ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF ARTISANAL GOLD MINING ON AGRICULTURAL PRODUCTION IN SIKASSO REGION, MALI

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A thesis submitted to Graduate School in partial fulfillment for the requirements of the Doctor of Philosophy Degree in Environmental Science of Egerton University

EGERTON UNIVERSITY

NOVEMBER, 2018

DECLARATION AND RECOMMENDATION

Declaration

This research thesis is wholly my original work and has not been submitted for an award of any degree in any other University.

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Recommendation

This thesis has been submitted with our approval as university supervisors for examination according to Egerton University regulations.

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DEDICATION

I dedicate this thesis to my family Jean Philip Waaub, Assitan Man Coulibaly, Moussa Keita, Salimata Keita, Aminata Keita and Issa Keita.

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ACKNOWLEDGEMENT

Many people contributed towards this thesis. I cannot mention all of them here by their names but I do acknowledge all with gratitude. The thesis work would not be done without their moral, material, technical and scientific support. I take this opportunity to mention here a few of them.

First, I would like to extend my gratitude to the entire Egerton University for offering me an opportunity to study in this world class institution. Secondly, I thank my home institution, The Rural Polytechnic Institute (IPR/IFRA) through the Ministry of Higher Education and Research of Mali for granting me permission to undertake my doctoral studies.

A special acknowledgement to my academic supervisors Prof. George M. Ogendi Department of Environmental Science, and Prof. George Owuor Department of Agricultural Economics and Business Management, Egerton University, who enthusiastically and tirelessly guided me out of mandate through this noble process. I also greatly acknowledge all the staff of Faculty of Environment and Resources Development (FERD), Egerton University for their valuable and positive critiques as well as encouragement throughout the course of study. In particular I acknowledge the GIS technical support that I received from Mr. Geoffrey Maina that enabled me produce a study area map. I cannot forget the Board of Graduate School, Egerton University for their availability and for facilitating my studies.

This material is based upon work supported by the United States Agency for International Development, as part of the Feed the Future initiative, under the CGIAR Fund, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crisis Mitigation II grant, Award number EEM-G-00-04-00013.

I acknowledge DRA - Sikasso, DRACPN - Sikasso, ODRS, the Board and residents of Tangandougou Commune and USTTB-CNR/Laboratory for their collaboration and assistance during my research work.

Without the moral and material support from my immediate Keita and the extended Coulibaly family members, it would not be possible to finish this program. To all of you, I say thank you. I won’t also forget to thank my Kenyan friends and student colleagues for their moral support and hospitality during my studies at Egerton University.

ABSTRACT

In West Africa, artisanal gold mining competes with agriculture, more specifically crop farming and livestock keeping. Mali is not an exceptional to this observation. In Sikasso region, women and youths have been reported to abandon agricultural activities for artisanal gold mining. It is against this background that this study was conducted to assess the factors that influenced households to be engaged in artisanal gold mining, to evaluate its impacts on water quality, subsistence crops, livestock production and to assess income sources of households in Sikasso region. This study was conducted using mixed methods approach: a Cross-Sectional survey as well as an ecological survey. The study used exploratory and descriptive methods as a research design and random sampling. The research tools used were structured questionnaire, focus group discussion, key informant interviews, observation check-list and secondary data review. Water sample collection and sample processing and analysis were done as per APHA protocols. The data was analyzed using descriptive and inferential statistics such as Pearson's Chi-square and correlation, logistic and multiple leaner regressions. The factors that had significant influence on artisanal gold mining included profession ($\chi^2 = 96.8$; $p < 0.001$), nativity ($\chi^2 = 78.1$; $p < 0.001$) and education level ($\chi^2 = 22.9$; $p < 0.001$) of the respondents. The concentration of cadmium and lead in the sampled water significantly exceeded WHO drinking water quality guidelines ($p < 0.05$). However, the concentration of Arsenic in water samples was not significantly different from the WHO drinking water quality guidelines. Artisanal gold mining impacted significantly on cereals crops ($\chi^2 = 13.9$; $p < 0.001$), vegetable farming ($\chi^2 = 48.9$; $p < 0.001$) and composting ($\chi^2 = 61.6$; $p < 0.001$). Further, artisanal gold mining significantly affected cattle, goat and sheep production ($\chi^2 = 58.3$; $\chi^2 = 13.9$; $\chi^2 = 27.5$; $p<0.001$) respectively. The study findings indicate that artisanal gold mining has negative effects on water quality as well as crop and livestock production. Artisanal gold mining has led to reduced labour for agricultural production thus minimized agricultural outputs. This will impact heavily on food and nutritional security not only for Mali but also the entire West African region. In addition, the income sources of households were influenced by profession, nativity, gender, age, education level and family size. These findings will contribute towards environmental conservation and safeguarding livelihoods, environmental and human health in Sikasso region. Further, the findings will contribute towards sustainable agriculture and hence enhanced food security in the region and the country in general.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

ACET:	African Center for Economic Transformation.
ARD:	Agriculture Regional Direction.
BHEARD:	Borlaug Higher Education for Agriculture Research and Development.
CIFOR:	Center for International Forestry Research.
CNRL:	Chemicals and Natural Resources Laboratory.
DPSEEA:	Drivers, Pressures, State, Exposure, Effect and Action.
DPSIR:	Drivers, Pressures, State, Impact, Responses.
EC:	European Commission.
EITI:	Extractive Industries Transparency Initiatives.
ESIA:	Environmental and Social Impacts Assessment.
GNP:	Gross National Product.
IFPRI:	International Food Policy Research Institute.
MRD:	Ministry of Rural Development.
MSU:	Michigan State University.
OPHI:	Oxford Poverty & Human Development Initiative.
PRM:	Presidency of Republic of Mali.
RDPCP:	Regional Direction of Pollutants Control and Pollution.
RGPH:	General Registration of Human Population.
RPI:	Rural Polytechnic Institute.
SRDO:	Selingue Rural Development Office.
USAID:	United States Agency for International Development.
USTTB:	University of Sciences, Techniques and Technology of Bamako.
WCED:	World Commission on Environment and Development.
WHO:	World Health Organization.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The management of communally-owned natural resources is a major challenge in many developing countries (Garrett, 1968). Communities with open access to such natural resources tend to exploit the resources on unsustainable basis causing environmental degradation. The degradation can be attributed to the competing uses and self-interests from the various stakeholders. The competition can also arise from the various forms of land uses and economic incentives. In different parts of the sub-Saharan Africa, agriculture competes with other economic activities. In Mali and specifically the Sikasso region, it competes with artisanal gold-mining for land and labor used in the agricultural production. The situation has led to rural populations moving from agricultural activities to artisanal gold mining. This has led to inadequacy of labor or agricultural workforces, combined with the continued land fragmentation, forest degradation, water pollution and rarity of rainfall has greatly affected Malian agricultural productivity across the country leading to food insecurity among other impacts. The engagement in artisanal gold mining has been encouraged by all Malian governments since independence and incentives have been offered to motivate national and international investments in this economic activity (PRM, 1999). This is because the mining code has financial advantages of investment to the promoters. Initially the prospecting and research stage of the artisanal gold mining process was cheap whereby the charges were $ 2 per kilometer square for the first expiration, $ 3 per km^2 and $ 4 per km^2 for the second and the third expiration of the leases. However, the charges have increased tremendously up to $ 200 per kilometer square, (Section 18 of mining code, 1999) but still the desire to invest in gold-mining is high. This has led to increased number of individuals and companies engaging in the gold mining industry. Even though the environmental and social impacts assessment (ESIA) was applied in West Africa's countries, specifically in Mali (PRM, 2003; MEA, 2007; MEA, 2008), so as to foresee the anticipated impact of plans, programs and projects before their implementation, they failed to implement the mitigation strategies as envisaged in the ESIA reports. Additionally, the materials intended to be extracted from earth included copper, nickel, silver, lead, zinc, cobalt, gold and platinum among others. The wide variety of the materials with varied specificity needed to be considered in the ESIA process. Furthermore, the traditional environmental knowledge held by the locals being one of the important parameters of resources management and a critical factor in any ESIA process was necessary to be captured through the process of public participation of all the concerned and affected stakeholders. Artisanal gold mining is one of the main economic activities for a major portion of the resident communities surrounding mining zones. Gold mining as an economic activity occupies large surface areas. These areas where artisanal gold mining activities are being carried out, initially they were used for crop farming and livestock production, fishing, picking and agroforestry. During the conversion of these fields into gold mining zones, the livestock grazing pasture and cultivable lands are grabbed without commensurate compensation to the affected parties. This was abated because, the land property rights is still unclear especially when it involves gold-mining projects in Mali. Thus artisanal gold mining has negative impacts on the environment, and the socioeconomic aspects of the resident communities and thus the country's development. These impacts include population displacement, loss of arable land, forests degradation, among others (Leblanc, 2006). Gold mining contributes to air and water pollution through the use of chemical products in extraction and processing. For example, the workers in artisanal gold mining use mercury and the industrial mining use cyanide for their extraction both of which cause widespread soil and water pollution and degradation as shown in limited agricultural production and deteriorating human and animal health within the mining zones (Tirina *et al.*, 2016; Gibb and O'Leary, 2014; Choi *et al.,* 2012; Mansour and Sidky, 2002). For instance, in 2012 the samples of soil and surface water from the mining zone of Sélingué were analyzed by Water Management Commission and the partial results showed that the cyanide concentration ranged between 36.75 mg/L to 42.75 mg/L against to 0.07 mg/L value recommended as safe by the World Health Organization (WHO). The same testing showed that the water contained fluoride concentration of between 3.540 mg/L and 4.353 mg/L way above the recommended WHO drinking water quality guideline of 1.5 mg/L (CLE and GIZ, 2012). Hollinger and Staatz (2015) documented that despite migration, rural populations continue to increase. Moreover, rural population is concentrated in terms of population per unit area whereby 16% of the rural population lives on 1% of the available rural space, and 51% lives on 10% of the rural space. As a result, rural population growth increases the pressure on land and natural resources and contributes to land fragmentation, especially in high-potential, densely populated areas with good market access. Since the reserves of unutilized land suitable for agricultural production are limited in West Africa and specifically in Mali, land conversion from forest or rangelands leads to increasing environmental cost and conflicts (Hollinger and Staatz, 2015). The effects of gold mining on environment and socio-economic pathways have been heightened by two sectors i.e. the industrial sector, in which companies resort to industrial mining methods and were supposed to be signatories to the Extractive Industries Transparency Initiatives (EITI), and artisanal sector, in which people in tens of thousands seek to exploit often in an environment free from regulation (MEA, 2008). All these coupled with limited legislations, policies and the poor assessment of the impacts of artisanal gold mining on the agricultural activities and the sustainability of the environmental is the motivation behind this study.

1.2 Statement of the Problem

Agriculture is the highest contributor to the Gross Domestic Products (GDP) in Sub-Saharan Africa countries. The majority of Africa Sub-Saharan people depend on agriculture for their livelihoods. The rate of Malian economic growth as at 2013 stood at 1.7% against a projected figure of 5.1%. This recession was as a result of a decrease in agricultural production and land degradation. The youth and women, who constituted the agricultural productivity workforce and manpower, joined gold mining activities because of the perception that the latter fetches more pay and easily. In spite of these observations, data and information on the impacts of artisanal gold mining on agriculture in Mali is limited and totally non-existent for Sikasso Region. Further, it has been demonstrated that mining workers suffer from health and associated occupational risks due to exposure to pollutants from the artisanal gold mining activities. Additionally, natural resources such as water, land and forests have been destroyed in mining zones a situation that make the local communities vulnerable to food insecurity. The paucity of the data and information on the aforementioned issues and the need to create sustainable economic activities carried out by a health population is the thrust behind this study.

1.3 Objectives

1.3.1 Broad Objective

The broad objective was to assess the environmental and socio-economic impacts of artisanal gold mining on agricultural production in Sikasso region and its overall impact on environmental and food security in the region.

1.3.2 Specific Objectives

i. To determine the socio-economic factors that influence households to engage in artisanal gold mining in Tangandougou commune.

ii. To assess the physico-chemical parameters of water quality of Sankarani River and tributaries in Sikasso region.
iii. To evaluate the impacts of artisanal gold mining on crops and livestock productivity in study area.
iv. To assess the different sources of households' incomes in the study area.

1.4 Research Questions

i. What are the socio-economic factors influence households engaged in mining in the study area?
ii. How does artisanal gold mining influence surface and ground water quality of surface waters in the study area?
iii. How artisanal gold mining does affects crops and livestock production in Sikasso region?
iv. What are the different income sources for households in study area?

1.5 Justification of the Study

The study was undertaken in line with the Malian government agriculture policy which is focused on four pillars: agricultural production yields improvement; environment protection and management; farmers' organization and revenues improvement; and climate change effects management in agriculture sectors (MRD, 2013; LOA, 2006). Additionally, the study subscribes to the United States Agency for International Development (USAID) policy under the program of *"feed the future"* of Mali. The study findings will contribute to the "Core Strategic Solutions" especially, to increasing household incomes; access to the consumption; provide an enabling environment for agricultural production for a prosperous nation (USAID, 2013).

The significance of this study on the environmental parameters and agricultural production in Mali cannot be understated. It provides insights into the impacts of artisanal gold mining activities on the agricultural sector which forms the backbone of not only Malian people but also most of the Sub-Saharan Africa countries. For instance, the real rate of Malian economic growth in 2013 was 1.7% against a projected figure of 5.1%. Furthermore, the share of the primary sector in 2013 was -7.3%, a huge variation from the 8.6% in 2012. This could be attributed to the transfer of the workforce and manpower from agriculture to artisanal gold mining leading to a decrease of agricultural production.

Combined with limited and unreliable rainfall and lack of manpower, the agricultural production in Mali has in the last one decade decreased drastically especially, in the sector of cereal crops and livestock. The Sikasso region was the best land for agriculture production because of fertile soil and good agricultural climate. However, the presence of artisanal gold mining activities within the same region, has slowly replaced agriculture as more households in Mali have been attracted to it due to the perception that the returns are high and fast as compared with agriculture thus abandoning farming.

Artisanal gold mining has negative implications on physical environment as it causes land degradation leading to reduced agricultural production, consequently contributing to poverty and food insecurity. Artisanal gold mining is less sustainable, and therefore there is need to look for others sustainable development activities like livestock and cereal crop farming which would ensure food security by increasing household incomes, reduce malnutrition and poverty.

Analysis of the main agricultural sectors within Mali (fisheries, crops and livestock production) could yield results which could be used to create awareness on implications of artisanal gold mining to rural population. It would also be possible to estimate the agricultural sector losses such as land cultivable surface, livestock pasture and fisheries. The socio-economic losses obtained from the estimates would be important in assessing financial strategic resources for agricultural production growth and its diversification which would assist in improving the income of rural populations. Further, the study findings contribute to the achievement of Sustainable Development Goals through the food, water and environmental security.

1.6 Scope of the Study

This study was carried out in Sikasso region in Mali and was conducted within a period of nine months. Sikasso region is the third administrative region of Mali, characterized by both agricultural and artisanal gold mining activities. The study concentrated on the villages of Farabacoura (where artisanal gold mining activity takes place) and Tieguecourouni (where there are no mining activities with only agricultural activities) in Tangandougou Commune for comparisons. The study was conducted within a $20km^2$ area. The study focused on the socioeconomic attributes of sampled households as well as the impacts of artisanal gold mining on livestock and crop farming. It was also limited to physico-chemical water quality parameters for surface waters within the study area.

1.7 Limitations and Assumptions

The period of data collection coincided with the raining season which made the initial process of sampling difficult. It was also difficult to collect data on the second site as it was planned, because of inter-clan conflicts in Machoko over natural resources pitting local communities against each other. However, the study rescheduled the interview period and made prior calls to the respondents through the local government officials to secure their availability. The conflict that impacted on region of Machoko was substituted with another site within Tangandougou in Sikasso region. Some of the respondents selected could not recall well and they lacked data and supporting information about the impacts of artisanal mining activities on agriculture. The study assumed that the observed effects on the physical environment that included water sources, forests and the agricultural production ranging from crops and livestock in Sikasso region of Mali was due to artisanal gold mining activities. The study also assumed that the impacts on these entities were mainly due to artisanal gold mining and that all other factors such as climate change, political issues and culture had minimal insignificant effect.

1.8 Operational Definition of Key Terms

Agriculture - is an activity of production which occupied population on cropping, fishing, livestock, hunting and picking. It is also an industrial activity of production destiny to be commercialized. It can take the form of industrial farming, family farming and community farming. They used their workforces to produce food for livelihood, commerce and others purposes.

Agroforestry - is an agricultural activity related to forests development, restoration and their ecosystem services so as to form a functional unit with the socio-system.

