of water by water pump over time. During the period when the flow rate is high, part of the ground channel is washed out, contributing to the increasing water turbidity readings. The recorded mean turbidity value of water samples (112.2 NTU) did not agree with WHO standards (5 NTU).

Total Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce a lather. It was measured by titrimetric test method that display the total hardness of upstream water was high (140.7 mg/l) in comparison with downstream water (138.6 mg/l). This high hardness value of water is mainly due to the dispersion of variety dissolved polyvalent metallic ions, predominantly calcium and magnesium cations and chloride anion in the Akobo River.

An increase in the total iron concentration for the study area was observed from the upstream to the mining area followed by a decrease downstream and the total iron (6.11 to 6.9 mg/l) were above the prescribed limit of WHO guidelines for drinking purposes. The high concentration of iron (6.9 mg/l) can be associated with the increase in the AS placer gold mining activities which took place in and around the river. In AS placer gold of mining, placer deposits come from a gold-bearing bedrock and most often this rock is accompanied by sulphide minerals such as pyrite. Thus, during the deposit of gold quantities of pyrite (FeS) are present and the dissolution of this minerals can contaminate the waters. During panning, the presence of iron oxide in the bottom of the panes is also observed. The presence of iron concentrations could be also attributed to natural geological weathering that increased amount of fine (<0.2 μm) Fe bearing particulates from eroded materials and dust to the downstream. The presence of Manganese demonstrate Contamination of water by heavy metals, mainly determined by natural weathering and erosion of bed rocks.

Chloride is one of the major inorganic anion in water and quantify by Mohr Argentometric test method. Low proportions of Na^+ (21 mg/l) and Cl^- (4.97 mg/l) in upper part of the river are an indication of the low existence of disturbance in Akobo River. Chloride occurs naturally in river waters but changes in concentrations (5.97 mg/l) to lower part may be an indicator of effluents and AS placer gold mine sewage pollution. Therefore chloride serve as a pointer of pollution by sewage. Nitrate is an indicator of the degree of organic pollution of the water source that shows incremental path towards downstream (0.34 to 0.44 mg/l). The main sources of nitrate in Akobo River are human and animal waste,

AS placer gold mining effluent and use of inorganic fertilizers in agricultural areas.

Fluoride concentration depends on the presence of fluorine-bearing minerals in rocks and sediments such as fluorite, apatite, mica, amphiboles and certain clays contact time of water with a particular formation. Temperature and residence time speed up the dissolution of fluorine bearing minerals present in the rocks. AS placer gold extraction process actions can also products significant fluoride pollution by increasing the surface area for mass transfer and generate effluents.

The low level of Phosphate (0.46 mg/l) observed may possibly be due to the uptake of the nutrient by algae and other aquatic plants, particularly, in the upstream part. The raised phosphorus levels (0.52 mg/l) may be due to the generation of large quantities of waste that produced during mining process of gold. The Phosphorus gets into the Akobo River through various sources like: weathered soils from surrounding rocks, domestic sewage containing human excrement and run offs from fertilized farm lands. During the natural process of weathering, the rocks gradually release the phosphorus as phosphate ions which are soluble in water and the mineralize phosphate compounds breakdown.

Tests	Test Results						Test Method	Mean	WHO (mg/L)
	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6			
PH (mg/L)	7.01	7.07	6.99	6.74	6.49	6.87	Potentiometric	6.86	6.5-8.5
Electrical Conductivity (µS/cm)	324	328	325	330	331	349	Potentiometric	331.2	-
Total Dissolved Solid (mg/L)	174.8	178.8	181.7	182.4	191	180.2	Potentiometric	181.48	1000
Turbidity(NTU)	85	95	130	120	123	120	Turbidimetric	112.2	5 (NTU)
Sodium (mg/L Na^{+})	21.5	21	21.5	22	23.5	22	Flame photometric	21.9	200
Potassium (mg/L K^{+})	4	3.9	4	4.2	4.1	4	Flame photometric	4	-
Total Iron (mg/L Fe^{2+} & Fe^{3+})	6.33	6.45	6.9	6.48	6.54	6.11	1,10-phenothroline	6.47	0.3
Manganese(mg/L Mn)	0.03	Trace	Trace	Trace	Trace	Trace	Periodate oxidation	Trace	0.4
Total Hardness (mg/L CaCo3)	140.7	138.6	134.4	140.7	139.5	138.6	Titrimetric	138.75	500
Calcium (mg/L Ca^{2+})	36.12	35.28	33.6	37.8	36.9	35.28	Titrimetric	35.83	200
Magnesium (mg/L Mg^{2+})	12.1	12.6	12.1	11.09	11.8	11.59	Titrimetric	11.88	150
Alkalinity (mg/L CaCo3)	186.1	187.46	185.4	185.4	186.1	179.22	Titrimetric	184.95	-
Carbonate (mg/L Co_3^{2-})	Nil	Nil	Nil	Nil	Nil	Nil	Titrimetric	Nil	-
Bicarbonate (mg/L HCO_3^{-})	228.7	228.7	226.19	226.19	227.4	218.65	Titrimetric	225.97	-
Chloride (mg/L Cl^{-})	5.69	4.97	6.96	5.97	5.93	5.96	Mohr Argentometric	5.91	250
Nitrate (mg/L No_3N)	0.43	0.47	0.34	0.4	0.42	0.44	Cadminium Reduction Method	0.42	10
Fluoride (mg/L F^{-})	0.32	0.37	0.36	0.37	0.36	0.53	Ion-Selective Electrode	0.39	1.5
Phosphate (mg/L PO_4^{3-}-P)	0.46	0.63	0.49	0.52	0.5	0.48	Ascorbic acid, Molybdate blue	0.51	-

Table 3 Physico-chemical parameters of Akobo River

5.4 Land use land cover of the study area in 2000, 2006, 2016 and 2020

5.4.1 Land use land cover of the area in 2000

In the year 2000, 15,538.2 ha i.e. 67.9% of the land was dominated by Cultivated Land. Forests and Grasslands were the second and third dominant LULC types covering 5242.9 ha (22.9%) and 1812.2 ha (7.9%) respectively of the study landscape. The total area covered by Artisanal Mining was 272.7ha (1.2%). Only 11.3ha (0.1%) of the total area was under Built Up.

	2000		2006		2016		2020	
Classes	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Artisanal Mining	272.7	1.2	766.6	3.3	3184.9	13.9	3515.8	15.4
Built Up	11.3	0.1	21.9	0.1	7295.1	31.9	10789.1	47.2
Cultivated Land	15538.2	67.9	15313.5	66.9	8765.1	38.4	5680.9	24.8
Grass Land	1812.2	7.9	1797.9	7.9	911.8	3.9	711.9	3.1
Forest	5242.9	22.9	4977.4	21.8	2720.4	11.9	2179.6	9.5
Total	22877.3	100	22877.3	100	22877.3	100	22877.3	100

Table 4 Land Use/Land Cover analysis of the district for 2000-2020

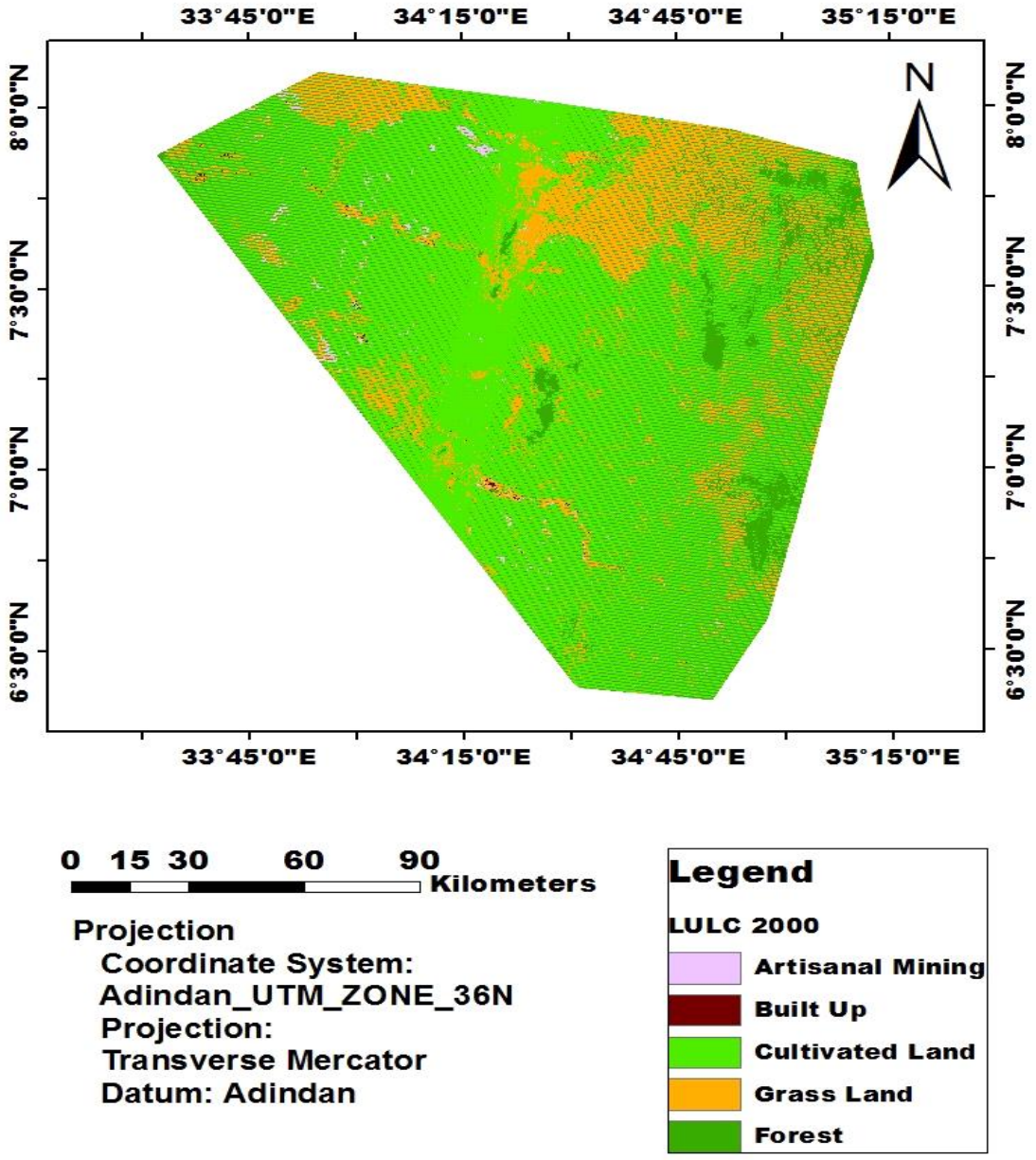

Figure 26 Land Use/Land Cover map for 2000 of the area

5.4.2 Land use land cover of the area in 2006

Cultivated Lands continued to be the dominant LULC 15313.5 ha (66.9%) in 2006. Forests 4977.4 ha (21.8%) and Grasslands 1797.9 ha (7.9%) were the prominent components of study area. The remaining portions were occupied by Artisanal Mining practices 766.6ha (3.3%) while Built Up occupied the smallest portion 21.9ha (0.1%) of the area.