Artisanal gold mining - is a single gold mining unit operation without advanced methods, materials and technologies. It is free from formal regulations in term of exploitation and mostly the land ownership is undertaken comminatory or government.

Biological environment - it is related to the interrelationships between living and non-living species as functional units in their environment. It is refers to vegetables, animals and aquatic species and their environment.

Climate change - it is a phenomenon pathway of causes and effects induced naturally or anthropogenic activities related to the evolution of global temperature of earth.

Crops production - it is an agricultural activity of cereals and vegetables production through rainfall or irrigation technologies system.

Externality - is the impacts or effects which are not integrated in the global process of production. It can be positive, negative or mix.

Fisheries - are an agricultural activity related to natural resources exploitation or development. It refers to aquatic ecosystem linked to fish production.

Food security - as a system in which, people are capable to produce, supply, access and utilize food for their life. They have to guarantee stability of food by adaptation to climate change; individuals ability to purchase it in sufficient and quality; and the use of food against malnutrition which could make people vulnerable to diseases.

Human environment - related to socio-economic interrelationships between humans as functional units in society. It is concentrated on human being interconnection.

Impacts - are a long term changes that artisanal gold mining activity induced on water sources, fishing, agroforestry, land, crops and livestock production.

Integrated sustainable agriculture - is a system of agricultural production based on natural resources, society and economic production the way forward agriculture sustainability. It considers land and water as fundamental natural resources for crops and livestock production system so as to ensure food security and nutrition.

Land property right - is an ownership attributed to public, communities or private related to land and natural resources exploitation and management.

Livestock production - is an agricultural activity of animals' production. It refers to extension, intensive and sample keeping as a system of animal production.

Mining - is activity of minerals extraction from earth with different methods. It concerns industrial resort, small-scale, and artisanal gold mining exploitation.

Natural resources - it refers to all resources naturally available to maintain the global ecosystem unit. They are two types of natural resources, those can be renewable and those cannot be renewable.

Physical environment - is environment which includes physical aspects such as earth, mountains, rivers and surfaces. It also refers to environment in which society exploited resources for their lives and the interaction between environment and society.

Production – the output based on the input from crops and livestock activities as an agricultural system.

Productivity – is global factors that facilitate agricultural production.

Risk - it refers to artisanal gold mining likelihood and the severity on environment and agricultural productivity.

Social change - is a phenomenon related to the causes and effects linked to the evolution of human societies. It is social effects which can humans' behavior and thinking.

Sustainable Development - as a process in which, people or communities are involved to attempt their wellbeing. It is also the development which integrated presence and future concerns of the system theory in production.

Traditional environmental knowledge - is a local knowledge of communities about environment evolution surrounding them or at local, national, sub-regional and regional.

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CHAPTER TWO
LITERATURE REVIEW

2.1. Environmental Policy and Institutional Framework in Mali

Management of the environment in Mali is governed by the Ministry of Environment and Restoration following the ordinance Number 98-027/P-RM of 25 August 1998, which fixed the different missions of DNACPN and the executive order Number 99-189/P-RM of 05 July 1999 instituted the procedure of environmental impact assessment (EIA) in Mali. This institution works in line with the agency of environment and sustainable development for further research linked to environment. The DNACPN is mandated to manage and make a follow up, monitoring and control of all pollution matter. This institution is the connection department between different Ministries for all purposes of environment and pollutants which include transportation of dangerous products.

2.2. Legal Instruments for Environmental Management in Mali

Environmental Impacts Assessment was instituted in Mali by enactment No 99-189/P-RM July 5th 1999 with was aborted and replaced by the enactment No 03-594 of December 31st 2003 through the rules and procedures related to environmental impacts assessment execution in all the Malian territory. The enactment was meant to evaluate all the mitigations and bonus impacts of all projects on natural and human environments. In addition, the social parameter was incorporated in the process of EIA with the enactment No 346 PRM of June 26th 2008. Since EIA became the environmental and social impacts assessment in Mali. It was stated that anybody can execute a project of category B without environmental permit in Mali. This obligation referee to the environmental permit was one of the significant rules cited in mining code of 1999.

2.3. Mining Policy and Institutional Framework in Mali

Mining in Mali is governed by the ministry of Mining and Petroleum through the National Direction of Geology and Mining (DNGM) with the order Number 02-583/P-RM of 20 December 2002, which describes the services and duties of DNGM. The mining and petroleum activities are all managed by DNGM through the ministry in concerned for all purposes including management, supervision, licensing and administration. However, it is mandated to work in close collaboration with the DNACPN on matters of social and environmental effects, impacts and pollution from mining and petroleum exploration research or exploitation across the country so as to prevent environmental and social disasters. The principal policy of mining is the code and it was reviewed to conform to the economic community of West African countries code established since 2003.

2.4.Agricultural Development Policy Framework in Mali

The agricultural development policy in Mali mainly focuses on four fundamental documents the "Cadre Strategique pour la Croissance et la Reduction de la Pauvrete" (CSCRP) as a policy which provided public investment planning by promoting economic growth and poverty reduction. The "Loi d'Orientation Agricole" (LOA), was envisaged with the establishment of a long-term vision for the agricultural sectors through sustainability and modernization of agricultural sectors based on small farming. The "Strategie Nationale de Securite Alimentaire" (SNSA), as one of main policy, was based on long-term vision of sustainable food security. It established a set of tools to deal with transitory food crises in Mali. The "Plan National d'Investissement du Sesteur Agricole" (PNISA), aimed at moving forward the strategic investment in value chains of rice, maize, millet, sorghum, fishing and livestock products. It also encompassed the dissemination of information on nutrition education system throughout the country (USAID, 2011). However with all these strategies, policies and frameworks in place, the country still currently faces food insecurity. This calls for the creation and generation of data and information to counter the impacts of the artisanal gold mining on the agricultural sector to enhance agricultural production, food security, health population, continued mineral exploitation and improved living standards in an environmentally sustainable manner.

2.5. Historical Crises

World Commission on Environment and Development (WCED) (1987) documented human activities and their impacts on the planet. For example, the impacts were grouped broadly by areas of concern including environment, economics and social pathways. By doing so, the impacts were neatly compartmentalized within nations and by sectors such as energy, agriculture, trade, extractive industries and many others. In the micro-areas where there are many others specific activities which escaped scientists' analysis like the artisanal gold mining impacts on agricultural productivity ought to be captured. This is because the environmental, economic and social crises are not separate crises; they are all one as a functional unit (WCED, 1987) and need to be addressed as one unit.

The planet earth has experienced unprecedented growth and change in terms of development and human population. However, this dramatic growth and fundamental change has been occurring at an increasingly higher rate due to the impacts of human activities. This growth can be related to the economic activities especially, the industrial production since 1950 (WCED, 1987). Nowadays, artisanal gold mining (AGM) were contributed to this fundamental change. Unfortunately the increase in the earthly changes would occur more than 90% in the poorest countries, and this growth has already overwhelmed most cities particularly within the Sub-Saharan Africa region. The effects of this growth are already being felt in many countries and the poor are the worst hit because of the limited cushioning strategies (Musah-Surugu *et al.*, 2017).

2.6. Gold Mining and the Physical Environment

Environment and socio-economic impacts of mining are depended on factors such as type of minerals extracted, technology and methods used, extraction, project location and geological structures. Furthermore, gold mining affects the physical environment directly or indirectly. The direct effects are linked to prospecting, exploration, site development, ore extraction, refining and transportation. The indirect effects are related to infrastructure development to mining sites such as energy, related services like roads and settlements on site. Kitula (2005) reported that, in Tanzania mining had a number of common stages or activities, each of which has potentially-adverse impacts on the natural environment, society and cultural heritage, the health and safety of mine workers and communities based in close proximity to operations. Therefore, before any form of mining, be it large scale or small scale is allowed to commence, the all impacts need to be predicted. The positive impacts need to be enhanced whereas the negatives need to be mitigated for sustainable development to be realized.

According to Aragon and Rud (2013), pollution arising from mining can affect agricultural productivity through crops health deterioration and leaf tissue injury or plant growth. This is through the direct impact of mining and pollution on agricultural production and the indirect impact through its effects on the quality of inputs such as land and labor.

As pertains to land use on artisanal gold mining, the habitat destruction is one of the key environmental effects. Mining has various effects on land which results to deforestation, soil erosion, land degradation and ecosystem disruption. Surface mining causes direct impact on land through mine excavations, processing plants, water and savage treatment plants, refuse disposal sites, power line access ways and access road (ACET, 2013).

The use of mercury and cyanide to extract gold from sediments can also contaminate soils and both surface and underground water. For example, the case of tropical regions has been documented that even though only traces of Hg (I) persists in soils and sediments it can be methylated by abiotic and microbial processes in soil systems and is the primary source of methylmercury compounds in soil (Isahak *et al.*, 2013). The type of mining extraction in Mali is mostly open-pit which has highest risks of soil and water contamination, especially during the rainfall season. Hence, chemical products such as cyanide and mercury should be monitored regularly so as to prevent soils contamination and water pollution and thus protect human health.

The forests that were initially replete with habitat of several faunal and floral species are currently on a rapid decline due to forests destruction by artisanal gold mining. The destruction of forests in artisanal gold mining begins during the mining exploration stage with a continuous installation and minerals extraction. According to Isahak *et al.,* (2013), the concessions are granted to the mining companies which are the common practices in this area. These concessions have little regard to the benefits derived from biodiversity within the affected ecosystems.

According to ACET (2013), in Africa, the extractive industry is the second biggest user of water after agro-industry. The industry competes with agriculture for surface and groundwater. Generally, the water sources are contaminated with residue deposits, watering during the mining operation, flooding of closed voids and discharge of untreated mining water. As a result, these sources of pollution cause rivers and backwaters contamination through erosion during the rainfall season. Consequently, aquatic organisms including fish in these rivers and backwaters are slowly being affected by heavy metals in terms of their growth, survival and reproduction. Indeed, the fishermen's hamlets which were set downstream to the mining zones undergo the direct consequences of the rivers' water contamination.

Aragon and Rud (2013), acknowledged that the pollutants in both surface and groundwater near Tarkwa in Ghana by heavy metal pollution decreased with distance from mining sites and that high levels of mercury and zinc were found in the topsoil in Wassa west in Ghana. This shows that the entries of the contaminants into the environment can bioaccumulate and bioconcentrate leading to adverse effects on both aquatic and terrestrial organisms.

Most of the available literature on the physical environment is generally focused on the environmental and social impacts assessment (ESIA) analysis. The issues of the ESIA are also emphasized in many studies. Mostly, the impacts of artisanal gold mining have received less attention from critics of ESIA (ACET, 2013; Actionaid, 2006; Isahak *et al*., 2013; Kitula, 2005).

The physical environment is an important component in agricultural production. Once agricultural land gets negatively impacted, the quality and quantity of foods produced decline and consequently increased likelihood of food insecurity in the region or country. Therefore, this research assessed the impacts of artisanal gold mining activities on the agricultural production and the connection to the health of the populations and the sustainability of the environment in the Sikasso region of Mali.

2.7. Gold Mining and Agricultural Development

According to Actionaid (2006), expansive fields of land in Obuasi previously used for cultivation are believed to have been contaminated through artisanal gold mining activities and toxic water pollution. This is undermining poor peoples' food security and right to food. The cultivation of fruit and vegetables – such as local crops, including 'Obuasi oranges' – on polluted land poses a risk to peoples' health and prevents them from selling their produce in local markets. This indicates people perceptions on artisanal gold mining impacts on local food supplies and the general health status and conditions not only in Obuasi, but also in Sikasso and Mali in general. Mining activities leads to reduction of food production in their communities due to conversion of the agricultural fields and the migration of productive labor force to the mining activities from the agricultural sites (Actionaid, 2006).

Apart from crop farming, livestock production was expanded in Mali as the meat production was increased from 7,000 ton in 1961 to about 25,000 ton in 2005. During this period the number of heads of cattle and goats tripled (Aune, 2008) making livestock one of the significant sectors of agriculture in Mali. From North, Central to the Southern part of Mali cattle-breeders moved with their livestock for transhumance between Mauritania, Burkina Faso, Cote d'Ivoire and Guinea, on their ways, while utilizing grazing pasture and water from rivers, lakes and backwaters across the territory to feed animals.

Chemicals used in artisanal gold mining in Africa have been compounded by certain aspects like socio-political factors. In fact, the risk assessment of impacts on human health is still difficult. The most significant factors that make the risk assessment exercise difficult is the general lack of data and information and accessibility to the information of mining (Isahak, *et al*., 2013).

Artisanal gold mining normally employs cyanide and mercury to extract gold from sediment. These chemicals are toxic to the environment and human health. Isahak *et al.,* (2013) reported that, the organic mercury compounds are more toxic than elemental mercury. Methyl-mercury is highly bio-accumulative and increases along a food chain.

The impacts of poisoning from artisanal mining can be widespread with mining's wastes when the raining water over flows. For example, this case was observed in Ghana (Isahak, *et al.*, 2013) and Gunung Pongkor in Indonesia (Rahman *et al*., 2014). The probability risk of contamination is highest through consumption of water in rural areas. For example, in Mali the major mining camps are not far from rivers and backwaters which increase the risk of contamination as rural people tend to use the same water for household activities such as drinking, showering, fishing and farming.

According to Zango *et al.*, (2013), the absorption of heavy metals in low doses by humans over a long period of time through food was showed to result to serious health consequences, which leads to decline in economic development in terms of low productivity as well as direct costs of treating illnesses. For example, the health implication of heavy metals in humans includes kidney disease, damage to the nervous system, diminished intellectual capacity, heart disease, gastrointestinal diseases, etc.

Literature on artisanal gold mining impacts on agriculture sector was mostly about soil contamination with heavy metals such as cyanide and mercury, which were also critical to the food production, fruits and vegetables cultivation. Moreover, the climate change was the new phenomenon which was aggravated Sahel's countries vulnerability such as Mali (Actionaid, 2006; Aune, 2008). The cyanide and mercury used to extract minerals both in industrial gold mining and artisanal was emphasized in the human health studies (Isahak, *et al.*, 2013; Rahman *et al*., 2014; Zango, *et al*., 2013). Indeed, the methyl-mercury was bio-accumulative and increased along the food chain. Malian society know the negative implication of chemicals used in mining but more research of depth analysis need to be done to ascertain link between artisanal gold mining and its impacts on agriculture.

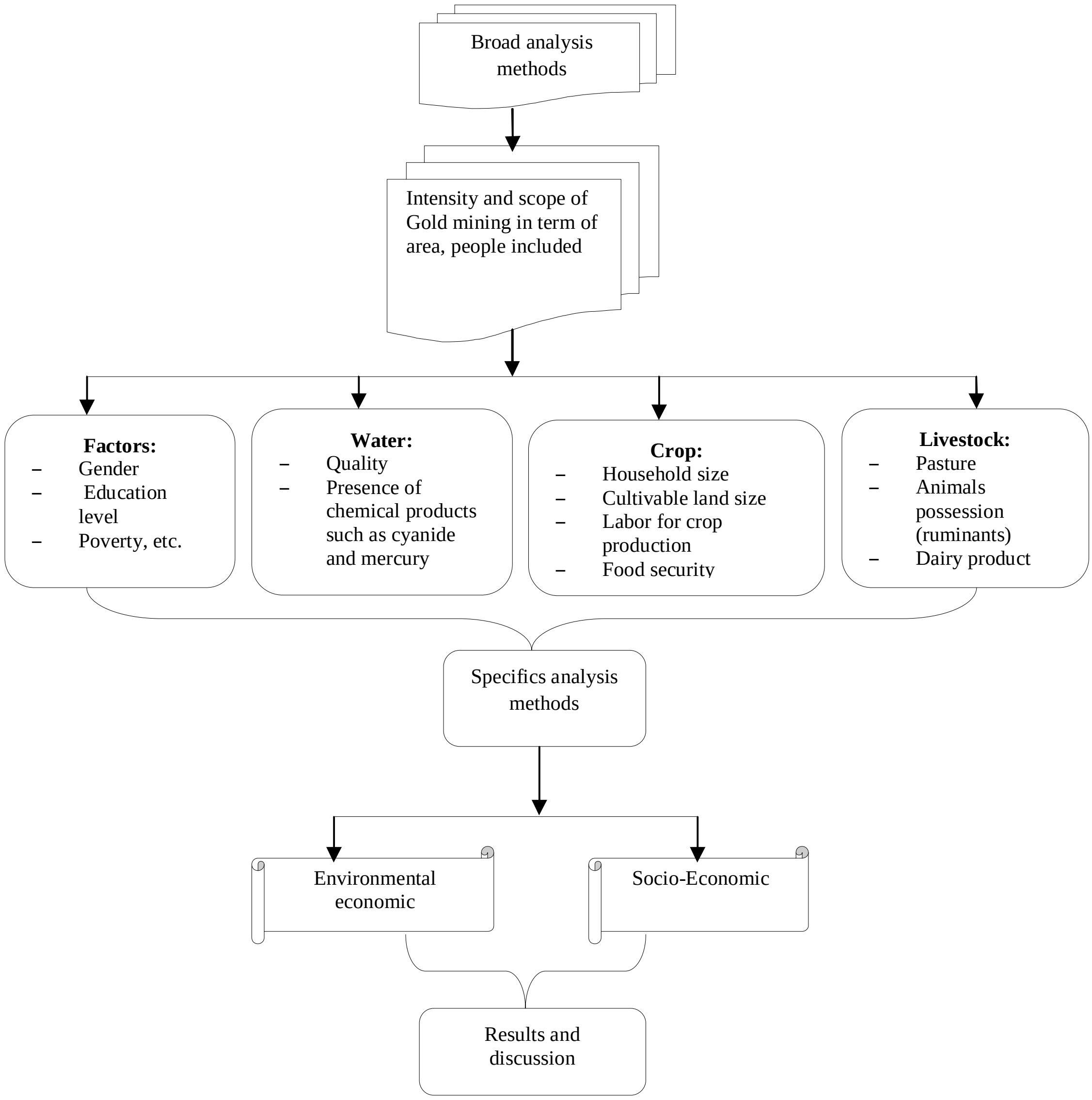

Figure 2.1: Flow Diagram of the Research Process

2.8. Theoretical Framework

Philosophically, the system theory stands for ecosystem and socio-system in term of entities relationships. The ecosystem has to ensure interacting functional unit in living and non-living environment while socio-system refers to humans' functional unit exploiting resources for their live (Abdelrehim *et al.*, 2011). An imbalance between entities in their functional units will drive to climate change in environment, society and economic activities. The imbalances of entities will impact sustainable development logical process to be realized in multidimensional context. The approach is focusing on the system model of Drivers-Pressures-State-Exposure-Effects-Actions (DPSEEA) inspired from Drivers, Pressures, State, Impacts, Responses (DPSIR) as defined by Abdelrehim *et al.,* (2011) and Innuacci *et al.,* (2011).

The statement of socio-system that "to preserve and improve the quality of human life" was only of interest the fact human pursues this aim. In doing so, they would interact with the ecosystem pathways. The ecosystem would be influenced by such interaction and a certain threshold would be attained. As a matter of fact, the ecosystem would modify its configuration as a functional unit. The modification of the ecosystem state has impacts on the functional unit which could be irreversible or not for all the systems. The irreversibility of the impacts would depend on the ecosystem resilience capacity and humans responses to resolve its. According to Iannucci *et al*., (2011), the systems theory, assumed to be the foundation of DPSIR, requires the ecosystem and its interactions with the humans to be modeled in terms of (block diagram) including transfer functions and feedback loops as shown below.

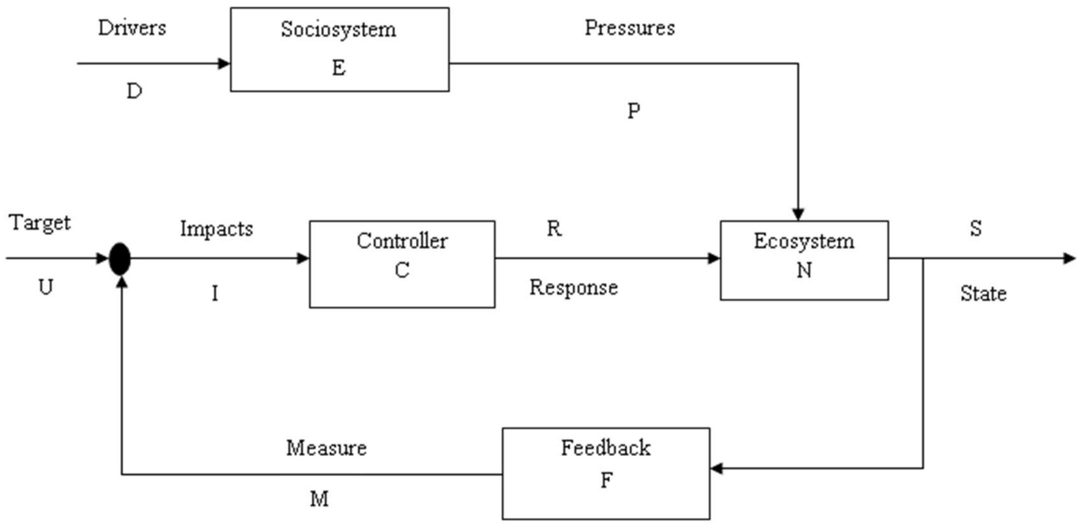

Figure 2.2: The DPSIR Components
Source: Iannucci *et al*. (2011)

Artisanal gold mining in Mali could impact negatively on two important sectors namely the physical environment and agricultural productivity through lands and water sources contamination with chemical products, fall in crop and livestock production reduced household income and increased risk of food insecurity. In addition, factors such as poverty, education level, climate change, weak policies, population growth and insufficiency of information can exacerbate the negative impacts of artisanal gold mining on water sources, fishing, agroforestry, crops and livestock production system.

The aim of this study was to investigate the impacts of artisanal gold mining based on the systems theory. The artisanal gold mining pressured on the ecosystem through water sources, fishing, agroforestry and land degradation. Consequently, it influenced agricultural productivity in terms of impacts with association of intervening variables such as climate change, rarity of rainfall, weak policy and population growth. The block diagram shown below describes theoretically the DPSIR application in this study.

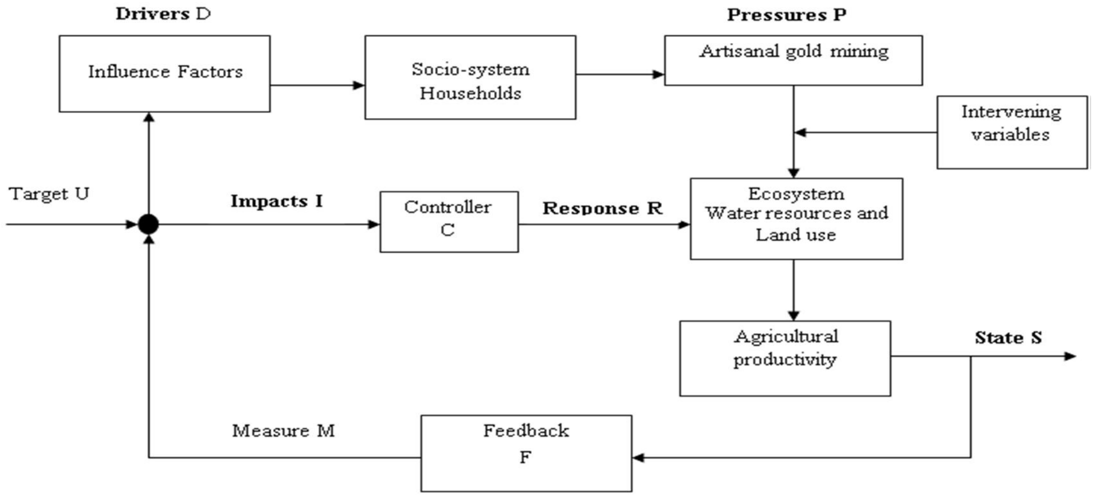

Figure 2.3: DPSIR of the Study

The study focused theoretically on three types of variables and factors that influence households to be engaged in mining. In practice, the study found out information about independent variable which was artisanal gold mining activity and it impacts on agricultural productivity as dependent variable. Therefore, the study collected data on influences of households' engagement in mining, water quality, and crop and livestock production system. Unfortunately, the intervening variables were out of scope of study, only they were taken into consideration from secondary data.

2.9. Conceptual Framework

The conceptual framework below gives a description of the interdependence of variables.

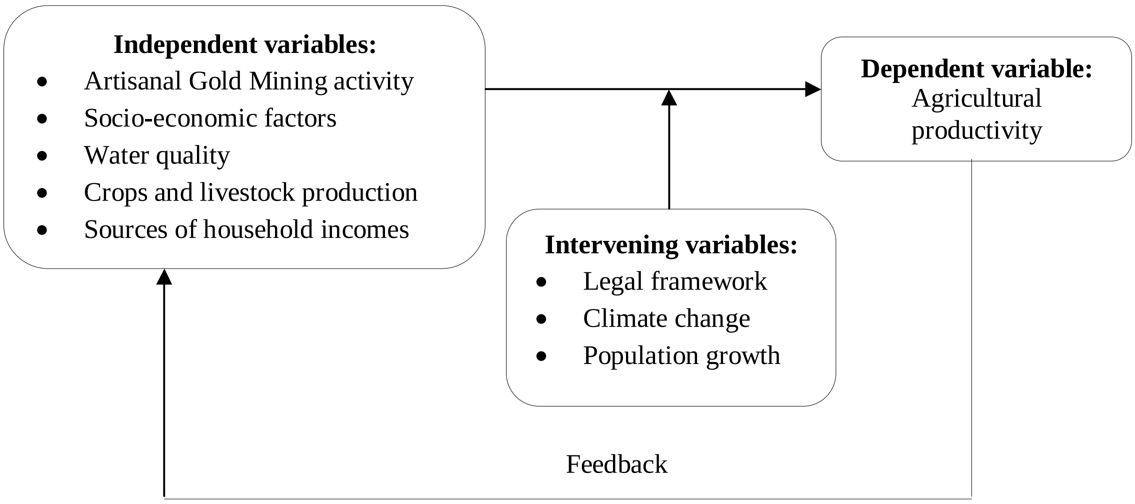

Figure 2.4: Conceptual Framework showing the relationships among the independent, intervening and dependent variables.

Land ownership and rights influences land use and land degradation in many Sub-Saharan African countries. Natural resources that are communally owned are characterized by open access, uncontrolled and unregulated use, overexploitation, and eventual collapse of the resource base. Property rights embedded in the national and local legal frameworks further influence the types of land uses practiced in an area, which in turn have a strong bearing on human and environmental health. Thus, environmental degradation can in part be attributed to land ownership and use rights. In addition, the influence of land ownership is barrier to agricultural development through limited local's exploitation. Furthermore, those who are able to exploit land for agricultural purposes are limited by access to land. The system theory could assist national government and local people to avoid conflicts over land use. The integrated sustainable agriculture is based on general systems theory (Mele *et al.*, 2010; Boulding, 1956). It focuses on the drivers, pressure, state, exposure, effect and action (DPSEEA) framework (Abdelrehim *et al.,* 2011) including land, water, livestock, crops, environment and socio-economics pathways to advance the development of Integrated System of Sustainable Agriculture.

2.10. The Opportunities Framework

The opportunities framework is an improvement of the DPSIR approach. Therefore, it includes an inclination towards the opportunities that the environment provides for sustainable development. This approach looks at the potential opportunities for reducing poverty and promoting sustainable livelihoods. Generally, it focuses on inventory of existing resources and looking at trends in the recent past at local, national, sub-regional and regional in term of interests by explaining why the observed trends have occurred (Abdelrehim *et al.,* 2011).

2.11. Strategy for Sustainable Agriculture

The strategy is focuses on natural resources development. Land and water can be used like a natural property given by nature under ecosystem and socio-system functional unit. These require improvement and protection because of their renewable aspects. In specific case, land and water should be exploited by youth and women for crops, livestock and agroforestry production within integrated unit functionality. These units could be organized throughout natural resources as a unit, food security and nutrition as a unit and climate change factors as a unit.

2.12. Land Conservation and Protection

Land protection system should be focused on identification and ownership endorsed by government and the local authorities. For example, the identification of land could be done based on the interest of various sectors and programed in term of short, medium and long term vision of exploitation. Geographically, it is possible to partition land exploitation to different sectors such as agriculture, mining, agroforest, rivers and so on. In doing so, the government has to certify all attribution to owners and it could be part of partners in term of foreigners' investment for land use.

2.13. Rainfall Water Conservation for Proximity Irrigation

Water conservation efforts should be concentrated towards rainfall water collection through domestic and small-bridge pathways toward proximity irrigation in rural areas (Mastrorilli and Zucaro, 2016). Both domestic and small-bridge requires simple technology to create water pans or basin of retention. Water collected in the pans and basins can serve multiple purposes including irrigation of the vegetables crop, livestock production and also domestic purposes. This therefore will be a major innovation in term of water conservation and management for households in rural areas. It is significant to move forward on that application because this system contributes towards combating food, malnutrition and environmental insecurities of vulnerable populations.

2.14. Food Security and Nutrition

The food security and nutrition system has to be organized along livestock production, especially cattle, sheep and goats' production in rural areas. It will have an integrated system ranging from maize, sorghum, bean and other herbs production for animal feed. The integrated system will contribute to increased meat production and consumption in rural areas (Bell *et al.*, 2013). It will lead to innovated meat commercialization methods and mechanisms through the establishment of modern butcheries at proximity of population.

2.15. Climate Change

The climate change pathway is focused on adaptation and resilience technologies undertaken in agricultural production system. Nowadays, lands have become poor in terms of soil nutrients due to anthropogenic effects such as deforestation and forests degradation. These anthropogenic effects have an impact on ecosystem and socio-system. Therefore, farm practices should be concentrated on adaptation and mitigation.

Adaptation requires adjustment of environment, social and economic pathways so as to minimize the effects of climate change on ecosystems and socio-systems. Therefore, it has to take into account vulnerability, resilience, adaptive capacities and risk faced due to the effects of climate change. Basically, it may focus on strategy of anticipatory and reactive adaptation methods. For example, the farmers have to change practices by including mitigation in case of rarity of rainfall or dry-spell, especially in developing countries. They should provide rainfall water collection for proximity irrigation purposes.

Mitigation requires efforts to reduce and prevent the emission of Greenhouse Gases (GHGs) or to enhance their removal from atmosphere. For example, making older equipment energy efficient, avoid new emission and enhance natural reservoirs or carbon sinks of GHGs by protecting them. It has also to promote the growing of crops such as Cassava to absorb GHGs and in turn to contribute to ensure food security.

Step 1: communities by practiced different activities, especially in rural areas have cumulated a lot of experiences about environmental changes. These experiences are tremendous knowledges which have to be combined with classic knowledges to come out with the issues of relationship between ecosystem and socio-system (figure 12).

Step 2: the interconnection between ecosystem and socio-system has to work as a functional unit. They cannot be treated separately towards environmental issues.

Step 3: the development of natural resources have to contribute for food security and enhance climate change effects on small-scale farming through research development.

Step 4: the research development is focused on land use, rainfall water conservation, livestock and crops production, agroforestry and socio-economic parameters. These components are interconnected for consistent proposal of integrated system.

Step 5: there are three major potential interventions to be taken under the integrated system for sustainable agriculture. The proximity irrigation has to be done from rainfall water conservation so as to develop vegetables crops. Both ruminants and cereals crop production are intervened for beef and food security. So that combination of production requires farming system adaptation to other parameters of climate.

Step 6: this is the last issues of the system, either the problem is resolved or not. So when the problem is not resolved there three options to be taken, the first is to check on traditional knowledge process, the second is to verify also the scientific knowledge and the third is to revise the research development process so as to check the ways forward.