Area change (ha)				
Classes	**2000-2006**	**2006-2016**	**2016-2020**	**2000-2020**
Artisanal Mining	493.9	2418.3	330.9	3243.1
Built Up	10.6	7273.2	3494	10,777.8
Cultivated Land	-224.7	-6548.4	-3084.2	-9857.3
Grass Land	-14.3	-886.1	-199.9	-1100.3
Forest	-265.5	-2257	-540.8	-3063.3

Table 5 Land Use/Land Cover Change during 2000–2006, 2006-2016, 2016-2020 and 2000-2020

NB: The plus (+) sign stand for incremental of specific LU/LC class whereas the minus (-) sign stand for a declining of specific LU/LC class.

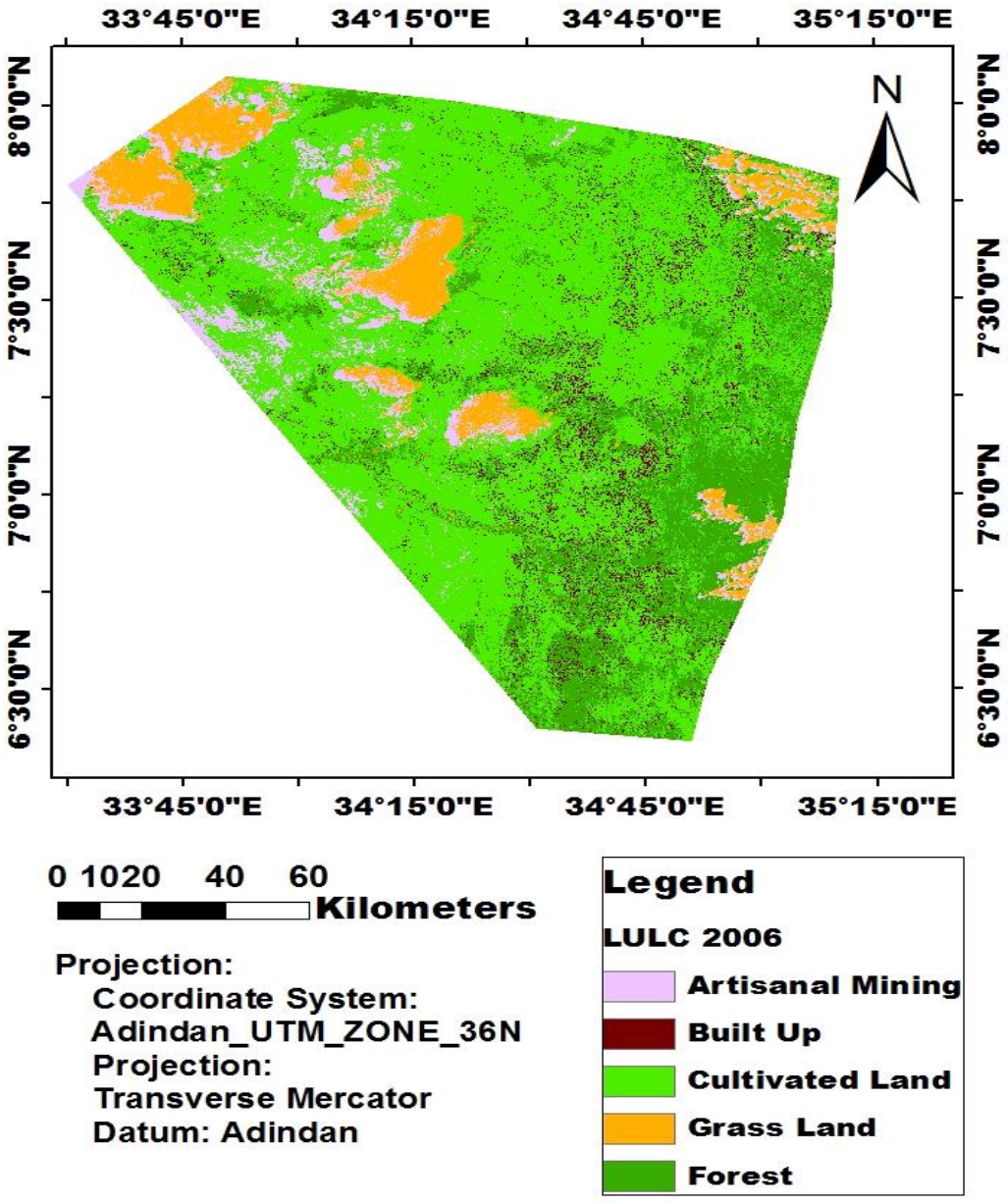

Figure 27 Land Use/Land Cover map for 2006 of the area

5.4.3 Land use land cover of the study area in 2016

The land use/land cover map of 2016 shows that the total Cultivated Land in the area landscape was 8765.1ha (38.4%). It was followed by Built Up 7295.1 ha (31.9%), Artisanal Mining 3184.9 ha (13.9%), and Forests 2720.4ha (11.9%) orderly. Among mentioned here (fig.20), the 2016 map classified land use land cover patterns of study boundary, Grasslands represented 911.8ha (3.9%).

Average rate of change per year (ha/yr)				
Classes	**2000-2006**	**2006-2016**	**2016-2020**	**2000-2020**
Artisanal Mining	82.3	241.8	82.7	162.16
Built Up	1.7	727.3	873.5	538.89
Cultivated Land	-37.5	-654.8	-771.1	-492.87
Grass Land	-2.4	-88.6	-49.9	-55.02
Forest	-44.3	-225.7	-135.2	-153.17

Table 6 Mean rate of Land Use/Land Cover Change per year in Dima

NB: The plus (+) sign stand for incremental of specific LU/LC class whereas the minus (-) sign stand for a declining of specific LU/LC class.

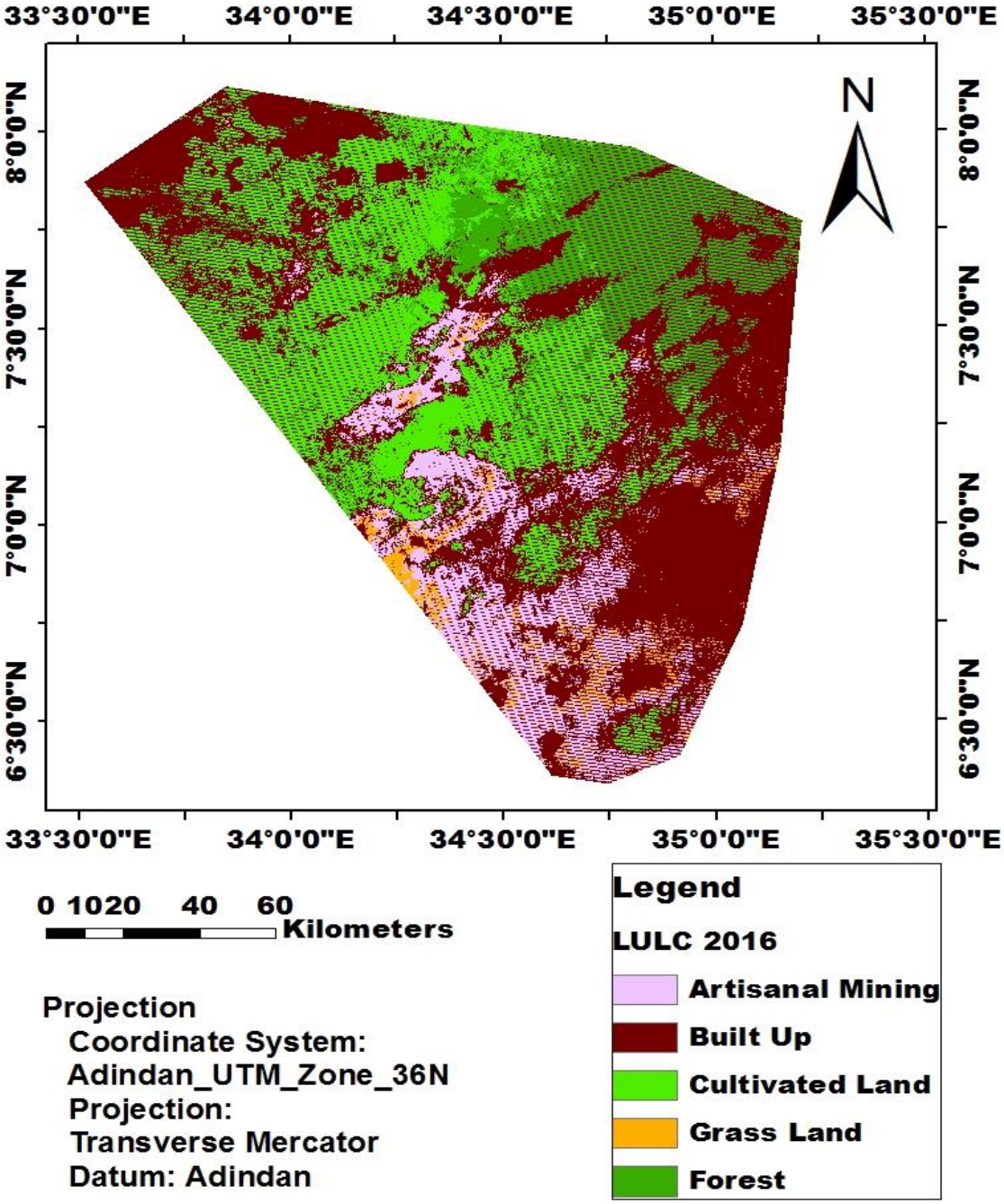

Figure 28 Land Use/Land Cover map for 2016 of the area

5.4.4 Land use land cover of the study area in 2020

In 2020, the whole circumstance was changed, so that Built Up areas accounted for the largest part 10789.1ha (47.2%) whereas Cultivated Land and Artisanal Mining classes were cover an area of 5680.9ha (24.8%) and 3515.8ha (15.4%) respectively. From the classified land use/land cover map of 2020, Forests marked 2179.6ha (9.5%) and Grasslands constituted 711.9ha (3.1%) of the total area.

LULC Class	2000 (%)	2020 (%)	Net change 2000-2020 (%)
Artisanal Mining	1.2	15.4	14.2
Built up	0.1	47.2	47.1
Cultivated Land	67.9	24.8	-43.1
Grass Land	7.9	3.1	-4.8
Forest	22.9	9.5	-13.4

Table 7 Net change in Land use land cover class during 2000-2020

NB: The plus (+) sign stand for incremental of specific LU/LC class whereas the minus (-) sign stand for a declining of specific LU/LC class.