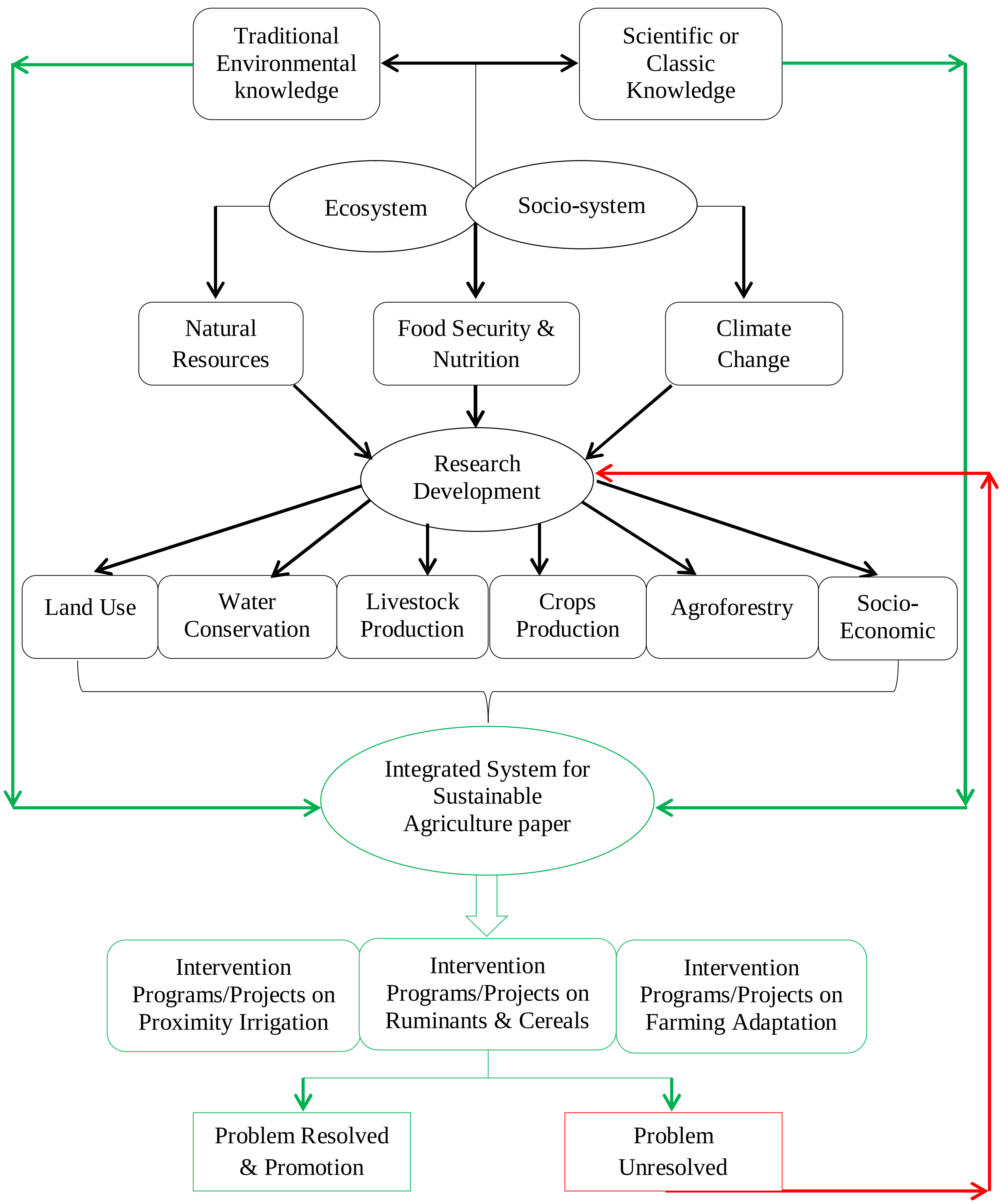

Figure 2.5: Integrated System for Sustainable Agriculture (ISSA)

Source: Keita, 2018

2.17 Mining Processes

2.17.1 Artisanal Gold Mining Processes

In most cases the techniques used for artisanal gold mining over the world are identical. The miners' community adapts the existing techniques to their specific context and environment of exploitation. The artisanal gold mining process consists of digging an open pit at exploration levels on site. The depth of the open pit depends on the depth of the gold bearing gravel. The mean depth of open pit is 2m in Mali.

The open pits are constantly filled by water as miners dig, especially during the rainy season. Motorized pumps are used to drain out this water. During the rainy season water is always a major problem for miners. Once the gravel level is reached, a portion of land is cleared and the gravel removed is deposited in heaps. The washing process includes a wooden box of 1.5m as larger and a wool carpet is put inside to trap gold particles. A mesh is placed inside the box to retain large stones and pieces of wood (photo 1). The gravel is put inside the box and water is pumped with a motorized pump into the sand. Water drains down the sand and the wooden riffles that had been earlier placed on its route, while the carpet and the riffles trap the gold particles.

2.17.2 Industrial Gold Mining Processes

Industrial gold mining refers to the processes required to extract gold from its ores. This requires a combination of mineral processing, hydrometallurgical and pyro-metallurgical processes to be performed on the ore. Gold mining from alluvium ores was once achieved by techniques associated with placer mining such as simple gold panning and sluicing, resulting in direct recovery of small gold nuggets and flakes. Hydraulic mining involves the breaking down of alluvial deposits with high-pressure jets of water. Once the ore is mined it can be treated as a whole ore using a dump or heap leaching processes. Normally, the ore is crushed and agglomerated prior to heap leaching. High grade ores and ores resistant to cyanide leaching at coarse particle sizes require further processing in order to recover the gold values. The processing techniques can include grinding, concentration, roasting, and pressure oxidation prior to cyanidation.

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CHAPTER THREE

METHODOLOGY

3.1 Description of Study Area

Sikasso region is located in the Southern part of Mali and it is also the third biggest administrative region of the country (Figure 3.1). It borders Segou region to the North, Republic of Cote d'Ivoire in the South, Republic of Guinea to the West, Burkina Faso to the East and Koulikoro region to the North West. Sikasso region covers 71.790 km^2 representing 3.8% of national territory. The region has 7 districts which include Sikasso, Bougouni, Kadiolo, Kolondièba, Koutiala, Yanfolila and Yorosso. In Sikasso region, there are 3 urban communes, 144 rural communes and 1.831 villages (ARS, 2011).

Farabacoura and Tiéguècourouni are villages in Tangandougou commune, district of Yanfolila in Sikasso region. Tangandougou commune is some 170 km from Bamako, the capital city of Mali. The study sites, Farabacoura are about 10 km from Selingué Dam which is on Sankarani River while Tiéguècourouni is 55 km away from Selingué. The population of the commune is about 5,775 inhabitants (RGPH, 2009). The major ethnic groups of the natives are composed of Bambara, Senufo, Manliké, Bozo and Peulh.

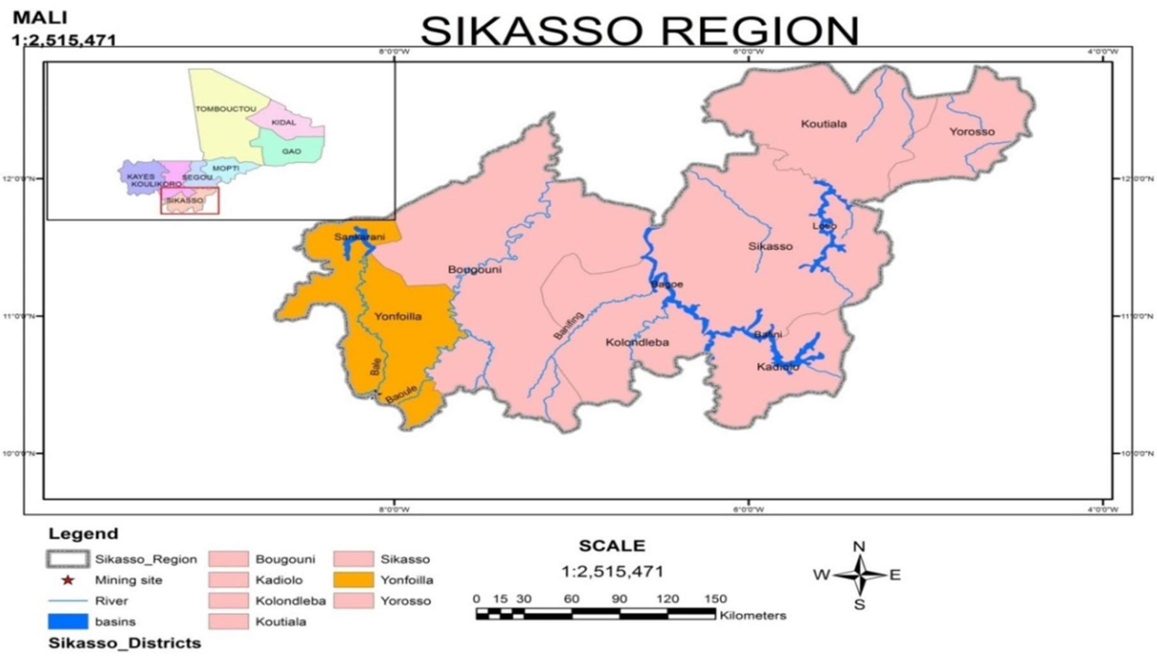

Figure 3.1: Map of the Study Area (Map of Mali Inset)

The economic activities of the commune include crop and livestock production, fishing, agroforestry, commerce and artisanal gold mining. These production systems are characterized by small-scale farming with low agricultural production. In term of cereals production, these small-scale farmers cultivate maize, sorghum and millet for subsistence purposes. The commercial crops include rice, cotton, groundnut and sweet-potatoes.

Livestock production is based both on extensive system for commercial purposes and traditional practices for the provision of households needs and to supply crop production with composting manure and other activities in farm. The main types of livestock reared comprises of cows, goats, sheep, donkeys and chickens. They are only reared for subsistence purposes and for other domestic expenditures such as such as health care and for traditional ceremonies like marriages, burial and other rites of passages.

In terms of forest and environmental management, the natives practice agroforestry activities mainly focused on both indigenous and exotic trees. The exploitation of the indigenous plants such as karité, néré, baobao, *Afzelia africana*, *Khaya senegalensis* and *Prosopis africana* is for food production, precious wood and medicinal purposes. The communities also grow fruits trees such as oranges, mangoes and papaya among others where they supply the local markets with fruits as a source of income apart from supplementing their diets.

Table 3.1: Protected Indigenous Trees Species Observed (+) and Absent (-) in Study Area.

Scientific Name	**Family**	**Local Name**	**Mining Site**	**Non-Mining**
Vitellaria paradoxa	Sapotaceae	Si	+	+
Parkia biglobosa	Fabaceae	Nere	+	+
Adansonia digitata	Malvaceae	Zira or Sira	+	+
Tamarindus indica	Fabaceae	Ntomi or Domi	+	+
Cordyla pinnata	Fabaceae	Dugura	+	+

Acacia Senegal	Fabaceae	Donkori or Patugu	-	+
Acacia albida	Fabaceae	Balanzan	-	-
Elacis guineesis	Arecaceae	N'ten	-	+
Commifora africana	Burseraceae	Barakante	-	-
Spondias monbin	Anacardiaceae	Minkon	-	-
Fagara zantalinioides	Fabaceae	Wo	+	+
Carapa procera	Meliaceae	Kobi	+	+
Detarium senegalense	Fabaceae	Tabacoum ba	+	+

Table 3.2: Partially Protected Indigenous Trees Species in Mali

Scientific Names	**Family**	**Local Name**	**Mining Site**	**Non-Mining**
Afzelia africana	Fabaceae	Lingue	+	+
Anogeisus leiocarpus	Combretaceae	Ngalama	+	+
Bambusa abyssinica	Poaceae	Bo	-	+
Bombax costatum	Malvaceae	Bumu	-	+
Borassus	Arecaceae	Sebe	-	+

aethiopium				
Ceiba pentendra	Bombacaceae	Banan	-	+
Dalbergia melanoxylon	Fabaceae	Kolochiyiri	-	-
Erytrophleum guineense	Fabaceae	N'Tali	-	-
Hyphaene thebaica	Arecaceae	Zimini	-	-
Khaya senegalensis	Meliaceae	Jala or Diala	+	+
Prosopis africana	Fabaceae	Guele	+	+
Pterocarpus erinaceus	Fabaceae	Gweni or Goni	+	+
Raphia sudanica	Arecaceae	Npan or Ban	-	-

Table 3.3: Classified Indigenous Trees Species Grown for Their Economic Values.

Scientific Names	**Family**	**Local Name**	**Mining Site**	**Non-Mining**
Daniella oliveri	Fabaceae	Sanan	+	+
Isoberlinia doka	Fabaceae	Ncho	+	+
Diospyros mespiliformis	Ebenaceae	Sounsounfing	+	+
Mitragyna inermis	Rubiaceae	Dioun	+	+

3.2 Geology

Mali has four agro-climatic zones in term of agricultural production. The Saharan zone, it has 632, 000 km^2 of surfaces about 51% of the Malian territory. The Sahelian has 285,000 km^2 of superficies which occupied 24% of the total territory. The Soudanian, it has 215,000 km^2 of superficies about 19% over total territory. The Soudano-Guinean has 75,000 km^2 surfaces with 6% of the superficies of the Malian territory (Roudier and Quirion, 2009).

The geology of the region called Bougouni Regional Geology is dominated by granitic-gneissis and Birimian greenstone belts. The region is composed of four Birimian belts of rock: the Bagoe, Bougouni-Keikoro, Yanfolila and Kangaba. The Yanfolila is composed of schists and greywackes with quartzites and minor volcanics. The Bagoe as a basin, it is composed of synclinorium along the Bagoe River. The Basin is composed of schists and greywackes and metavolcanics. The Bougouni-Keikoro is composed of thermally metamorphosed rocks and contains andesites. The Kangaba belt has a similar geology of the Yanfolila belt and extending into Guinea (Chirico *et al.*, 2010).

3.3 Climate

Saharian zones receive an average rainfall of not more than 200 mm annually, sahelian zones 200 mm to 600 mm and soudanian zones receive an average between 600 mm to 1000 mm with soudano-guinian zones receiving more than 1000 mm. The rainfall is lowest in the north part of the country and relatively higher in southern part of Mali. For instance, the raining season goes for two months in the two agro-climatic zones of north and five to six months for the two zones of southern part of Mali (Roudier and Quirion, 2009).

The Sikasso region is composed of Sudano and Sudano-Guinean climates where the current study will be focused. It is characterized by the variability of rainfall. The annual rainfall is often more than 1300 mm, especially in the south part zone of the region. The temperature is over 30 c as a maximum all the year. The air humidity is low from January to March with a maximum value of 43 to 53% and minimum of 13 to 17%. The Harmattan is characterized of dry wind during the period April to May. The humidity increases often more than 90% as a maximum value and 60% for minimum value during the period July to October. The rainfall is usually superior to evaporation during the period June to September (Diallo, 2014).

3.4 Research Design

The research design adopted in this study mainly focused on exploratory and descriptive methods basing on ex-post facto with social and ecological survey. The study utilized data from household survey and different reports from various agencies, government offices and NGOs. Exploratory research was used to clarify the definition of the problems and specifics terms. On the other hand, descriptive methods were used to explain statistical information from the data that was collected from the household survey.

3.5 Sampling Procedure

The sampling technique that was employed in this study considered artisanal gold mining as a factor that caused impacts on social economic functions of the natives of Sikasso region. Data was collected by the use of structured questionnaire which were administered through interviewing the households' heads. In each case one representative of the household who was 18 years old and above was interviewed. The sample size was 200 households consisting of respondents drawn from the study area and had some information about artisanal gold mining and impacts on the social economic systems. The questionnaires were administered in Farabacoura and Tieguecourouni villages both in Tangandougou commune, of Yanfolila district.

The respondents were drawn from the two villages equally as follows:

– *The mining site:* Farabacoura village respondents represented the mining site. These respondents were involved in either mining and/or agricultural activities. The information on these activities was collected from an area of approximately 20 km^2.

– *The non-mining site*: as a nearby site of Tieguecourouni village, the study interviewed 100 households by soliciting information about mining and agricultural activities based on study objectives. The distance between the two study villages was approximately 45 km but within the same commune.

The distribution of population within Tangandougou commune is described in Table 1. It describes population by household, gender and rate of annual mean increment according to RGPH (2009).

Table 3.4: Population Distribution in Tangandougou Commune

Sites of data collection	Number of Households	Number of male	Number of Female	Population in 2009	Population in 1998	Increasing rate per annual mean
Tangandougou commune	888	2,913	2,862	5,775	14,101	-7,8

Source: (RGPH, 2009)

The sample for this study was calculated using the Nassiuma (2000) formula indicated here below.

$= \frac{\quad}{[\quad(\quad)\quad]}$ ……………………………………………………………………..Eqn i

Where:

= The sample size

= The known population of Tangandougou commune

= The error margin of (3%)

= The coefficient of variation (30%)

The sample size based on this formula was:

$= \frac{.}{[\,.\quad(\quad)\,.\quad]} \approx 100$ …..Eqn ii

One hundred respondents were randomly selected from each of the two villages.

3.6 Household Survey

A structured questionnaire was administered to the 100 heads of households that were selected randomly. Formal survey of households stratified by gender, youth and aged groups was carried out. Then structured interview was administered for households to explore the various factors underpinning household incomes, water quality, water sources, agroforestry crops and livestock production related to mining activity.

3.7 Participatory Rural Appraisal

The focus group discussions were composed of chiefs, local leaders, administration representatives, men, women and youth who were considered as opinion leaders. The FGDs comprised of 8 individuals drawn from different specialties including the miners, farmers and local government of Tangandougou. These exercises focused mainly on increasing household' incomes, environmental degradation, conflicts of land use, water sources, vulnerabilities and risks of food insecurity and labor displacement from agricultural sectors to artisanal gold mining. The check-list used was in the format of broad thematic to the specific ones. A total of three focus groups discussions were done within Farabacoura and Tieguecourouni community and the staff of Tangandougou commune. This was necessary to complement the information that could not be obtained through questionnaires and from the household level and this information was then analyzed and interpreted.

3.8 Key Informant Interviews

The key informant interviews were carried out to provide information that could clarify the data and results collected through questionnaires and focus group discussions. The key informants were selected based on their experience and expertise in the areas of specializations. Experts from environment, socio-economic and agricultural sectors were interviewed on the impacts of artisanal gold mining in relation to physical environment and agricultural production. To come up with these issues, the checklist and recorder used were to collect data from different specialists in form of an evaluation of impacts of artisanal gold mining on human and environmental health as well as agriculture.

3.9 Observation Checklist

To get clear scenarios of artisanal gold mining state and its associated environmental degradation, an observation check-list was used to gather information on different activities from field. The state of liquid and solid wastes deposit on sites and land degradation were recorded. Furthermore, the photographs were taken from the state of the artisanal gold mining site.

Table 3.5: Summarize of Data Analysis Methods

Objectives	Research questions	Variables	Statistical methods
To determine the socio-economic factors that influence households to engage in artisanal gold-mining in Tangandougou commune.	What are the socio-economic factors influence households engaged in mining in the study area?	• Socio-economic factors	Logistic regression: • Questionnaires
To measure the physico-chemical parameters of water quality of Sankarani River and tributaries in Sikasso region.	How does gold-mining influence surface and ground water quality of surface waters in the study area?	• Water quality	Standards of heavy metals using APHA protocols. • WHO references • Sigma plot • EXCEL
To evaluate the impacts of artisanal gold-mining on crops and livestock productivity in study area.	How does gold-mining affects crops and livestock production in Sikasso region?	• Crops and livestock production	Logistic regression: • Questionnaires • SPSS
To assess the different sources of households' incomes in study area.	What are the different income sources for households in study area?	•	Multiple linear regressions (MLR): • Questionnaires • SPSS

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CHAPTER FOUR

ARTISANAL GOLD MINING AND SOCIO-ECONOMIC PARAMETERS

4.1 Introduction

The most prominent elements of change in the Peruvian lives course has been a dramatic increase in both the pace and scale of mineral exploration and exploitation activities. Following the country's sudden turn to neoliberal economic policies and structural adjustment in the early 1990s, transnational mining corporations have transformed Peru into one of South America's leading exporters of mineral resources. New transnationally based 'mega' mining operations have become some of the largest and most influential landowners and agents of change in regions of the country that have traditionally been plagued by high rates of poverty and unemployment (Bury, 2004).

Mishra and Mishra (2017) reported that, while many economies predominantly depend on mining for their growth and development, implementation of such strategy requires acquisition of large amounts of land leading to changes in its ownership rights and characteristics. This often leads to social conflicts that are generally driven by the socioeconomic and political setup, stakeholders' bargaining power and their perceptive differences about the outcomes of mining at various levels.

Residents of Sikasso region like many people in Mali live on less than one dollar a day, and thus rampant cases of food shortage and malnutrition witnessed in the countryside. Part of those experiencing food shortages are involved in artisanal gold mining in such areas as the Sikasso region. The government's effort to reduce food insecurity through agricultural interventions by sponsoring youth and women, have not born any fruits due to the continued migration from agricultural production activities to artisanal gold mining (LOA, 2006). This has resulted to reduced agricultural productivity due to the dwindling labor involved agricultural activities. Consequently, it has led to food insecurity in these areas. Additionally, artisanal gold mining is one of the human economic activities that leads to the destruction cultivable land, forests, water quality and grazing pasture when open pits collapses, erosion and the use of chemicals used in processing of gold from the ore (Kitula, 2005). Gold mining is an attractive activity which involves household and different communities surrounding mining areas. Funoh (2014) reported the socio-economic impacts of artisanal gold mining on local communities of Cameroon. This case study reveals the development of local market through small business despite the involvement of household by leaving agricultural activities and many others. In addition, the impacts of artisanal gold mining were documented in term of forests destruction, water resources contamination and cultivable lands degradation. In Tanzania, the economic impacts of artisanal gold mining has been studied by Kitula (2005) in terms of source of income for communities. The communities of Goita district in Tanzania were in difficult situation of income sources related to gold mining and agricultural production. The Malian government' is keen on modernizing agriculture through introduction of irrigation technologies and promotion of Agribusiness enterprises which are supportive for crops production, fishing, agroforestry and livestock breeding. The aforementioned interventions are expected to contribute to sustainable agriculture and environmental security. The objective of this chapter is to assess the socio-economic factors that influence households to engage in artisanal gold mining in Sikasso region.

4.2 Materials and Methods

4.2.1 Instruments used for Data Collection

A Structured questionnaire was used for the households' survey. In addition, three Focus Group Discussions with local government of Tangandougou, miners on Farabacoura site and village leaders of Tieguecourouni were used plus key informant interviews and observation check-list. Data collected was analyzed using the SPSS 22.0 and EXCEL version 8.0 software and ArcGIS was used for generation of the study area map.

4.2.2 Methods of Data Collection and Analysis

Data analysis was done using descriptive statistics and other methods like Chi-square, correlation and logit regression model computed with location as dependent variable. Further, a logistic regression was employed to assess the relationships between dependent variables that are categorical and one or many independent variables of any nature (Kleinbaum and Klein, 2010). It was done by using logistic function to estimate probabilities. This function is a cumulative logistic distribution which in turn is symmetric with the mean of zero and a variance of $\pi^2/3$. This formula was defined as follows.

Y_i is called manifest response. It is assumed that there is a continuous random variable Y^* that is unobservable and can take any value. The manifest response, Y_i takes value of one if only the latent variable Y^* exceeds a certain threshold τ, otherwise Y_i takes the value of zero.

$$Y_i = \begin{cases} 1, & \beta_0 + \beta_i x_i + \mu > 0 \\ 0, & otherwise \end{cases}$$ …………..……………Eqn iii

Where:

β_0 is the intercept;

β_i represents the coefficient of independent variables;

μ represents error term from logistic distribution. This error term is unobservable, thus the Y^* is likewise unobservable. Additionally, the coefficient β is not expressed by any direct formula as it is in the case of ordinary regression. Therefore, a complicated iterative search process (mostly used by software) was used to get the expression of the "Maximum Likelihood".

The specification of the model in this study was that:

§ The study considered location as dependent variable and is dichotomous, that takes the value of 1 or 0 with the probabilities ρ_i and $1-\rho_i$, respectively.

§ The logistic function is able to take any real input x as value, (x ε R), while the outcomes are binary, (1 or 0). This function is defined as following:

$$P(x) = \frac{1}{e^{\alpha}+1} = \frac{1}{1+e^{-\alpha}} \quad \text{.........Eqn iv}$$

Since α is multiple explanatory variable (independent variables), it can be expressed as:

$$\alpha = \beta_0 + \beta_i + \mu_i \quad \text{.........Eqn v}$$

The specified logistic function can now be expressed as:

$$P(x) = \frac{1}{1+e^{-(\beta_0+\beta_i x_i+\mu_i)}} \quad \text{.........Eqn vi}$$

4.3 Results and Discussion

The actors and the drivers of the various activities in both the artisanal gold mining and the agricultural activities were classified into professionals, nativity, gender, age, education level, marital status, presence of children on site and family size. These parameters were analyzed on both mining and non-mining sites as shown in the results.

4.3.1 Observed Profession in Study Areas

The professions within the study area were categorized into four types based on the activities engaged in during household survey on both sites. Of these categories, 55% of them were farmers who practiced crop farming. This comprised 88 farmers from the non-mining site and 22 from the mining site (Table 4.1). Livestock farmers constituted only 4% of the respondents and all of them were from the mining site. Twenty-five percent of the respondents were artisanal gold-miners whereas 16% were involved in other small scale business or activities connected to gold mining. The study findings indicate that there was a significant association between gold-mining and respondents' professions (χ^2 = 96.80; p = 0.000).

Table 4.1: Different Factors Observed on Study Sites

Variables	**Freq.**	**%**	**N = 200**		**χ^2 Value**	**P Value**
			Non-mining	**Mining**		
Professions						
Crops	110	55	88	22		
Livestock	8	4	0	8	**96.805**	**0.000**
Mining	50	25	1	49		
Others	32	16	11	21		
Origin						
No	67	33.5	4	63		**0.000**
Yes	133	66.5	96	37	**78.128**	
Gender						
Female	45	22.5	16	29		**0.041**
Male	155	77.5	84	71	**4.846**	
Ages						
15-25	52	26	20	32		
25-35	72	36	31	41		
35-45	42	21	25	17	**11.612**	**0.020**
45-55	19	9.5	14	5		
55+	15	7.5	10	5		
Education levels						
None	141	70.5	83	58		
Primary	44	22	8	36		
Secondary	13	6.5	8	5	**22.943**	**0.000**
University	2	1	1	1		
Marital status						
No	31	15.5	8	23		
Yes	169	84.5	92	77	**8.589**	**0.006**
Children presence						
No	174	87	95	79	**11.317**	**0.001**
Yes	26	13	5	21		
Family size						
1-5	111	55.5	44	67		
6-10	53	26.5	34	19	**10.789**	**0.005**
10+	36	18	22	14		

4.3.2 Origin of Observed Population

Of the 200 respondents in this study, a total of 67 individuals were considered non-native and they represented 33.5% of the entire population of Farabacoura mining area (Table4.1). Approximately 67% of the respondents were natives of the study area. The study findings indicated that there was a significant association between nativity and gold-mining ($\chi^2 = 78.12$; $p = 0.000$).

The social problem drivers are many in artisanal gold mining areas. The local population who are living with low economic status become oppressed and marginalized by miners' community. Owing to the deplorable conditions within the mining sites women and children become the most affected by such social ills as prostitution, drugs and unsanitary environment. Furthermore, mining site and nearby are exposing to multinational problems because of the nature of free entrance of artisanal mining (Kitula, 2005). Couch (2002) reported the case of environmental and socio-economic impacts on Aborigines in Canada, which was strongly highlighted by policies than the ongoing on artisanal gold mining sites, generally in Africa and especially in Mali. This process was out of the problems of intercultural communications between a multinational corporation, four small Aboriginal groups and officials working in a period of transition within government (Couch, 2002)

4.3.3 Gender Representation of Population

Approximately 23% of the respondents were female (Table4.1). The distribution was 16 females from the non-mining site and 29 from the mining site whereas 84 males were drawn from the non-mining site and 71 from the mining site. Our study findings demonstrated that there was a significant association between gender and gold-mining in the study area ($\chi^2 = 4.84$; $p = 0.041$).

Gender was referred to socially constructed relationships between men and women (Kimani, 2015). Gender differences were evident in Tangandougou Commune not only for biological sex of individuals, but also through the roles they play and the expected responsibility on them in the society. These roles of gender are very dynamic and related to the time lines of changes in many environmental and socio-economic factors. The integrations of these considerations into the different projects of artisanal gold mining and agricultural production is very helpful for local and national governments, and populations.

4.3.4 Distribution of Age Structure of Respondents

The ages of the individuals who formed the study population was arranged into five categories for households interviewed. The results showed that 26% of the respondents were between 15 and 25 years old (Table4.1). Within this age bracket, there were 20 respondents from the non-mining site and 32 from the mining site. Those who were between 26 and 35 years old constituted 36% of the respondents. This comprised of 31 people from non-mining site and 41 from the mining site. The last age bracket of 55 years old and above constituted only 7.5% of all the individuals interviewed. Again, there was a significant association between age of the respondent and gold mining ($\chi^2 = 11.61$; p = 0.020).

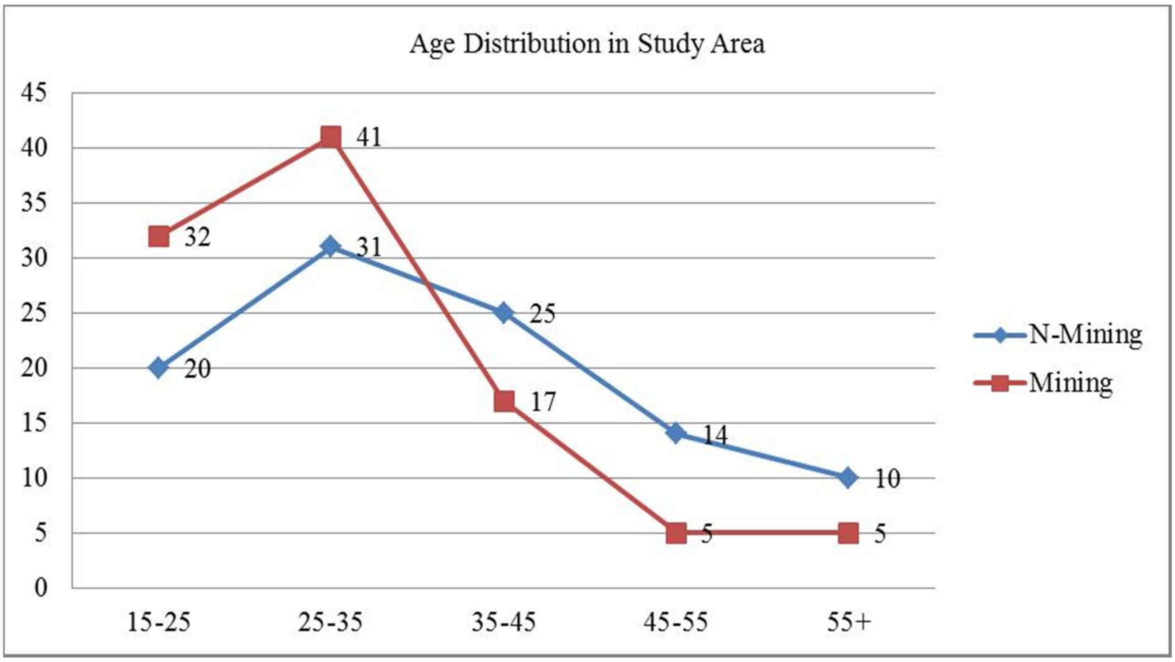

Figure 4.1: Distribution of Ages Structures in Study Area.

The ages were ranked categorically so as to find out different age brackets of workforces on both sites of study. The expected output of age limits was the involvement of youth in gold mining and also agriculture production in Tangandougou commune. For instance, the age bracket of 15 to 45 years old constituted the majority of those working at the mining sites. These workforces express the rude activity of artisanal gold mining and that impacts agricultural production which is also related to the same bracket of age. Funoh (2014) has reported the above problems of workforce's availability for agricultural production in Cameroon, especially during the period of production.

4.3.5 Education Levels of Respondents

The levels of education ranged from illiterate (no formal education) through the primary, secondary and college or university. There were more none educated individuals than other levels as shown in the results. Out of the 200 respondents, those without formal education constituted 70.5% (Table4.1). The distribution was 83 from the non-mining site and 58 from the mining site. Those with college and university level education were only 2 representing 1% of the total sample. A significant relationship was observed between level of education and gold mining and other activities including agriculture at the study are ($\chi^2 = 22.94$; $p = 0.000$).

The research was expected that education level of population was one of the best explanatory variables which influenced them to be engaged in artisanal gold mining Tangandougou Commune. The results of this study were confirmed that more people are educated the more they are out of artisanal gold mining activity and even agriculture.

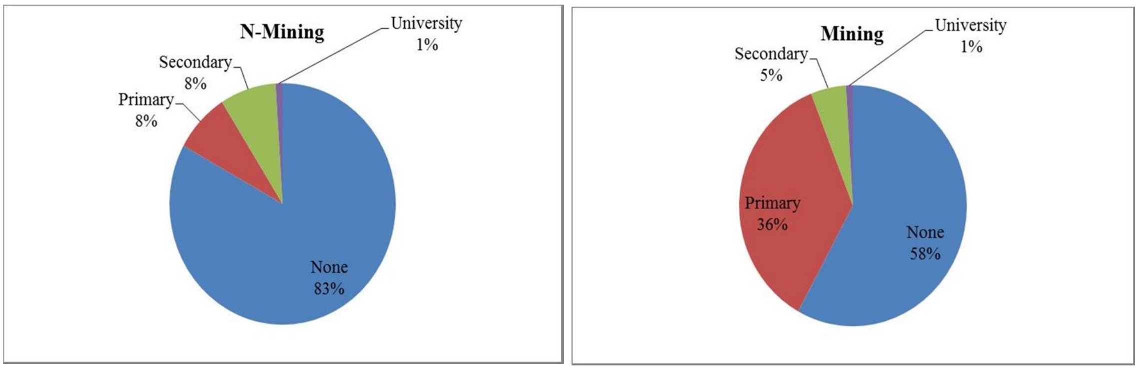

Figure 4.2: Education Levels on non-mining and mining sites.

4.3.6 Marital Status of the Respondents

Out of the 200 respondents that were interviewed, 15.5% of them were not married whereas 84.5% of them were married. Again our Chi-Square indicated that there was a strong and significant association between marital status and their involvement in gold mining or agriculture ($\chi^2 = 8.58$; $p = 0.006$).