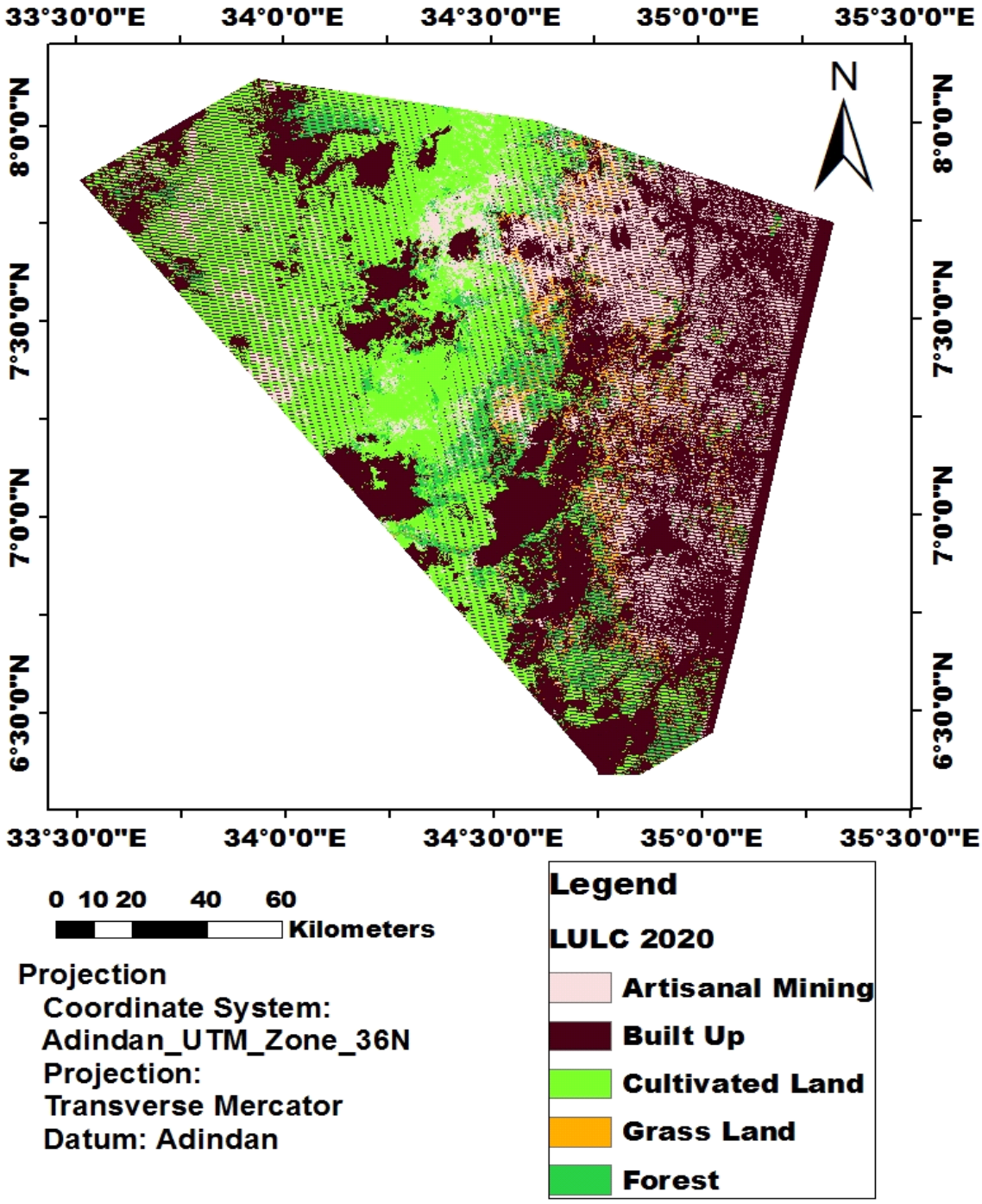

Figure 29 Land Use/Land Cover map for 2020 of the area

5.5 Change Detection

Post-classification change detection was used to find out shifts in land use and land cover of "from-to" intervals, 2000–2006, 2006–2016, 2016–2020 and 2000–2020. There was a sharp increase in Artisanal Mining extent of surface with net change of 14.2% in 20 years. In the year of 2000, the data showed that the Artisanal Mining was 1.2%. It further increased to 3.3% in 2006, 13.9% in 2016 and 15.4% in 2020. Similarly Built Up or settlement areas has expanded by 47.1% in last 20 years. As shown in figure 23 below, The Average rate of change per year of its incremental coverage was 1.7ha/yr.,727.3 ha/yr. and 873.5ha/yr. in the years of 2000-2006, 2006-2016 and 2016-2020 respectively.

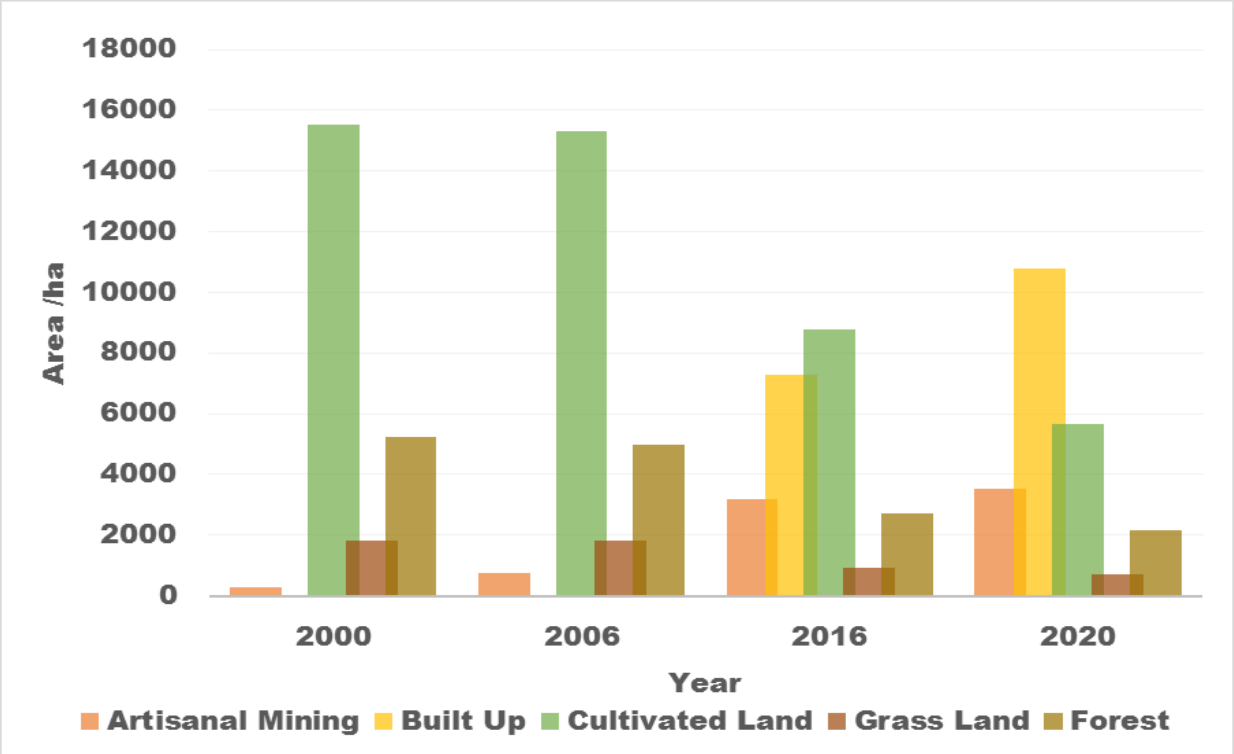

Figure 30 Histogram presenting areal coverage (ha) of each class with respective years

On the other hand areas of Cultivated Land, Grass Land and Forest were diminished in the past 20 years. The central trigger of this land use change is growth of Artisanal and small-scale placer mining activities and settlements around there. In 2000, Cultivated Land recorded15538.2ha area coverage but drop off by 43.1% in the year 2020 with 5680.9ha left. Grass Lands were 7.9% in 2000, which decline to 3.1% in 2020. Forest in the district likewise reported for the conversion from 22.9% to 9.5% in the period 2000‑2020.

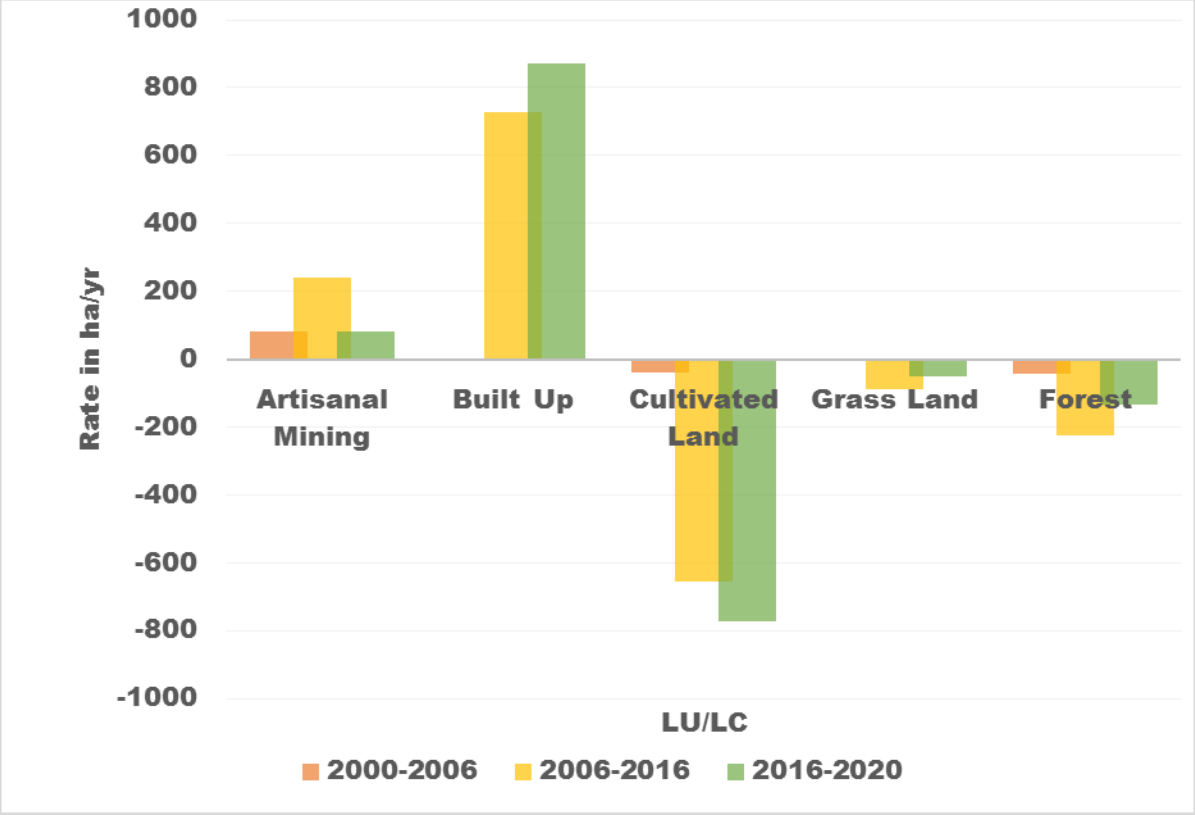

Figure 31 Histogram presenting average rate of change per year with respective years

On the whole, the reduction in natural land cover is consequence of increasing human-persuade land use in the District from 2000- 2020. The Governments at all levels should give attention to these obstacles of land cover changes in the District. The overall accuracies for 2000, 2006, 2016, and 2020 were, respectively, 83.4%, 88.8%, 92.9% and 97.8% by using error matrices for evaluation of classification accuracy. This met the recommended value suggested by Jams et al. (1976).