Marital status is one of the significant considerations in society, especially in Malian society. That marital status consideration is due to the socio-culture and religions impacts on populations. Coulibaly (2017) was within that logic of marital status which is one of the socio-cultural parameters to involve married people in artisanal gold mining in Mali. That involvement is motivated by weak likelihood of household, so they have to move to supplement activities so as to supplement expenditures as a head of family.

4.3.7 Presence/Absence of Children in Households

Eighty-seven percent of those interviewed had no children. This comprised of 95 respondents from the non-mining site and 79 from the mining site. The respondents whose children were involved in different economic activities within the study population constituted 13% of the entire study population. The distribution was 5 respondents from the non-mining site and 21 from the mining site. There was a significant association between presence/absence of children in the households and in the existing economic activities ($\chi^2 = 11.31$; $p = 0.001$).

This parameter was paramount to determine whether the interviewed households allowed their children to be involved in artisanal gold mining and other forms of production activities on both mining and non-mining sites of Tangandougou commune. The assumption was that the involvement of children in different activities could affect their progression at school and also the future development of the commune. Human Rights Watch (2011) documented the presence of children on mining sites and whereby site in Mali is estimated to be between 20,000 and 40,000 those working in Mali's artisanal gold mining sector. These children are subjected to the worst forms of child labor, leading to injury, exposure to toxic chemicals, and even death. Furthermore, these children suffer serious pain in their heads, necks, arms, or backs, and risk long-term spinal injury from carrying heavy weights and from enduring repetitive motion. In addition, the same similarity of the presence of children and their exposure to different negative factors through child labor was reported from Philippines (Caymo II, 2016; Human Rights Watch, 2015). These children risk grave injury when working in unstable shafts, which sometimes collapse, especially during the rainfall season.

4.3.8 Family Size

Household size was categorized into three groups ranging from 1 to 5 people, 6 to 10 and those have more than 10 family members. Results showed that 111 households had a family of between 1 to 5 members representing 55.5% of the interviewed households (Table4.1). They comprised 44 households from the non-mining site and 67 from the mining site. Those households who had between 6 to 10 family members were 53 which was represented 26.5% of the respondents. It was 34 households from the non-mining site 19 from the mining site. Those that had more than 10 family members were 36 households representing 18% of the interviewed households. The distribution was 22 on non-mining site and 14 on mining site. The Chi-Square calculation indicated a significant association between household size and gold mining/agriculture in the study area (χ^2 = 10.78; p = 0.005).

Family size is not directly linked to marital status, but results shows that most of the interviewees were justified their involvement in mining by the largest of household and its expenditures. Coulibaly (2017) reported that households were impacted from climate change that why they were run for other alternatives to sort the poorest likelihood, especially those with a large family.

4.3.9 Pearson's Correlation of Socio-Economic Factors

The correlation of socio-economic factors was applied on different factors including profession, originality of the respondents, gender, age, education level, marital status, children presence on mining site and family size. Results showed that they were significant negative relationships (Table4.2). The results showed that there were significant positive relationships between location and profession (r = 0.48; p > 0.01), education levels (r = 0.16; p > 0.05), presence of children on mining site (r = 0.23; p > 0.01) (Table4.2). There were significant positive relationships between profession and education level (r = 0.28; p > 0.01), children presence on mining site (r = 0.35; p > 0.01). There were significant positive relationships between age and marital status (r = 0.43; p > 0.01), family size (r = 0.71; p > 0.01), education levels versus children presence on mining site (r = 0.32; p > 0.01), between marital status and family size (r = 0.34; p > 0.01) (Table4.2).

Table 4.2: Pearson's Correlations of Socio-Economic Factors

	Location	Profession	Nativity	Gender	Age	Education Level	Marital Status	Children Presence	Number people (Family size)
Location	1								
Profession	0.485**	1							
Nativity	-0.625**	-0.299**	1						
Gender	-0.156*	-0.072	-0.002	1					
Age	-0.225**	-0.328**	0.300**	0.146*	1				
Education Level	0.169*	0.280**	-0.220**	0.167*	-0.213**	1			
Marital Status	-0.207**	-0.329**	0.252**	-0.065	0.437**	-0.238**	1		
Children Presence	0.238**	0.353**	-0.198**	0.101	-0.397**	0.322**	-0.861**	1	
Number people (Family size)	-0.201**	-0.295**	0.328**	-0.029	0.711**	-0.184**	0.347**	-0.313**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

4.3.10 Results of Logistic Regression of Socio-Economic Factors

The results showed that primary profession had a significant influence on agricultural production ($p > 0.001$), nativity ($p > 0.001$), gender ($p > 0.003$), marital status ($p > 0.019$) and children' presence on gold-mining site ($p > 0.003$) is significant and positively influenced participation in artisanal gold-mining in Tangandougou (Table4.3).

Table 4.3: Logit Regression Results of Socio-Economic Parameters

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Profession	0.839	0.170	24.358	0.000***
Nativity or Origin	-4.826	0.786	37.685	0.000***
Gender	-1.659	0.553	8.986	0.003**
Age	0.292	0.268	1.184	0.277
Education Level	-0.441	0.387	1.297	0.255
Marital Status	2.947	1.257	5.494	0.019**
Presence of children	4.172	1.417	8.674	0.003**
Number people/Family size	0.281	0.423	0.442	0.506
Constant	**-0.472**	**1.351**	**0.122**	**0.726**

Note: ***; ** significant at 1% and 5% levels of respectively.

The negative relationship between gender and location (-1.659) indicate lack of gender balance in agriculture activities as more males are engaged in gold-mining than women. In addition, the strong relationship between location and nativity given by a negative coefficient of (-4.826) indicates that the presence of more non-natives undertaking artisanal gold-mining activities. The derived Multiple Linear Regression equation was as provided here below: $= 0 + + + + + + + +$

Then $= 0.839 - 4.826 - 1.659 + 0.292 - 0.441 + 2.947 + 4.172 + 0.281 - 0.472$

4.4 Conclusion and Recommendations

The study concludes that agriculture has been negatively impacted by artisanal gold mining and connected activities in Tangandougou commune, Sikasso region. Thus, for food security to be realized, emphasis should be on youth and women involvement in agriculture through agribusiness enterprises and promotion of modern and sustainable agricultural technologies.

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CHAPTER FIVE

IMPACTS OF ARTISANAL MINING ON WATER QUALITY

5.1 Introduction

Unsustainable natural resource utilization is on the increase in the developing countries especially the sub-Saharan Africa thus jeopardizing the ability of many local communities to meet their basic needs including food, water and shelter. Heavy metals pose a lot of concern to the general public given their toxic effects not only on man but also to all ecosystems. It is however sad to note that man contributes more than 95% of the total heavy metal contaminants in the environment thus impairing his own health (Mansour and Sidky, 2002). Studies in Brazil estimated total mercury loses during gold mining processes in the entire Amazon River basin to be about 100 tons per year with 45% being released into the river and 55% into the atmosphere (Akagi *et al.*, 1995).

Uncontrolled artisanal gold mining in Sikasso region is one such an anthropogenic activity that is of great environmental concern to developing countries including Mali owing to its potential adverse impacts on water quality, human health and environment in general. The adjacent community depends on water drawn from Sankarani River for household use as well as livestock production. They also rely on fish caught from this river to supplement their protein requirements. There are many health hazards associated with artisanal gold-mining. For example, consumption of mercury- contaminated fish and shellfish has been observed to cause visual impairments (Scotomata), visual field constriction (Ataxia), paresthesias (early signs), hearing loss, dysarthria, mental deterioration, muscle tremor, movement disorders, paralysis and death (with severe exposure), prenatal exposure: fetal toxicity, cognitive and motor delays and impairment (Steckling *et al.*, 2016; WHO, 2016). The highly toxic methyl mercury (MeHg) which forms 90% of total mercury (THg) has been shown to adversely affect a child's neurodevelopment.

Research findings have also linked methylmercury exposure to an array of health conditions ranging from delays in walking, talking to lower scores on neurological tests. The latter include retarded memory, motor, and behavioral functions in children (Campbell *et al.*, 2003). The most common form of prenatal exposure is maternal fish consumption. Except for the carnivorous tiger fish, from Lake Turkana which had THg concentrations near or above the international marketing limit of 500 ng g^{-1}, THg concentrations in the studied fish were generally below those of World Health Organization's recommended limit of 200 ng g^{-1} for at-risk groups such as pregnant and breastfeeding women. However, with increasing fishing, industrial and agricultural development in and around these lakes, there is a potential for elevated mercury contamination in the fish (Campbell *et al.,* 2003). Further, mercury can cause neuropathologies resulting to changes in behavior of the bald eagle such as a disruption in foraging and reproduction.

The changes result in poor forage and return to the nest with prey items to feed their young (Jagoe *et al.,* 2002). Arsenic inhalation and ingestion during copper, gold and metal mining activities may pose health outcomes as hyperpigmentation, depigmentation, bladder cancer, skin cancers, peripheral neuropathy and lung cancer (Choi *et al.,* 2012). In addition, the inhalation and ingestion of lead contaminated dust released by grinding ore to extract gold likely poses health problems related to death, Lead encephalopathy, impaired neurocognitive development, abdominal colic, Anorexia and premature birth (Tirima *et al.,* 2016; WHO, 2016). Elevated cadmium levels have been shown to be detrimental to survival, growth and reproduction of cladocerans, fish and birds (Scheuhammer *et al.,* 1987; Diamond *et al.,* 1992).

Lead is a non-specific poison affecting all body systems of various organisms. Increased metal loads in lake water and sediments are also a human health concern due to biomagnification of metals along the aquatic and terrestrial food chains and food webs. Overall, human health risks are primarily due to the elevated concentrations of Hg, Pb, Cd, As, and Se in water and fisheries that are part of the local people’s diet. Consumption of arsenic-laden water and food crops rice in Southeast Asia including Bangladesh, India and the Bengal region in general has been linked to several health conditions such as cancer of the skin, kidneys, bladder and lungs (Dipankar *et al.,* 1999; Mandar *et al.,* 1999; Shoko *et al.,* 2011). Cadmium has also been linked to kidney and liver damage as well as osteoporosis and pulmonary emphysema as was the case in Japan where people consumed rice cultivated using cadmium-contaminated irrigation water.

Osteoporosis, brittle nails and hair loss have been attributed to consumption of selenium-contaminated foods as was the case in China. Water and foods containing elevated copper and nickel have been linked to liver and kidney failure. Artisanal gold mining takes place nearby rivers and backwaters in Mali so as to facilitate gold washing. Further, the exploitation of this natural resource is characterized by open access and limited regulation and weak implementation that in part explains the rising levels of environmental degradation (Funoh, 2004). Owing to the release of wastewater containing mine tailings, the surface waters are contaminated and thereby pose a health risk to communities living in the surrounding areas. A study by Gibb and O'Leary (2014) demonstrates the consequences of artisanal gold mining on resident communities as well as those living in the riparian zones of rivers draining through gold-mining areas.

The ill effects were due to consumption of Mercury –contaminated water and fish. Similar findings were reported by Amzal *et al.* (2009) and Choi *et al.* (2012). The effects of heavy metals on human health in developing countries have reported by Dooyema *et al.* (2012). This case study highlighted lead poisoning effects on children related to artisanal gold mining in Northwestern region of Nigeria in 2010. Heavy metal pollution of soil and water pollution are currently a major global environmental concern. The metal contaminants have significant effects on soil and water quality, which reduces the productivity, yield and quality of agricultural products, especially in developing countries such as Mali (Chaab *et al.*, 2016). The global estimates of the costs related to lead exposure in children in developing countries was documented by Attina1 *et al.* (2013) in Low and Middle-Income countries.

This study estimated a total cost of $977 billion of international dollars in low- and middle-income countries, with economic losses equal to $134.7 billion in Africa, $142.3 billion, Latin America and the Caribbean $699.9 billion and Asia. So Attinal *et al.*, (2013) reported a total economic loss in the range of $728.6 – 1162.5 billion. It is against this background that this study was conceived to assess the impacts of artisanal gold-mining on water in Tangandougou Commune in Sikasso region of Mali.

5.2 Materials and Methods

5.2.1 Materials for Physical and Chemical Analysis

Plate 1: Equipment for Measuring Physical and Chemical Parameters of Water Quality

5.2.2 Methods of Data Collection and Analysis

Water samples were collected from three different points purposively selected with the consideration of mining site, upstream and downstream. The equipment used for sample collection, storage and analysis of heavy metals were pre-cleaned with high-purity nitric acid in Chemical and Natural Resources Laboratory (CNRL) of University of Sciences and Technology of Bamako in Mali. They were rinsed with copious amounts of Milli-Q water so as to ensure that they were free from any trace-metal. Water samples were collected in polypropylene bottles and filtered immediately using GF/C Whatman filters of 0.45µm, and acidified with ultra-pure HNO_3 to pH < 2. The samples were stored at 4° C and transported to the lab for heavy metal analyses. The bottles were stored in double-bagged zip-lock polyethylene bags.

The physical and chemical parameters that were analyzed included pH, temperature, conductivity, total dissolved solids (TDS) and Salinity with the pH/Cond 3320 Set 4 WTW. Lead, cadmium and arsenic were also determined at CNRL with the Spectrophotometer Perkin Elmer Analyst 200. Some of the equipment used in the measurement of physical and chemical water quality parameters are shown on plate 1. Water sample processing and analysis for heavy metals was done according to APHA protocols as described by Ogendi and Hannigan (2014). Data from Laboratory measurements was analyzed using descriptive and inferential statistics. The heavy metals concentrations were compared with those of the European Community (EC) and World Health Organization (WHO) guidelines of drinking water. The Mean and Standard deviation for the heavy metal concentrations were calculated as per equations i and ii.

$X = \overline{}$ ……………………………………...………………………Eqn vii

$s = \sqrt{\overline{} \sum (x - x)}$ ……………………..……………..…………………… Eqn viii

The study carried out Arsenic analysis only due to the limitations cited by laboratory where processing and analysis of specimen and generation of data was done and not for cyanide and mercury due to inexistence of analysis process of cyanide and mercury.

 

Plate 2: Water Samples Collection on Sankarani River and Tributaries.

5.3 Results and Discussions

There were no significant differences in physical chemical parameters (pH = 7.01, temperature = 25^{o}C, conductivity = 40.4 µs/cm, TDS = 39 mg/L and Salinity = 0.0) of water quality of Sankarani River. However, the concentrations of Cd and Pb were significantly different from EC and WHO drinking water references. Similarly, there was no significant difference from European Community and World Health Organization drinking water guidelines ($P > 0.05$) amongst the sampling sites.

Table 5.1: Heavy Metal Concentrations at 3 Sampling Sites Adjacent Gold Mining Site With Distances Consideration of 5km (P_1, P_2, P_3) Whereby P_1 Represented the Artisanal Gold Mining Site, P_2 the Upstream and P_3 Downstream.

Sites	Cadmium Cd	Lead Pb	Arsenic As
P1	0.405	0.374	0.005
P2	0.310	0.141	0.010
P3	0.340	0.245	0.005
EC/DW	0.005	0.010	0.010
WHO	0.003	0.010	0.010

The Cadmium concentrations amongst the study sites are as shown on Figure 5.1. In comparison, these results were higher than the references of European Community's drinking water (0.005) and also the World Health Organization norm (0.003). The concentration of lead in the three sampling sites is shown on Figure 5.2. The Pb concentration in all the 3 sites exceeded the WHO and EC drinking water standards. The last heavy metals analyzed, Arsenic concentrations shown on Figure 5.3. These results were lower at point one and three but equal at point two to WHO and EC drinking water standards.

Artisanal Gold mining is detrimental to the environment in terms of mine-tailings that contain chemical residues from the gold-processing. Of particular concern are chemicals used in the amalgamation of gold from ore (Claus Hann *et al.,* 2016). This may pose health effects in miners' community, upstream community and riverine community of mining sites. Gibb and O'Leary (2014) reported that 17 studies of literature described health effects of artisanal and small-scale mining communities from 10 different countries in South America, Africa and Asia. Further negative impacts of gold mining in terms of diseases have been documented by Steckling *et al.,* (2016). Other studies have documented that most mining workers involved in artisanal gold mining suffer from neurological disorders that include tremor, ataxia, memory problems, and vision impairment. These problems are not endemic to miner communities only, but also among fish consumers living downstream of mining sites (Gibb and O'Leary, 2014). Tomicic *et al.,* (2011) in Gibb and O'Leary (2014) reported that, the mean urinary Hg among gold dealers in Burkina Faso was 299.1 µg Hg/g-creatinine and that is one of the important evidences of exposures to Hg vapor in West Africa.