5.6 Analysis of Respondents Rate

The researcher adduced a total number of one-hundred (100) copies of questionnaires to respondents though ten of them were not answered in few cases. The demographic data collected included the respondent's age, gender, education level, Marital Status and size of household. Furthermore of giving personal information, respondents were requested to share their opinion on Environmental, Social and Economic impact of ASGM with respect to the summarize questionnaire. The generated data was statistically processed on Microsoft excel (2013) sheets presented below.

Out of 90 respondents, Demographic findings from the study revealed that 67 (74.75%) were male while 23 (25.25%) were female. The result also shows that most of the respondents (81.8%) were mainly teenagers and youths generally within the age range of 18-45 years where as 8.1% were category of adults and old age with the series of 46-65 years and above 65 year. The remaining 10.1% were under 18 age. In terms of education level, most of them (60.6%) were uneducated or illiterate since 20.2% could only read and write that they drop out

of school without finishing their elementary grades. 8.1% and 5.1% of the respondents' possessed primary education and secondary education respectively. while about 6% completed diploma and university programmes.

Feedbacks Collected Through Questionnaires				
No	**Category**	**Number of Questionnaires Distributed**	**Feedback Rate in Number**	**Feedback Rate in percent (%)**
1	Artisanal and small-scale miners	48	44	91.7
2	Residents living around the mining area	42	36	85.7
3	Relevant stakeholders	10	10	100
Sub Total		100	90	90
Feedbacks Collected Through Group Discussion				
No	**Category**	**Plan**	**Feedback Rate in Number**	**Feedback Rate in percent (%)**
1	Community elders	15	15	100
Feedbacks Collected Through Interviews				
No	**Category**	**Plan**	**Feedback Rate in Number**	**Feedback Rate in percent (%)**
1	Respective kebele administrators	1	1	100
2	Youth and Women affairs representatives of Dima Woreda	1	0	0
Sub Total		2	1	50
Grand Total		**117**	**106**	**90.6**

Table 8 Summary of Respondents Rate by Category

Source: Researcher's field survey result February, 2021

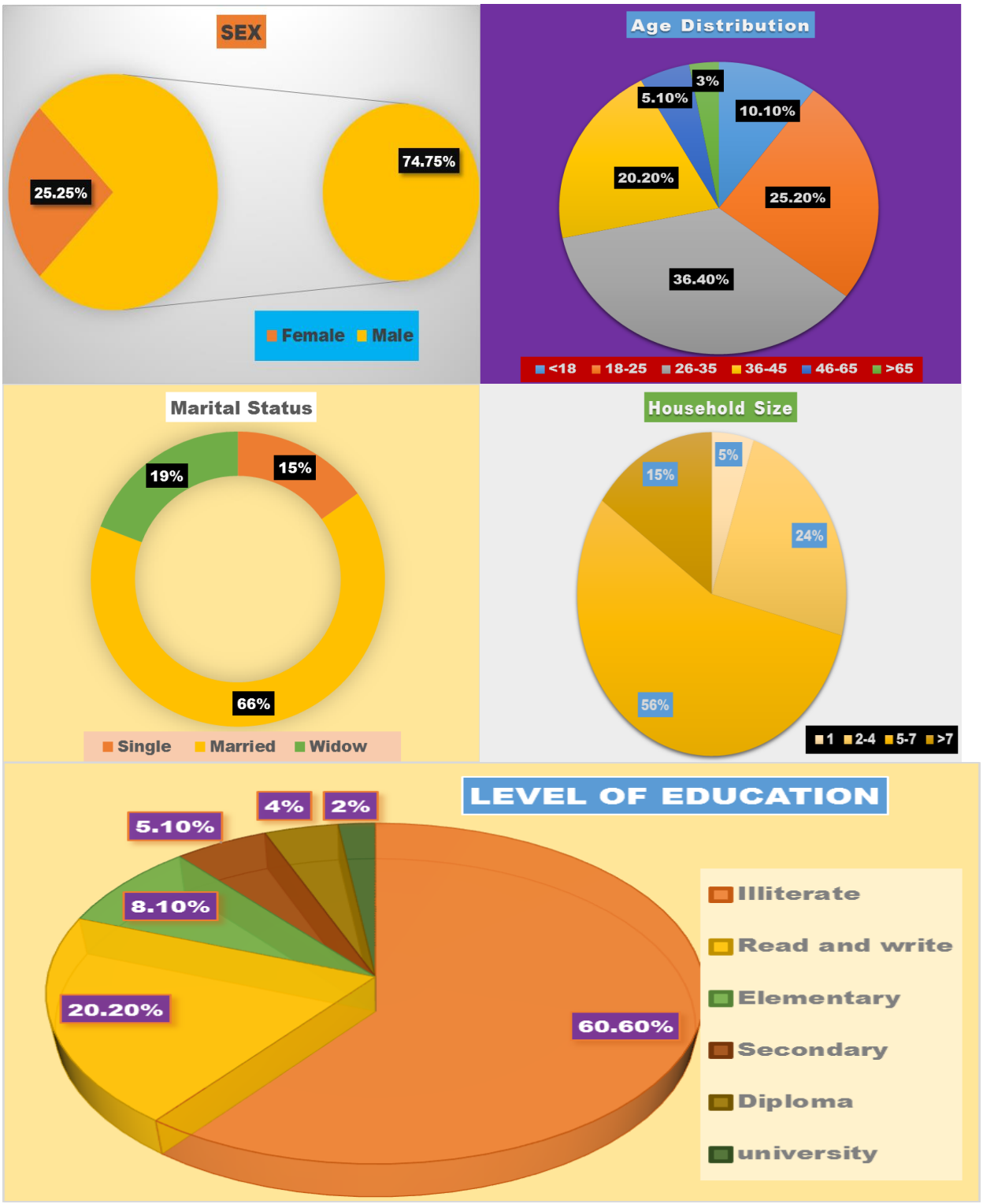

Figure 32 The demographic data of respondents

On the other hand, the study discovered about marital status of the respondents that, 66% were married and 15% were singles. The rest, which constituted 19% were widows. In the analysis of household size regarding number of children, this study revealed that 56% had 5-7 children, 24% had 2-4 children, 15% had more than 7 children and only 5% had 1 child.

5.6.1 Responses on Environmental impact of ASGM

The environmental impacts of ASGM in the district was portioned in to four sets: impact on cultivated land, pollution of Akobo River water, contributed to deforestation and exercising of any chemical to separate gold from soil or rock.

- **ASGM impact on the forest (deforestation)** - Regarding the negative impacts of ASGM on forest, 83% stand out undisputed response of "Yes" from all respondents, while responses of "No" and "Don't Know" ranked 12% and 5% respectively. Despite the fact, there was distinction on the degree of impact on response of "Yes" in such that 87% of each grouped the impact as low(insignificant), 12% of each labeled the impact as medium(significant), whereas 5% of each illustrated the impact as high (very significant) as clarified in figure (25), (28) below. Removal of vegetation and cutting trees affect the biodiversity of the district that results the loss of flora and fauna communities including microscopic organisms, and increase in disturbed of the natural communities.

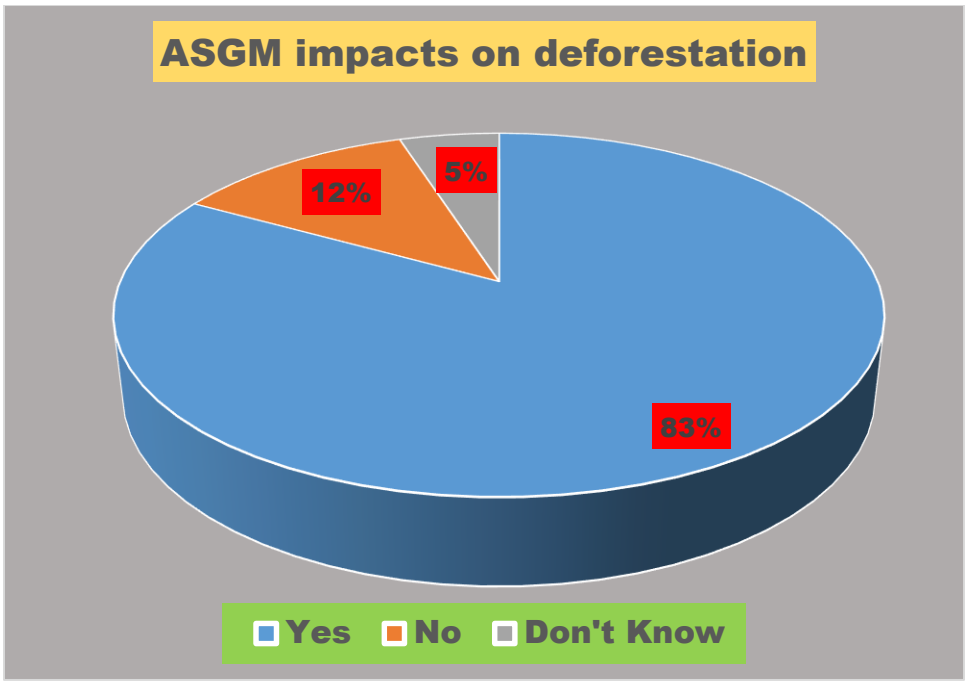

Figure 33 ASGM impacts on deforestation in the area

- **ASGM impact on the cultivated land** –Varied replies were gotten from total of 90 respondents about diminish of farm land results from ASGM. Out of them, 89% reacted "Yes", the rest 9% and 2% pointed up "No" and "Don't Know" returns. In spite of this, the outlook of "Yes" feedback also altered. Seventy six individuals (76) stand for 85% of "Yes" opinion that offer high impact(s) of ASGM on cultivated land, at same time twelve individuals (12) signifying 13% of "Yes" answers to medium impact(s) and two individuals (2) symbolized 2% of "Yes" reports to low impact as give details in figure (26),(28) under.

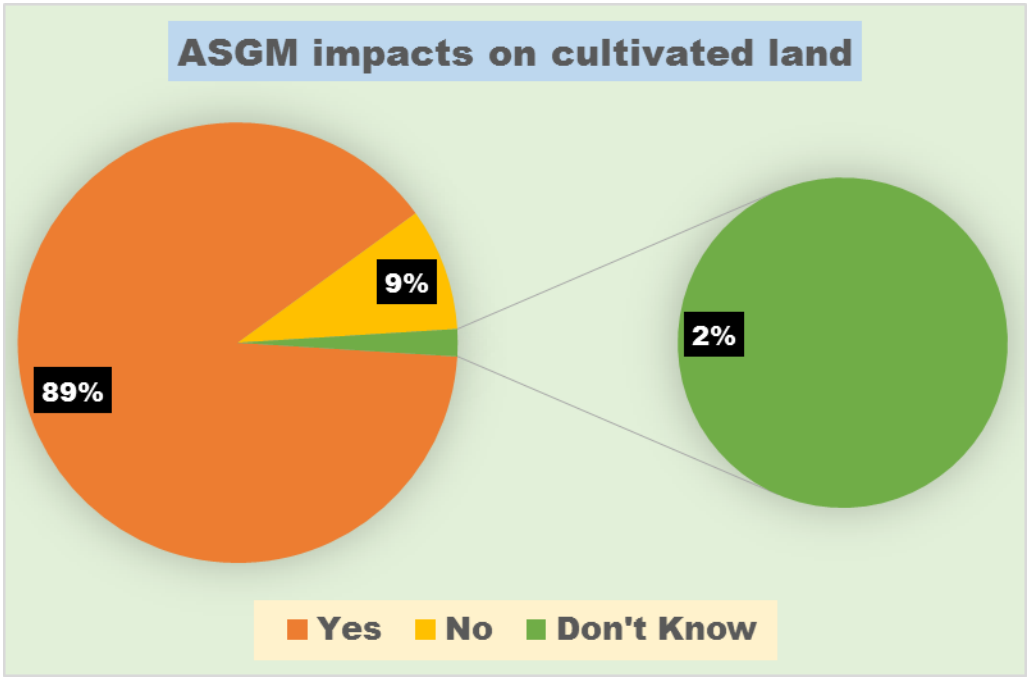

Figure 34 ASGM impacts on cultivated land in the area

- **ASGM impact on the pollution of Akobo River water** – Data attained on the chance of pollution of Akobo River water by ASGM activities in the district, there was a common "Yes" response from all ninety (90) independent cross-examined. Nevertheless on the intensity of the impact, 85% of each agreed the impact as high (very significant), 14% of each subscribed the impact as medium (significant), and only 1 % of each stated the impact as low (insignificant). The outcome of this is displayed in figure (28) below.

- **Using of chemical on ASGM** - The end result from respondents on chemicals utilizing or not on ASGM processes in Dima district demonstrated variation. As indicated in figure (27) beneath, the response rate was 94% for "No" status, while 6% for "Don't Know" order.

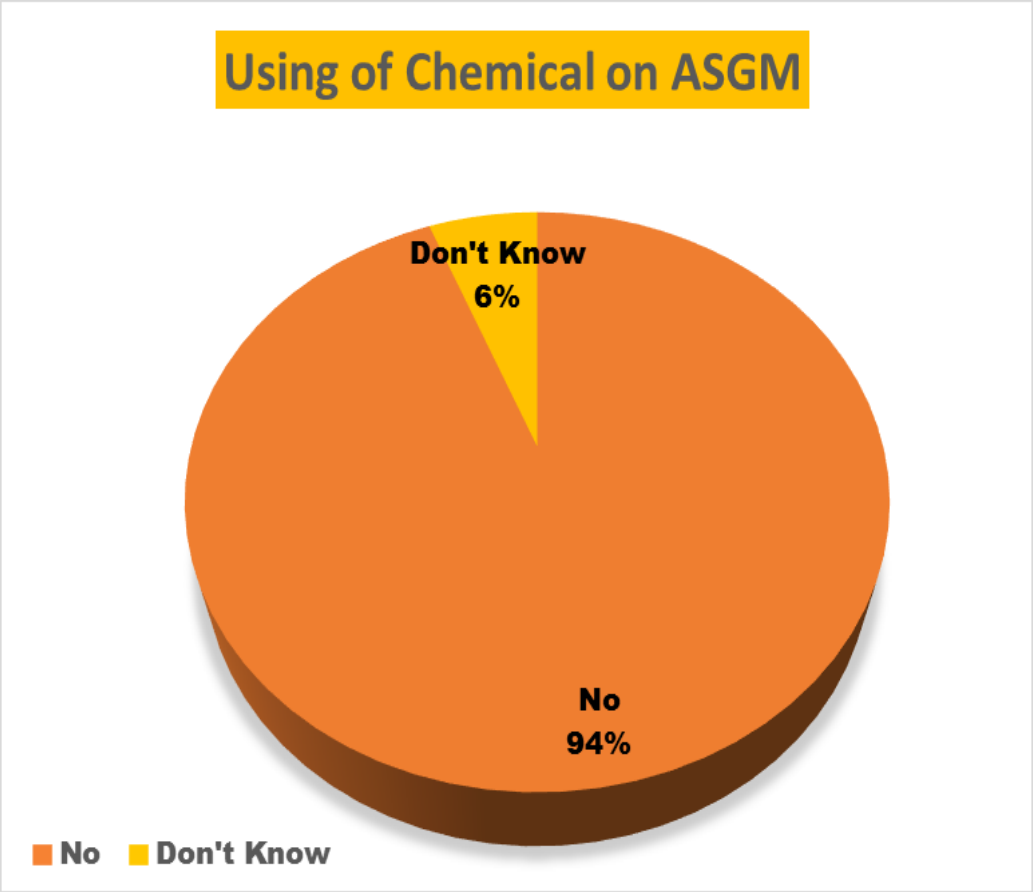

Figure 35 Respondent's rate on using of any chemical on ASGM in the area

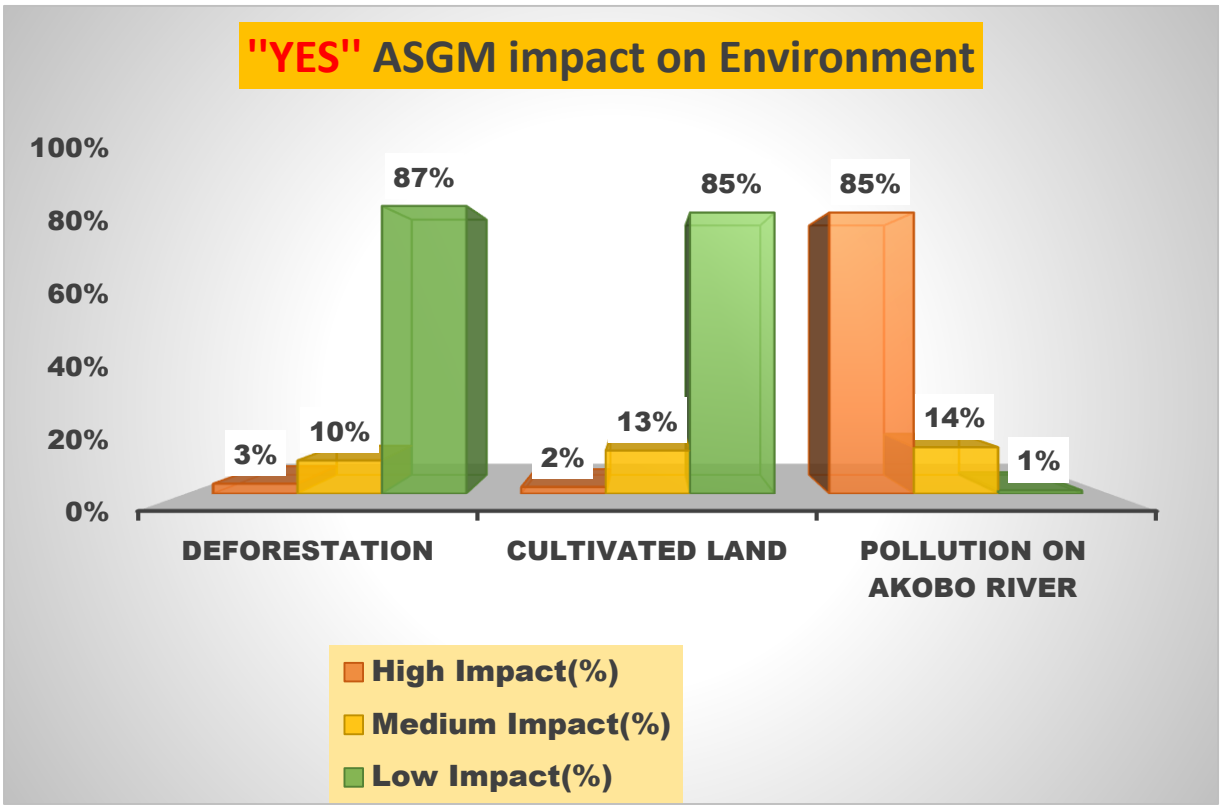

Figure 36 Degree of ASGM impacts on environment

5.6.2 Responses on Social impact of ASGM

Data's obtained from respondents about social aspects of ASGM were categorized into three: Health of residents as well as Artisan miners, any accident (death or physical injury) related to ASGM activities and conflicts on resources related to ASGM practices.

- **Health**- The findings showed that 95% of every single out from total number of 90 as 100% input "Yes" category refer to having an impact on human health of both the miners and residents around there generated by

ASGM working in the area. In contrast, no more than 5% of every single entered "Don't Know" requisition. However, reviewing the degree of impact from "Yes" groups, 65% characterized the negative impact of ASGM as high (very significant), 24% typified the impact as medium (significant), besides 11% stamped the impact as low (insignificant).

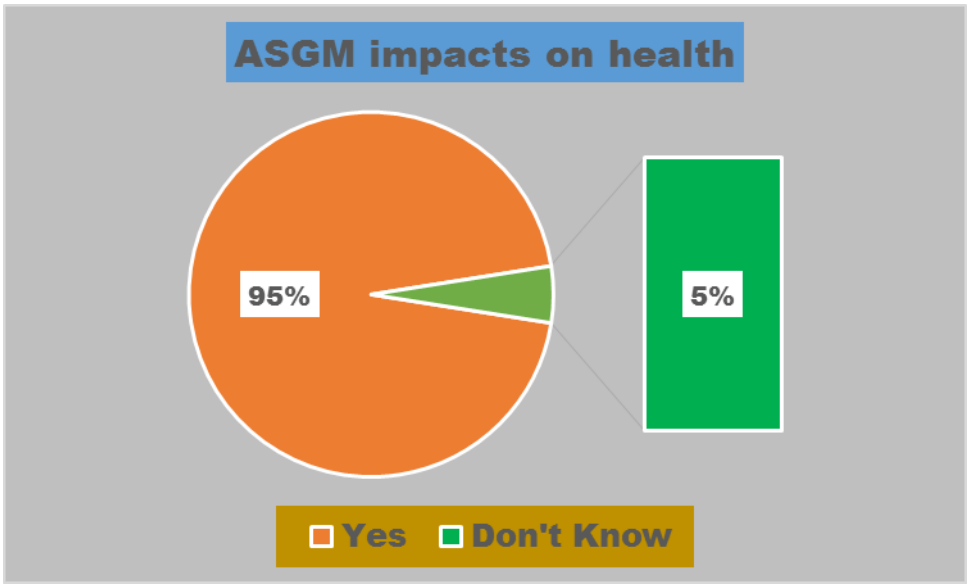

Figure 37 ASGM impacts on health

- **Accident**- The descriptive statistics survey for accidents (death or physical injury) results from ASGM in the district suggested 60% were under "Yes" class. What's more, 10%, 30% individuals representing "No" and "Don't Know" clusters respectively. Even though, Seventeen (17) individuals representing 19% of the respondents "Yes" attitude mentioned accidents raised from mining and production process of artisanal and small-scale placer gold in the district as high impact (very significant).