The results of Cadmium reported in terms of ± lower and upper limits were for the P_1 $0.402 \leq 1 \leq 0.408$, at P_2 $0.307 \leq 2 \leq 0.313$ and at P_3 $0.337 \leq 3 \leq 0.343$. In comparison with EC/DW (0.005) and WHO (0.003), results which exceeded the standards of concentration in the sampled water (Figure 5.1).

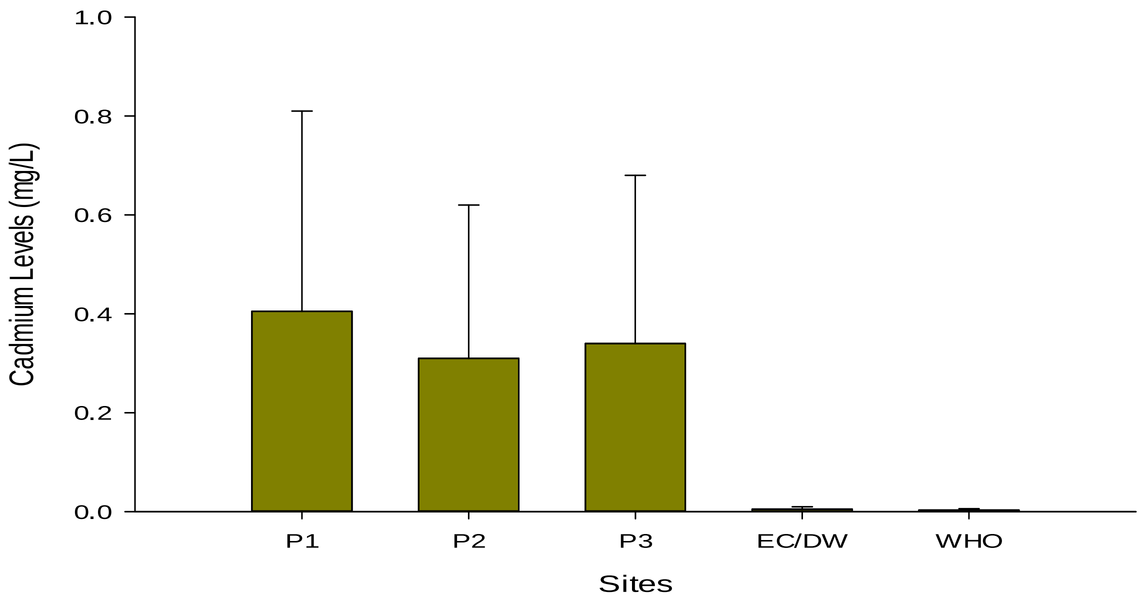

Figure 5.1: Mean and Standard Deviation at Sampling Sites of Cd in Comparison to EC and WHO

In terms of lower and upper limits of mean and standard deviation for Lead at P1 0.372 ≤ 1 ≤ 0.376, at P2 it was 0.139 ≤ 2 ≤ 0.143 and at P3 it was 0.243 ≤ 3 ≤ 0.247. The current study metal concentrations were much higher than the proposed EC reference values of (0.010) and 0.010 by WHO (Figure 5.2).

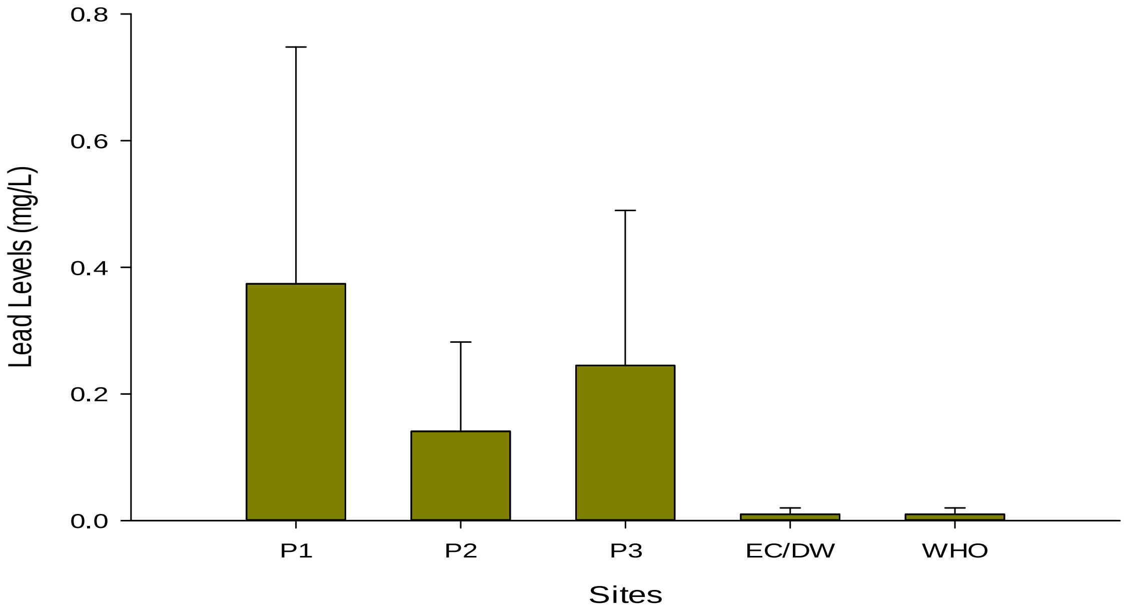

Figure 5.2: Mean and Standard Deviation at Sampling Sites of Pb in Comparison to EC and WHO

It is within the results of this study that was reported by Natali *et al.,* (2016) from Italia. The comparison of the results with that literature data highlights the possibility of water and soil contamination by heavy metals, because the traces of Pb and others have been found in the shells of farmed Manila (***Ruditapes Philippinarum***) collected within the sediment samples was confirming the bioavailability and accumulation.

Similar observations were made for Arsenic in which the lower and upper limits at P1 were 0.003 ≤ 1 ≤ 0.007, 0.006 ≤ 2 ≤ 0.014 at P2 and at P3 they were 0.003 ≤ 3 ≤ 0.007. The results showed that Arsenic concentrations were higher at all sampling points than the EC and WHO guideline values of 0.010 and 0.010 (Figure 5.3).

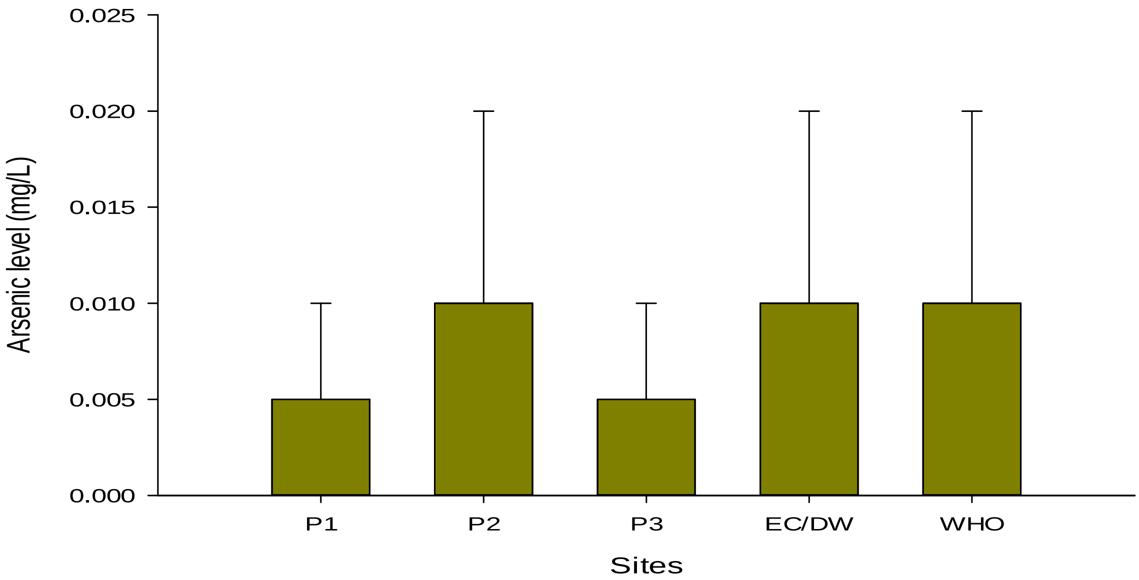

Figure 5.3: Mean and Standard Deviation at Sampling Sites of As in Comparison to EC and WHO

Most of the existing literature on impacts of artisanal gold mining is focused on mercury and less of Cadmium, Lead, and Arsenic. Heavy metals and other contaminants from gold mining processes have been reported to impair water quality; including rivers, backwaters and underground water which are for the main sources of water for humans, crops and livestock production (Basri *et al.*, 2017; Basu and Lokesh, 2014; WHO, 2016). These pollutants impacted heavily on drinking water, aquatic organisms and water used for agricultural production (Traore and Houhamdi, 2017). Gold mining is therefore likely to impact on human and environmental health owing to consumption of metal-contaminated water by humans and animals and plants in the study area.

5.4 Conclusions and Recommendations

In conclusion, the water in the selected sites of Sankarani River and its tributaries in artisanal mining area of Farabacoura are contaminated with heavy metals, though in low concentrations relative to the WHO and EC/DW drinking water quality guidelines. However, the heavy metals may pose health risks to humans and other organisms due to their bioaccumulation and bio-magnification nature. The study therefore recommends continuous monitoring of the water quality in all water sources surrounding mining areas so as to protect human and environmental health.

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CHAPTER SIX

ASSESSMENT OF ARTISANAL GOLD MINING IMPACTS ON CROPS AND LIVESTOCK PRODUCTIVITY

6.1 Introduction

Mining activities are interconnected to other economic activities surrounding gold mining areas. These activities were characterized by research of incomes so as to cover households' expenditure in Tangandougou community. Globally, these economic activities are focused on gold commerce, which includes small business and construction, selling food, selling water, daily work and transport. There were different economic activities connected to artisanal gold mining in Farabacoura. On both the mining and the non-mining sites, the other economic activities comprised of cereals crops production, vegetables crop, fodder production, livestock production, agroforestry and fisheries. Basically, cereals crop and livestock production are the major sources of rural populations in West Africa (Okuyama *et al.,* 2017). The objective of this chapter is to evaluate the impacts of artisanal gold mining on crops and livestock production in Tangandougou commune in Sikasso region, Mali. There are many challenges with respect to land tenure in Mali; these revolve around lack of land ownership titles and lack of land classification based on land use. For instance, the similar case is a study in Colombia which was referred to the magnitude of the impacts of conflict (Barthel *et al.,* 2016). Land uses conflict due to artisanal gold mining exploitation is frequent in Mali and that is not enabling sustainable agriculture and rural development. Land uses are one of the fundamental problems agriculture, agroforestry, pastoralism and agro-pastoralism in Mali. The case study in Ethiopia was reported by Awgichew, Flintan and Bekure (2016) which highlighted land uses under pastoral and agro-pastoral. They recognized that the collective common property arrangements of land tenure were under pressure of forces of change and that was not necessarily appropriate land uses. In Mali, land uses by artisanal gold mining are under community property right which is not clearly given facilitate the development of agriculture in artisanal gold mining areas. Henderson *et al.,* (2018) were of perception that biological oxygen demand (BOD) affects rice cultivation in Tha Chin River basin in Chinia. As a matter of fact, water quality degradation affects rice farming and many others in term of yield reduction, which in turn affects farmers' livelihood such as in developing countries. This objective was interested to check on subsistence crops such as cereals, vegetable and agroforestry in term of practices within household selected in study areas. The same evaluation was done for livestock production practice at household level.

6.2 Materials and Methods

6.2.1 Data Collection and Analysis

Structured questionnaires were used for households head or representative interviews. In addition, three focus group discussions were conducted plus key informant interviews and observation check-list used. The data collected was analyzed using the Statistic Packages for Social Sciences (SPSS) while ArcGIS was used to come up with study area map.

The study used exploratory and descriptive research designs with random sampling of 200 households. The questionnaires were administrated on mining site of Farabacoura and none mining site of Tiéguècourouni. The two study sites were approximately 45 km apart. The proportionality of 100 samples was used for household survey between the two sites. Data was analyzed using descriptive and inferential statistics such as Chi-square, correlation and logic model computed with location as dependent variable. The logistic regression measures the relationship between dependent variables that are categorical and one or many independent variables. It does so by using logistic function to estimate probabilities. This function is a cumulative logistic distribution which in turn is symmetric with the mean of zero and a variance of $\pi^2/3$. This formula can be defined as follows;

Y_i is called manifest response. It is assumed that there is a continuous random variable Y^* that is unobservable (underlying assumption) and can take any value. The manifest response, Y_i takes value of one if only the latent variable Y^* exceeds a certain threshold τ, otherwise Y_i takes the value of zero.

$$Y_i = \begin{cases} 1, & \beta_0 + \beta_i x_i + \mu > 0 \\ 0, & otherwise \end{cases}$$ ………….…………………. Eqn ix.

Where:

β_0 is the intercept;

β_i represents the coefficient of independent variables;

μ represents error term from logistic distribution. This error term is unobservable, thus the Y^* is likewise unobservable. Additionally, the coefficient β is not expressed by any direct formula as it is in the case of ordinary regression. Therefore, a complicated iterative search process (mostly used by software) is used to get the expression of the “Maximum Likelihood” (Kleinbaum and Klein, 2010).

The specification of the model in this study was that:

- § The study considered location as dependent variable and is dichotomous, that takes the value of 1 or 0 with the probabilities ρ_i and 1-ρ_i, respectively.
- § The logistic function is able to take any real input x as value, (x ε R), while the outcomes are binary, (1 or 0). This function is defined as following:

$$P(x) = \frac{1}{e^{\alpha}+1} = \frac{1}{1+e^{-\alpha}} \quad \text{..........Eqn x}$$

Since α is multiple explanatory variable (independent variables), it can be expressed as:

$$\alpha = \beta_0 + \beta_i + \mu_i \quad \text{..........Eqn xi}$$

The specified logistic function can now be expressed as:

$$P(x) = \frac{1}{1+e^{-(\beta_0+\beta_i x_i+\mu_i)}} \quad \text{..........Eqn xii}$$

6.3 Results and Discussions

This analysis focused on mining and its connected activities, crops production, livestock production, agroforestry, fisheries, land property right in mining areas, traditional knowledge of environment change and social change on both mining and non-mining sites of Tangandougou community in Sikasso region, Mali.

6.3.1 Descriptive Statistics of Gold Mining and Connected Activities

The people who were involved in gold commerce were 101 of all the respondents interviewed which represented 50.5% of the total in study area. Those who were not involved in the gold commerce activities were 99 which were 49.5% of the individuals interviewed. For those who participated in the gold mining, 36 respondents were from the non-mining site and 65 from the mining site. In contrast, those who were not doing any activities connected to gold mining were 64 from the non-mining site and 35 people from the mining site of Farabacourou in Tangadougou commune. The calculated Chi-Square was (χ^2 = 16.82) with the significant level of (p = 0.000) in study area.

Table 6.1: Gold Mining and Connected Activities

	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
Gold commerce						
No	99	49.5	64	35	**16.822**	**0.000**
Yes	101	50.5	36	65		
Small-scale business						
No	145	72.5	79	66	**4.238**	**0.057**
Yes	55	27.5	21	34		
Construction						
No	197	98.5	97	100	**3.046**	**0.246**
Yes	3	1.5	3	0		
Selling food						
No	192	96	98	94	**2.083**	**0.279**
Yes	8	4	2	6		
Selling water						
No	192	96	100	92	**8.333**	**0.007**
Yes	8	4	0	8		
Casual employment						
No	199	99.5	99	100	**1.005**	**1.000**
Yes	1	0.5	1	0		
Transport						
No	192	96	98	94	**2.083**	**0.279**
Yes	8	4	2	6		

This parameter was run to find out the proportion of people among households who were undertaking gold commerce and related activities. Results showed that people were more concentrated on gold activity than agriculture production. This fact may pose food insecurity in mining areas due to imbalance between agriculture productions and gold commerce in terms of the land allocation, distribution of the labor force among others.

The small businesses were represented by 55 people in study area at around 27.5% of interviewed in households. Those who were not doing businesses were 145 people which were 72.5% of interviewed in both the non-mining and mining sites. The distribution was 21 respondents from the non-mining site and 34 from the mining site for those doing businesses. In contrast, those who were not doing businesses were 79 from the non-mining site and 66 from the mining site. The worked out Chi-Square was (χ^2 = 4.23) with a significant level of (p = 0.057).

This parameter was run so as to know which activities that most of the people were engaged in within the study area other than agriculture production and gold commerce.

The construction activity was occupied by 3 individuals all from the non-mining site representing 1.5%. Those who were not engaged in the construction sector were 197 representing 98.5% of the responds. Those not working in the construction sector were 97 from the non-mining site and 100 from the mining site. The Chi-square of construction was ($\chi^2 = 3.04$) with a significant level of ($p = 0.246$) on both sites.