Correspondingly, thirty-two (32) individuals or 36% of the people labeled the accident impact by ASGM as medium (significant) impact and forty-one (41) individuals representing 45% of the respondents "Yes" mass embodied the impact as low (insignificant). Figure (30), (32) below exemplified the result.

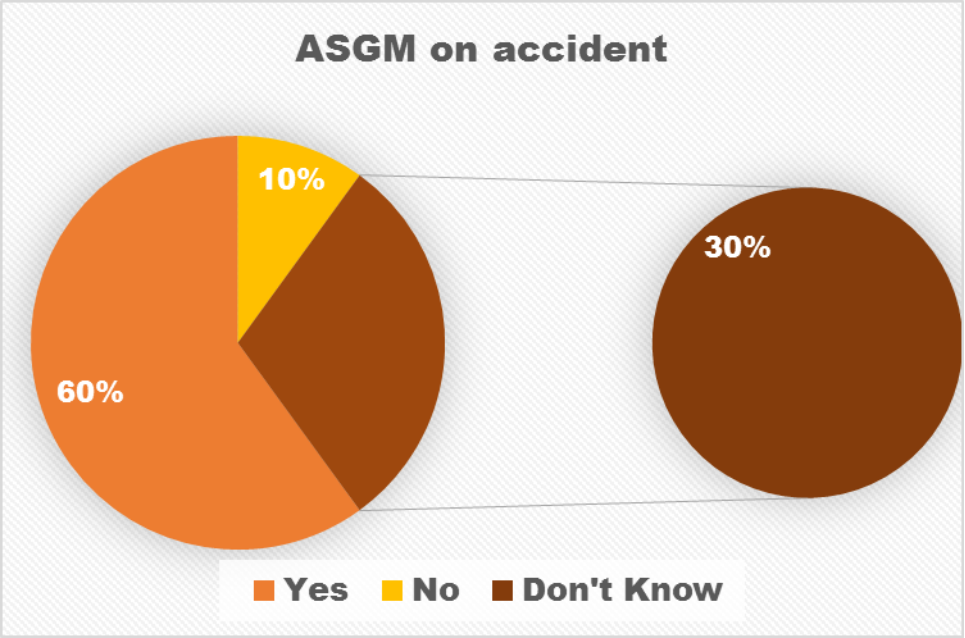

Figure 38 ASGM impacts on accident

- **Conflict**- Data gathered in this regard open-up "Yes" response accounted 85% denoting seventy-seven each from total people while the rest 15% or thirteen (13) each stands for "Don't Know" class. Among the "Yes" feedback on resource conflict(s) bring up from ASGM in the district, 80% presenting the extent of impact as high (very significant), on the other hand

15%, 5% existed a symbol of medium and low impact grades respectively as indicated in figure (31), (32) down.

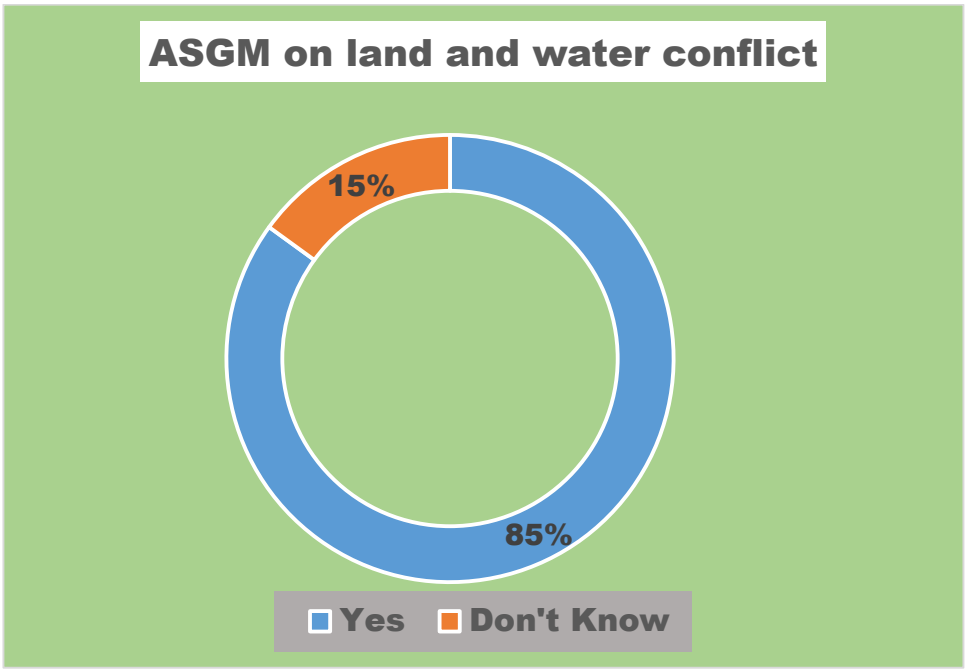

Figure 39 Impacts of ASGM on land and water conflict

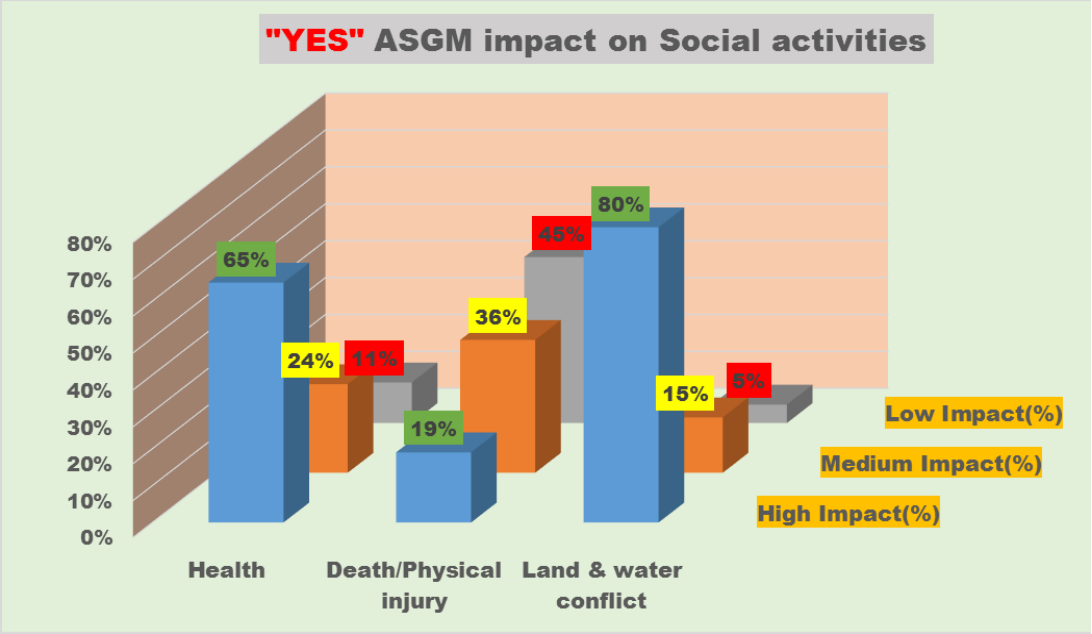

Figure 40 Degree of ASGM impacts on social conditions

5.6.3 Responses on Economic impact of ASGM

The findings on Economic section of ASGM were based on economic development generated by ASGM, income generating of ASGM, creating employment and other benefits from ASGM activities in the study area.

- ✓ **Economic development**- Despite the artisan miners having financial capital be contingent on dutiful working and chance of them, the results gained from the respondent in which thirty-three (33) individual presenting 75% indicate that, the miners could minimum get up to five-hundred (500) Birr per day with the intention adequate for daily consumption of themselves and their families. But it doesn't mean that they get all the time as well as the value depends on the market and varies from time to time. The possibility of getting not only depends on hard working of miners but it also depends on luck.

  On the other hand, the miners with hydraulic water pump earned more than these in which eleven (11) individual manifesting 25% mentioned that, they could minimum get up to twenty-five thousand (25,000) Birr per day with the purpose of saving and investing to other microbusinesses such as opening shops and trades beyond securing of their livelihoods. Generally the researcher concluded that in the vicinity of Akobo River, Production of placer gold is variable, tricky, a "hand to mouth" activity and the profits are usually very low for the miners, as they sell the gold on the site. The

profits are for the buyers and/or intermediate traders since they sell gold in the big cities (Gambella) or abroad (e.g., Ethiopia).

To realize the degree of the positive impact of ASGM on economic development by saving and investing in the district, 65% of the people argued the impact as low (insignificant), 35% of the individuals yield the rank as medium (significant) while 5% of the people described the impact labeled as high (very significant) as shown in figure (33), (36) below.

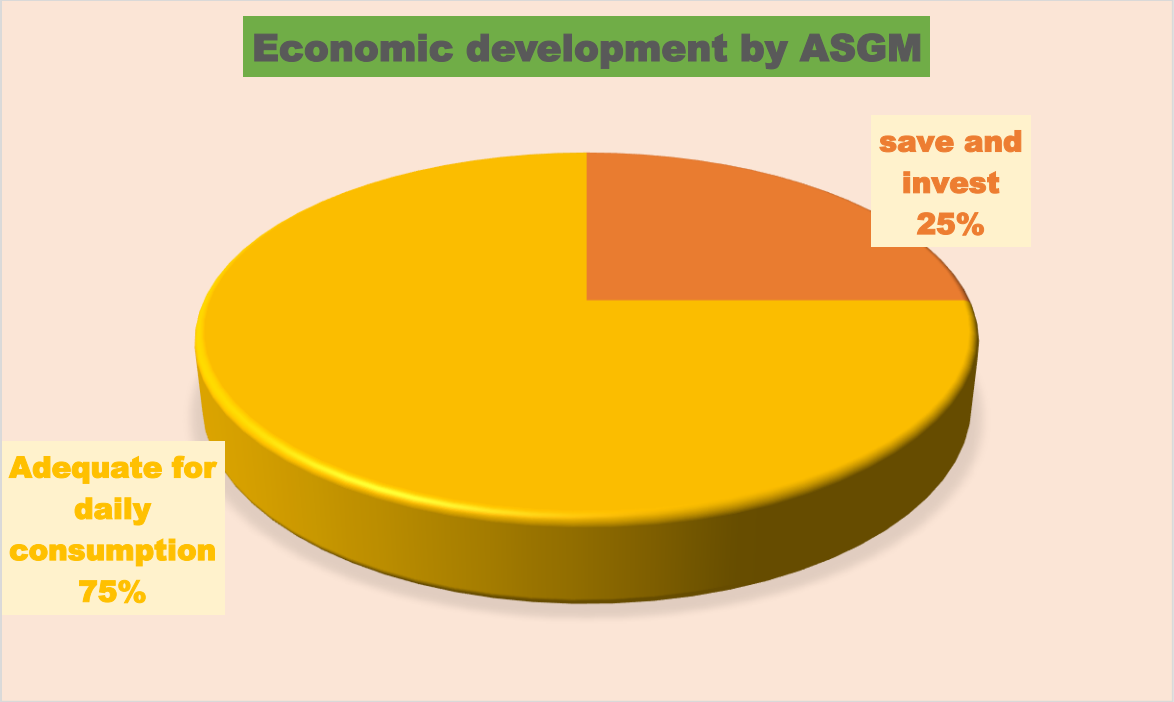

Figure 41 Economic development by ASGM

- ✓ **Income generating**- In dealing with order of income generating in the district, 65% of the respondents argued that engaging in ASGM acquired economic effectiveness by hiring minimum inputs to generate greater

output for income generating relative to other economic alternatives in the study area including Agriculture, Livestock production and trade. Following ASGM sector, the data obtained from the respondents showed 25% were highly dependent on Agriculture for their livelihoods while 9% and 1% of them depend on trade and Livestock production employments in the district respectively in order of income generating.

The results based on the responses gathered through questionnaires, 25% of them go over the generating of income by ASGM means on high (very significant) assembly, at the same time, 65% of them ranked medium (significant) and the rest 10% rate low impact (low significant).

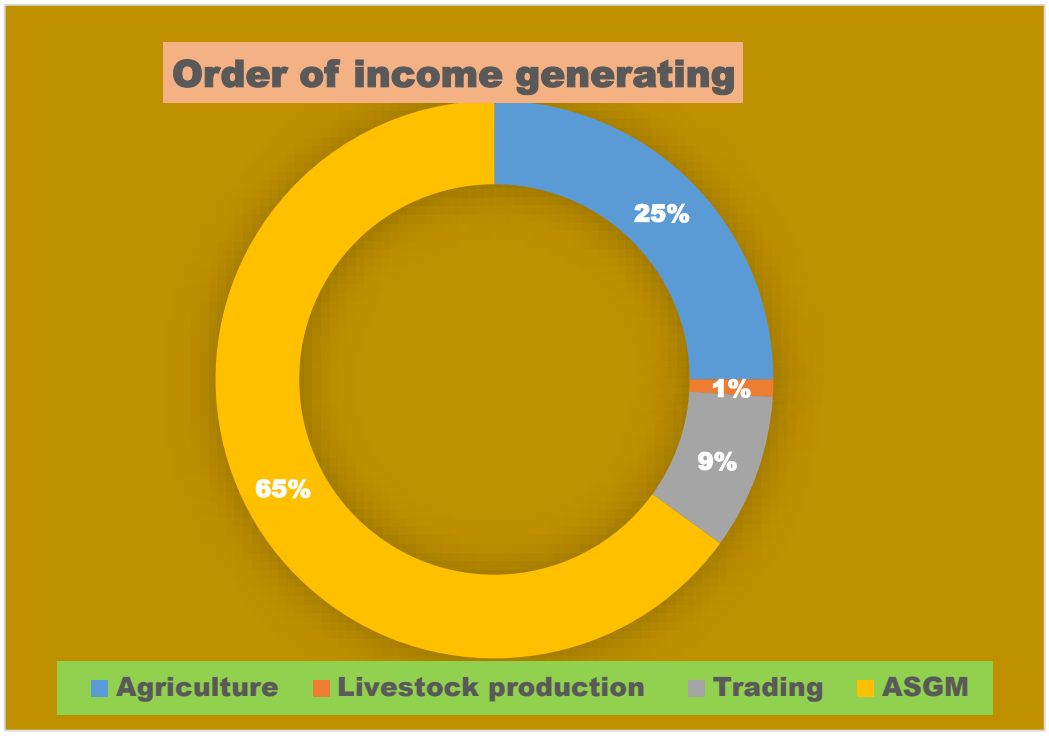

Figure 42 Order of income generating of different sectors in the area

- ✓ **Creating employment**- According to information from eighty-one (81) each respondents (90%), the contribution of ASGM sector to the employment opportunity surrounding Akobo River agreed strongly. In addition to this, it was proved by 9% of respondents agree ASGM be a primary source of employment for job seekers. However, 1% of them were not sure by contributing of ASGM to providing employment.

  Regarding the impact(s) of ASGM on creating employment, 90% each reacted the impact in high (very significant) category where as 9%, 1% individuals graded the impact in medium and low groups respectively.

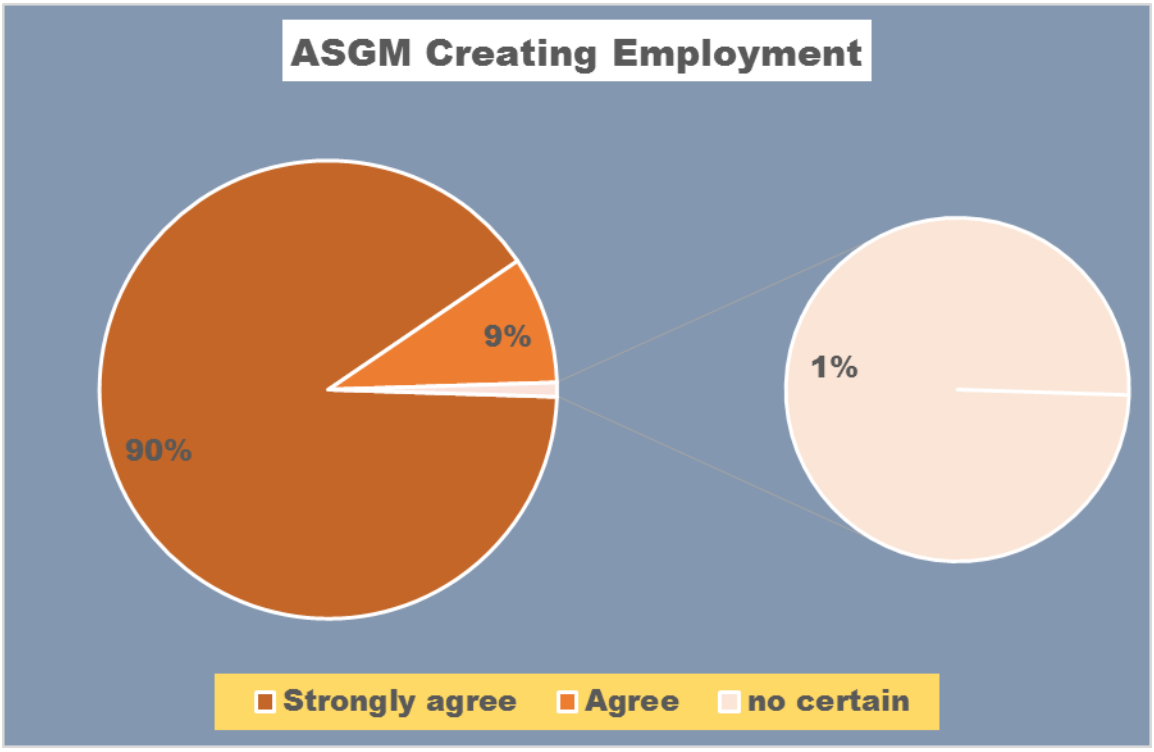

Figure 43 Creating of Employment by ASGM

- ✓ **Other benefits**- In the case of Akobo district, majority of the artisanal and small-scale miners engaged on this sector were poverty driven and gained low income. Although most of them couldn't break down poverty cycle, the sector became a matter of survival for themselves and their families. Majority of the artisan gold miners argued that they recovered from poverty fears and stresses for short term that didn't have sustainable economic strategy.

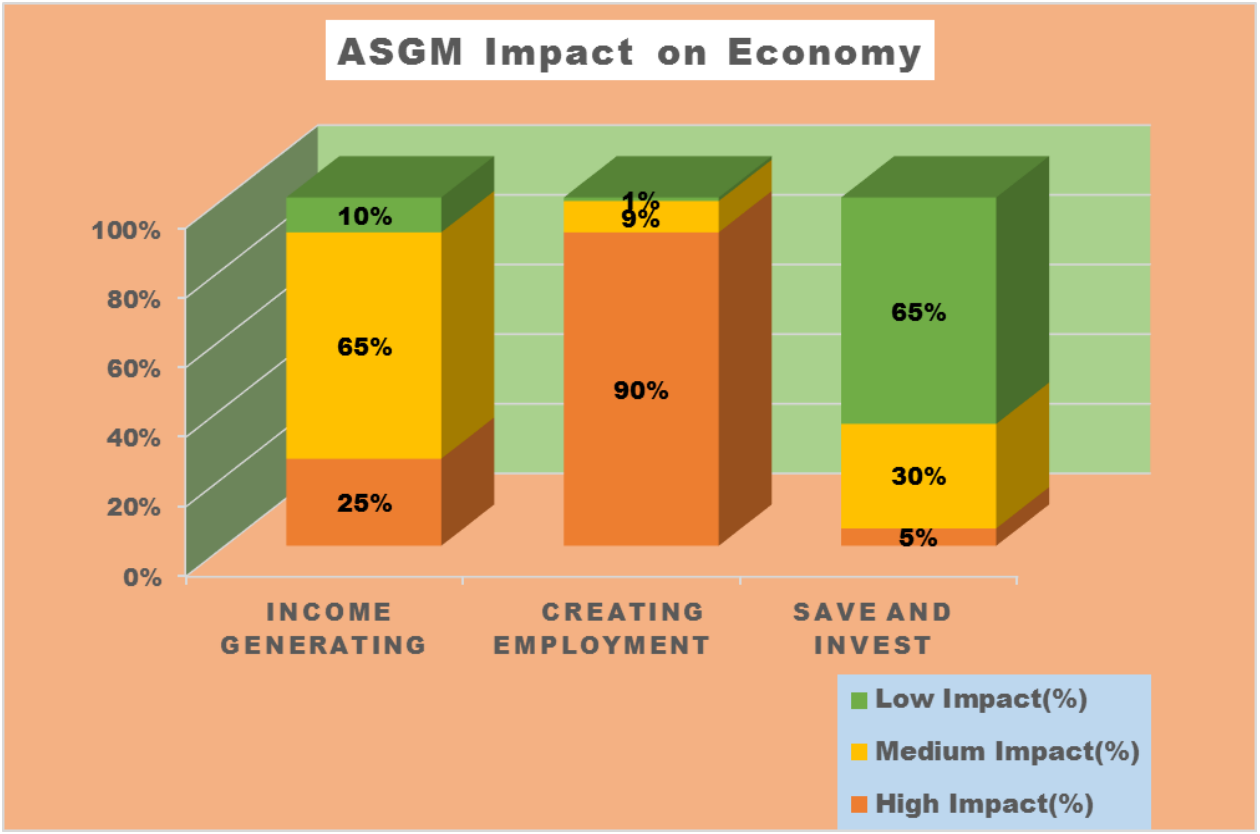

Figure 44 Degree of ASGM impacts on economy

Chapter Six

Conclusion and Recommendations

6.1 Conclusion

This study evaluated the impact of artisanal and small-scale gold mining in Akobo River mining area from both environment and socioeconomic perspectives. Obtained environmental results revealed the bearing of ASGM in the district on the physicochemical parameters of the Akobo River water; LULC change based on analysis of Landsat 7 ETM data of the years 2000, 2006, 2016 and 2020; and respondents' perceptions of the level of associated risk.

Pan and Sluices are inexpensive to obtain, operate, and maintain. They are portable and easy to use, and they understandably play an important role in low-cost, placer-gold-recovery operations. ASGM in Dima district involves Gravity concentration (panning & ground sluicing) which use gravity to separate particles on the basis of density or size to obtain a gold-rich final concentrate, can reduce mercury consumption, but they are still not effective enough.

From present investigations we concluded that there are considerable differences in concentration of physicochemical parameters among the different sampling stations which might be due to disposal of sewage from domestic activities, agricultural runoff and wastewater source from ASGM works with an incremental path from upstream to downstream.

From analysing and mapping of LULC of the area by remote sensing imagery of different year, it can be used to display the LULC dynamics over two decades in

Chama and Merkes environments. Thus, the study revealed that the expansion of artisanal and small-scale gold mining; settlements or built ups from 2000 to 2020 while land cover of forest, cultivated land and grasslands show declining rate.

Beyond this, the involvement of respondents' opinion from different sex, age and background education level on ASGM operations in the study area in order to gain information about communities' as well as artisan miners' social and economic problems. From the result we detected that ASGM is a meaningful source of livelihood for the miners. However, its marked different issues such as health (water-borne diseases, malaria and HIV/AIDS), under-aged participation, resource conflicts, cycle of poverty, and safety (ground collapse, poor ventilation and dust) were massive.

Land cover is diminishing whiles land use is increasing in the district is the result of the following factor: poverty, youth unemployment, deforestation, ASGM, urbanization and illiteracy. It is important to prevent or take urgent action against further expansion of the above mentioned factors which might have negative impacts on the environment and socio-economic conditions.

The overall trade in ASGM activities is linked to illegal trade pushed through various borders that brings them illegal forex, whereas the Ethiopian National Bank can only pay them in local currency on an official forex rate. In this year, the country's council of ministers approved a 10-year economic plan, which beset

to enhance the amount of foreign-exchange earned through export and import substitution of minerals from $265 million currently to $17 billion by 2030.

Because high gold prices are increasing Ethiopia's mining revenue and attracting more investor interest in a sector that is largely dominated by artisanal and smaller players, the government should called on investors to partner with the government to engage in the mining sector with a special emphasis given to gold by giving several incentives. And also, it must be undertaking several measurements to control the deteriorating account of gold produced by artisanal miners coming into the arms of the formal sector; Ethiopia's central bank for hard currency. These measures and effects work can minimize the expanded illegal trade activities.

6.2 Recommendations

To recover environmental and socioeconomic tricky of ASGM in the study area, the researcher forwarded the following suggestions:

- **Laws and policy implementation**: It is imperative that the implementing of laws and policies be strengthened by establishing offices in those remote mining areas; involving a collaboration frameworks with the communities in sustainable management of natural resources; establishing unbiased monitoring team by the authorities to follow up the status; putting security and restraint measures in place to cross-check those who hesitate; sanitizing the process by which government stack holders giving services that enforce people to operate illegally.

- **Environmental Management:** A proper environmental control measures should be take place. Make an attempt to recover and reclaim the abandoned mine sites by planting trees with wider spacing to allow undergrowth so that erosion will be prevented or minimal and biodiversity protection . On the other hand, for natural regeneration put in place integrate several crops and tree species in the agroforestry practices with low moisture demand and harvest water during the rainy water for dearth period use. Further than, avoiding or minimizing the generation of domestic waste materials by recover and reuse wastes.

- **Provision of Financial services:** The government should attempts to creation formal mining cooperatives by bring together the individual miners with setting up of training on technical, social, financial and environmental issues; formalize mutual group saving systems and encouraging the financial institutions to granting access to credit facilities and provide the use of third party guarantees to the miners. The governments also be relevant modern tools or equipment's and portable or permanent sanitation facilities serving all miners.

- **Education:** A large proportion of artisanal miners are unaware of the environmental damages they are causing through their activities and they seems their activities are dangerous only when critical cases appeared. Therefore, it was recommendable that the authority needs to made education programs through media and building partnerships with different communities and miners on improving their personal skills so as to benefit both in mining and other entrepreneurial endeavors; targeting under-aged children in mining areas for their education; conducting mining activity within a far distance to river water and preventing sluice from having contact with the environment; prohibiting household discharges enter to the river having harmful effect on human health.

- **Effective Management:** The government as well as relevant stack holders should first need to consider how to alleviate poverty and vulnerability within the AS gold miners by taking them as alternative to other local economic sectors (agriculture, livestock production and trade) to generate additional incomes for better livelihood; Organizing the ASGM miners under a structured system for effective monitoring regulation of the mining activities, enactments of appropriate laws, and enforcement; Promoting partnership between miners and large-scale investors; providing services in marketing; setting preventive measures for accidents and other hazards by "health and safety first" slogan.

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Appendixes

Appendix A-1 Error matrix accuracy totals for the classified image (2000).

Class types determined from classified map	Class types determined from reference source							
	Year: 2000	Cultivated Land	Forests	Grasslands	Artisanal Mining	Built Up	Classification overall	Producer accuracy %
	Cultivated Land	85	0	19	0	2	106	54.1
	Forests	0	74	0	0	0	74	100
	Grasslands	37	0	258	1	2	298	92.1
	Artisanal Mining	9	0	1	52	0	62	98.1
	Built Up	26	0	2	0	27	55	87.1
	Truth Overall	157	74	280	53	31	595	
	User accuracy %	80.2	100	86.6	83.9	49.1		
	Overall accuracy = 83.4%							
	Kappa = 0.76							

Appendix A-2 Error matrix accuracy totals for the classified image (2006).

Class types determined from classified map	Class types determined from reference source							
	Year: 2006	Cultivated Land	Forests	Grasslands	Artisanal Mining	Built Up	Classification overall	Producer accuracy %
	Cultivated Land	104	0	4	0	0	108	88.9
	Forests	0	108	4	0	0	112	100
	Grasslands	4	0	91	25	0	120	85.8
	Artisanal Mining	9	0	0	79	4	92	73.1
	Built Up	0	0	7	4	101	112	96.2
	Truth Overall	117	108	106	108	105	544	
	User accuracy %	96.3	96.4	75.8	85.9	90.2		
	Overall accuracy = 88.8%							
	Kappa = 0.86							

Appendix A-3 Error matrix accuracy totals for the classified image (2016).

Class types determined from classified map	Class types determined from reference source							
	Year: 2016	Cultivated Land	Forests	Grasslands	Artisanal Mining	Built Up	Classification overall	Producer accuracy %
	Cultivated Land	59	1	0	15	0	75	96.7
	Forests	0	80	0	0	0	80	98.8
	Grasslands	1	0	77	1	0	79	95.1
	Artisanal Mining	0	0	4	73	4	81	81.1
	Built Up	1	0	0	1	78	80	95.1
	Truth Overall	61	81	81	90	82	395	
	User accuracy %	78.7	100	94.5	90.1	97.5		
	Overall accuracy = 92.9%							
	Kappa = 0.91							

Appendix A-4 Error matrix accuracy totals for the classified image (2020).

Class types determined from classified map	Class types determined from reference source							
	Year: 2020	Cultivated Land	Forests	Grasslands	Artisanal Mining	Built Up	Classification overall	Producer accuracy %
	Cultivated Land	94	1	0	0	0	95	97.9
	Forests	1	45	0	0	0	46	95.7
	Grasslands	1	1	44	0	0	46	100
	Artisanal Mining	0	0	0	46	0	46	88.5
	Built Up	0	0	0	6	230	236	100
	Truth Overall	96	47	44	52	230	469	
	User accuracy %	98.9	97.8	95.7	100	97.5		
	Overall accuracy = 97.8%							
	Kappa = 0.97							

Appendix A-5 Questionnaires about demographic information of respondents.

Dear respondents;

The aim of this questioner is to assess the environmental and socio - economic impacts of Artisanal and small-scale gold mining in Gambella, the case of Dima Woreda.The information is only for academic purpose with great confidentiality. Please, response your positive opinion based on my questioner outline.

1. Age:
   a) Less than 18
   b) 18-25
   c) 26-35
   d) 3 6-45
   e) 46-65
   f) Above 65

2. Sex:
   a) Male b) Female

3. Level of Education:
   a) Illiterate
   b) Read and write
   c) Elementary
   d) Secondary
   e) Diploma
   f) university

4. Marital Status:
   a) Single b) Married c) Widow/Widower

5. Size of household:
   a) 1 b) 2-4 c) 5-7 d) 7+

Appendix A-5 Questionnaires about environment information of respondents.

1. Has Artisanal and small-scale gold mining contributed to deforestation?
   a) No b) Yes c) Don´t Know

If your answer is yes, please discuss it ----------
---

2. Does Artisanal and small-scale gold mining have any impact on cultivated land?

a) No b) Yes c) Don´t Know

If your answer is yes, please discuss it ----------

3. Has Artisanal and small-scale gold mining activities brought Pollution on Akobo River?

a) No b) Yes c) Don´t Know

If your answer is yes, please discuss it ----------

4. Does the chemical is used to separate gold from soil or rock?

a) No b) Yes c) Don´t Know

If your answer is yes, please list the type of chemical ----------

Appendix A-7 Questionnaires about Social information of respondents

1. Does Artisanal and small-scale gold mining affected the health of people in the area including Artisan miners?

a) No b) Yes c) Don´t Know

If your answer is yes, please discuss it----------

2. Is there any accident (death or physical injury) related to Artisanal and small-scale gold mining activities?

a) No b) Yes c) Don´t Know

If your answer is yes, please discuss the rate and type of accident----------

3. Have social problems such as land/water conflict related to Artisanal and small-scale gold mining activities?

a) No b) Yes c) Don´t Know
If your answer is yes, please list the extent and type ----------
---

Appendix A-8 Questionnaires about Economic information of respondents

1. How do you explain the economic development generated by Artisanal and small-scale gold mining activities comparing with other sectors?

a) Good enough to save and invest
b) Adequate only for daily consumption
c) Not adequate to cover daily consumption

2. What are the major economic activities in the district in order of income generating?

a) Agriculture
b) Livestock production
c) Trading
d) Artisanal and small-scale gold mining
If your answer is other than the above, please specify it ----------
---

3. Do you believe that Artisanal and small-scale gold mining changed your status by creating employment?

a) Strongly agree b) Agree e) no certain
c) Strongly disagree d) Disagree

4. For what benefits that Artisan gold miners involve and stay in Artisanal and small-scale gold mining?

THANK YOU VERY MUCH!