The construction work was run to come up with importance of this activity in study area. Because of the density of small rooms and hut made by miners on mining site. Results showed that it is an individual work. For instance, each of miners could provide herself or himself with this service of small rooms and huts construction in and mining site.

The individuals that were involved in the selling of food were 8 respondents representing 4% of the total respondents. In contrast, there were 192 respondents (96%) who were not involved in the selling of food in study area. The distribution was that on non-mining site, they were 2 people on that activity and 6 from the mining site. There were 98 from the non-mining site and 94 from the mining site a total of observed people not interested to selling food. The chi-square of this parameter was ($\chi^2 = 2.08$) with a significant level of ($p = 0.279$) on non-mining and mining site.

The parameter of selling food was run purposely to find out the types of business in study area. Results showed that a few people were interested in selling food as a lucrative activity. However, it is one of the lucrative activities to be improved on the mining site, because of the conditions in which people worked in along with the chemical products.

It was observed that 8 respondents representing 4% of total were engaged in the business of selling water in the study area. In contrast, those who were not selling water were around 192 representing 96% of the total respondents. Within the non-mining site, there were only 8 individuals involved in the water selling activity against 92 from the mining site. Results showed that the chi-square was ($\chi^2 = 8.33$) with a significant level ($p = 0.007$) of observed people.

Selling water was run as a parameter to find out the available opportunity of that activity. Results showed that people were less interested in selling water in study area. In the context of mining, selling drinking water should be promoted for health purposes.

The daily work in which individuals were engaged in was mentioned by only 1 respondent from the non-mining site which was represented by 0.5% of the total respondents. Those who did not mention their daily work were 199 (99 from the non-mining site and 100 from the mining site) which represented 99.5% of the respondents in the study area. The chi-square was (χ^2 = 1.00) with a significance level of (p = 1.000).

The parameter of daily work was run with employment position of study area population. Results showed that people were not interested to daily work. They were focused more on self-employment in most of the cases observed in study areas.

Transport activities engaged only 8 respondents (2 from the non-mining site and 6 from the mining site) who represented 4% of the total respondents. Those who were not interested in the transport sector were 192 (98 from the non-mining site and 94 from the mining site) with the proportion of 96% of the total respondents. The chi-square was (χ^2 = 2.08) with a significance level of (p = 0.279).

6.3.2 Correlations Influence of Gold Mining on their Activities

The gold-mining and its connected activities included gold commerce, petty business, construction work, selling food, selling water, daily work and transport. There was a significant negative relationship between gold commerce and selling water ($r = 0.15; p > 0.05$). In addition, there were significant positive relationships between location and gold commerce ($r = 0.29; p > 0.01$), petty business ($r = 0.14; p > 0.05$) and selling water ($r = 0.20; p > 0.01$). There were also significant positive relationships between petty business and selling water ($r = 0.21; p > 0.01$) and selling food versus selling water ($r = 0.34; p > 0.01$).

Table 6.2: Pearson's Correlations of Gold Mining and Connected Activities

	Location	Gold commerce	Petty business	Construction	Selling food	Selling water	Daily work	Transport
Location	1							
Gold commerce	0.290**	1						
Petty business	0.146*	-0.040	1					
Construction	-0.123	-0.042	-0.076	1				
Selling food	0.102	-0.053	0.103	-0.025	1			
Selling water	0.204**	-0.155*	0.217**	-0.025	0.349**	1		
Daily work	-0.071	-0.072	-0.044	-0.009	-0.014	-0.014	1	
Transport	0.102	-0.002	0.046	-0.025	-0.042	-0.042	-0.014	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

6.3.3 Regression Results of Gold Mining and Connected Activities

Gold commerce was only positive and significant ($p < 0.001$) than other connected activities of gold mining during this research period in Tangandougou commune. This was expected because of the influence of mining on others activities. They were linked to gold mining in this area. These other connected activities were temporary business.

Table 6.3: Logit Regression of Gold Mining and Associate Activities

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Gold commerce	1.432	0.317	20.400	0.000***
Others business	0.502	0.361	1.940	0.164
Construction	-20.840	22206.401	0.000	0.999
Selling food	0.410	1.015	0.164	0.686
Selling water	21.557	13838.493	0.000	0.999
Casual employment	-20.204	40192.970	0.000	1.000
Transport	1.312	0.870	2.274	0.132
Constant	**-0.999**	**0.260**	**14.722**	**0.000**

Note: *** significant at 1% level.

These parameters were run so as to know which of them drive people to off-farm activities. Results showed that gold commerce (1.432), others business (0.502), selling food (0.410), selling water (21.55) and transport (1.312) were positively correlate to location. For instance, these activities were important and justified the presence of people on gold mining site. The construction activity (-20.840) and employments (-20.204) were having a strong negative correlation. Because of the nature of gold mining enterprise which is always a temporary activity hence people worked on site in most of the cases by self-employment. The equation was $= 0 + \quad + \quad + \quad + \quad + \quad + \quad + \quad +$ and $= 1.432 \quad + 0.502 \quad - 20.840 \quad + 0.410 \quad + 21.557 \quad - 20.204 \quad + 1.312 \quad - 0.999$

6.3.4 Descriptive Statistics of Crop Production

The respondents who were involved in cereal crops productions were 142 representing 71% of interviewed people. In contrast, there were 58 people who did not engage in cereal crops production representing about 29% of interviewed population. In the non-mining site, there were 83 respondents who worked as cereal crops famers against 59 from the mining site. Those who were not practicing cereal crops agriculture were 17 and 41 from the non-mining and the mining sites respectively. The Chi-Square was (χ^2 = 13.98) with a significance level (p = 0.000).

Table 6.4: Crops Production Observed in Tangandougou Commune

	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
Cereals crop						
No	58	29	17	41	**13.987**	**0.000**
Yes	142	71	83	59		
Vegetables crop						
No	124	62	38	86	**48.896**	**0.000**
Yes	76	38	62	14		
Fodders						
No	191	95.5	94	97	**1.047**	**0.498**
Yes	9	4.5	6	3		
Composting						
No	147	73.5	49	98	**61.635**	**0.000**
Yes	53	26.5	51	2		

Gardening or vegetables crop farming was carried out by 76 respondents representing 38%. Those who did not engage in vegetables crop production were 124 which represented 62% of total interviewed population. For instance, there were 62 respondents from the non-mining site and 14 from the mining site doing that activity. However, there were 38 respondents from the non-mining site and 86 from the mining site who did not practice vegetable crops farming. The Chi-Square was (χ^2 = 48.89) and the significance level (p = 0.000).

Fodders production in term of farm activity was carried out by 9 respondents representing 4.5% of the respondents' population. Those who were not carrying out the fodder farm activity were 191 who represented 95.5% of the respondents in study areas. It was observed that on non-mining site 6 respondents against 3 on mining site engaged in fodder farming. The distribution of those who were not farming fodder was 94 on non-mining site and 97 on mining site. The Chi-Square was (χ^2 = 1.04) with the significance level (p = 0.498).

The composting of manure from crops residual was done by 53 farmers representing 26.5% of respondents' population. This activity was not done by 147 or about 73.5% of the interviewed people. Results showed that 51 respondents were from the non-mining site and 2 from the mining site. Those who were not doing manure composting were 49 from the non-mining site and 98 from the mining site. The Chi-Square observed was ($\chi^2 = 61.63$) with a significance level ($p = 0.000$).

Agriculture development was linked to many parameters on the study area. For instance, land and water conservation were the first challenges recognized by the residents around the AGM area (Nurbekov *et al.,* 2016). These natural resources impacts livestock and crops production which will turn into food insecurity and nutrition path ways. In addition, the climate change is an intervening path way which should be considered globally in sustainable integrated agriculture. Gold mining was an extensive activity characterized by the density of population. These populations were interested to gold-commerce, selling food, transport and other associated businesses. Those who engaged in other business were likely to more fortunate than artisanal gold miners. Gold miners were subject to fail in uncertainty and unemployment situation which made them vulnerable to extreme poverty. On a sustainable basis, the AGM activities will become a kind of local market for most of the miners transformed to small-traders and retailers of various items in mining areas (Funoh, 2014).

Despite the enormous potential for agriculture (Okuyama *et al.,* 2017), households were on vulnerability situation in study area. Households were mainly engaged in subsistence cereals crops production in the non-mining area and vegetables crop were practiced in majority by women. The workforces of these farm activities were assumed by holders, second holders, women and children of households. They could not produce enough or surpluses to ensure food security of their household. Furthermore, these workforces could not be considered as a pillar of any sustainable agricultural system. Sustainable agriculture should not be dependent on youth men and women so as to excel and move from the stage of subsistence crops production. Sustainability needs consistent knowledge, capacity building and strengthening farmers' organization and institutions (Mishra *et, al.,* 2016).

6.3.5 Correlation of Crops Production in Tangandougou Commune

The correlation on crops production included subsistence cereals production, gardening or vegetable crops, fodders production and compost from crop residues. Results showed that there were significant negative relationships between location and cereals production ($r = -0.26$; $p > 0.01$), vegetable crops ($r = -0.49$; $p > 0.01$) and compost from crops ($r = -0.55$; $p > 0.01$).

They were also significant positive relationships between cereals crops production and vegetable crops (r = 0.36; p > 0.01), composting from crops production (r = 0.33; p > 0.01) and vegetable crops versus compost (r = 0.37; p > 0.01).

Table 6.5: Pearson's Correlations of Crops Production

	Location	Cereals crop	Vegetables crop	Fodders crop	Composting crop
Location	1				
Cereals crop	-0.264**	1			
Vegetables crop	-0.494**	0.364**	1		
Fodders production	-0.072	0.086	0.128	1	
Composting crops	-0.555**	0.334**	0.370**	-0.021	1

**. Correlation is significant at the 0.01 level (2-tailed).

6.3.6 Regression Results on Crops Production

Crop productions were secondary activities in gold-mining site. Majority of the people are concentrated on seeking money from others activities especially, gold production and its connected activities. Thus, leaving behind cereals, gardening, fodders and compost production out of exploitation for many households in the mining areas. The vegetables crop (p > 0.001) and compost productions (p > 0.001) showed a significant difference and a strong negative correlation.

Table 6.6: Logit Regression of Crops Production

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Cereals production	0.213	0.430	0.244	0.621
Vegetables crop	-2.034	0.430	22.338	0.000***
Fodders production	-0.607	0.894	0.462	0.497
Composting	-3.736	0.778	23.072	0.000***
Constant	**1.232**	**0.319**	**14.862**	**0.000**

Note: *** significant at 1% level.

The majority of cereal products consumed by miners are imported from other countries. For example, most of the rice is imported from Brazil, Vietnam and Chania. The vegetables crops (-2.034) and organic manure (-3.736) are deficient in this area, because of land degradation and the intensity of mining which are not allowing farmers to be able to ensure gardening production sufficiently over year. The logic model equation was =

$$0 + \quad + \quad + \quad + \quad +$$

$$= 1.232 \quad + 0.213 \quad - 2.034 \quad - 0.607 \quad - 3.736$$

6.3.7 Descriptive Statistics of Livestock Production

Livestock especially cattle production was practiced by 100 respondents among households which represented 50% of study population. The distribution was 77 from the non-mining site and 23 observed on mining site. Those who did not practice livestock production were 23 from the non-mining and 77 from the mining site. The Chi-Square was (χ^2 = 58.32) with the significance level of (p = 0.000).

Goat production was practiced by 84 farmers or about 42% of study populations. Those who were not practicing goat production were 116 represented by 58% of the total interviewed population (45 from the non-mining site and 71 from the mining site). The distribution was 55 goat farmers from the non-mining and 29 farmers from the mining site. The calculated Chi-Square was (χ^2 = 13.87) with the significance level (p = 0.000).

Sheep production was practiced by 67 farmers who represented 33.5% of the respondents of the population of the study areas. Those who were not engaged in sheep production were 133 representing 66.5% of the interviewed population. The distribution was 51 people from the non-mining site and 16 from the mining site from the sheep farmers. The respondents who were not engaged in sheep farming were 49 from the non-mining site and 84 from the mining site. The Chi-Square was (χ^2 = 27.49) with the significance level of (p = 0.000).

Dairy farming was done by only 3 (all from the non-mining site) people representing 1.5% of the interviewed populations in the study areas. Those who did not practice dairy farming were 197 who represented 97% of interviewed population. This comprised of 97 respondents from the non-mining site against 100 from the mining site. The Chi-Square was (χ^2 = 3.04) with the significance level of (p = 0.246).

The hides' commerce was done by 2 people representing 1% of study population. However, 198 people representing 99% did not practice hides commerce. The distribution was 1 respondent from the non-mining site and another from the mining site. In contrast, there were 99 respondents who did not practice hides business from the non-mining site while 99 respondents were from the mining site over the total interviewed population of the study. That gave a Chi-Square of ($\chi^2 = 0.00$) with the significance level ($p = 1.000$).

Table 6.7: Livestock Production in Tangandougou Commune

	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
Cow production						
No	100	50	23	77	**58.320**	**0.000**
Yes	100	50	77	23		
Goat production						
No	116	58	45	71	**13.875**	**0.000**
Yes	84	42	55	29		
Sheep production						
No	133	66.5	49	84	**27.494**	**0.000**
Yes	67	33.5	51	16		
Dairy						
No	197	98.5	97	100	**3.046**	**0.246**
Yes	3	1.5	3	0		
Hides commerce						
No	198	99	99	99	**0.000**	**1.000**
Yes	2	1	1	1		
Composting						
No	158	79	59	99	**48.222**	**0.000**
Yes	42	21	41	1		

The production of organic manure from livestock and crop residues was practiced by 42 (41 from the non-mining site and 1 from the mining site) interviewed respondents which represented 21% of study population. There were 158 respondents representing 79% of the total respondents in study areas who were not practicing that activity of composting. In contrast, there were 59 of the respondents observed in the non-mining site against 99 respondents from the mining site who did not engage in the manure compositing activity. The Chi-Square for the engagement in the manure compositing was ($\chi^2 = 48.22$) with the significance level of ($p = 0.000$).

The system of livestock production was still based on the traditional methods and the application of the industrial and commercial systems is still lacking. Furthermore, these households kept a few cattle and only for domestic purposes. Sheep and goats were reared by households for social and cultural functions. For example, they do traditional sacrifices with a goat or a sheep in villages in Tangandougou commune. However, these small ruminants have a lot of potentials for the economy of the concerned households, because the local and international markets are readily available. For local market, is mostly eaten outside households in Mali. Sheep and cattle beef are exported to countries like Senegal and Cote d'Ivoire. There was really a big potential for cow, sheep and goat production in Sikasso region.

6.3.8 Correlations of Livestock Production

The items considered under livestock production in Tangandougou commune included location, cattle production, goat production, sheep production, hides commerce and compost from livestock wastes. The significant negative relationships were observed to exist between cattle production and location ($r = -0.54$; $p > 0.01$), goats production versus location ($r = -0.26$; $p > 0.01$), sheep production and location ($r = -0.37$; $p > 0.01$) and between composting of livestock wastes and location ($r = -0.49$; $p > 0.01$). In contrast, the significant positive relationships were observed between goats and cattle production ($r = 0.34$; $p > 0.01$), sheep and cattle production ($r = 0.49$; $p > 0.01$), composting of livestock wastes and cattle production ($r = 0.31$; $p > 0.01$), sheep and goats production ($r = 0.31$; $p > 0.01$) and composting of livestock wastes and sheep production ($r = 0.20$; $p > 0.01$) (Table6.8 below).

Table 6.8: Pearson's Correlations of Livestock Production

	Location	Cow production	Goat production	Sheep production	Dairy produce	Hides commerce	Compost livestock
Location	1						
Beef production	-0.540**	1					
Goat production	-0.263**	0.344**	1				
Sheep production	-0.371**	0.498**	0.319**	1			
Dairy produce	-0.123	0.041	0.062	0.087	1		
Hides commerce	0.000	0.000	0.118	0.035	-0.012	1	
Compost livestock	-0.491**	0.319**	-0.041	0.206**	-0.064	-0.052	1

**. Correlation is significant at the 0.01 level (2-tailed).

6.3.9 Results of Regression on Livestock Production

Mining areas are not appropriate to livestock production because of the associated characteristics and their influences and connected activities which usually impacts land, water and destroys forests heavily. Artisanal gold mining is characterized by open pits and their collapses' risk that make spaces surrounding mining out of exploitation for livestock production activities. This therefore, reduces exploitable land for livestock forcing the households to keep their animals at home or in farm for few of them.

Modern livestock farming was not practiced by households. Only a few of households kept their animals in the farms. Therefore, most of them used traditional breeding system which involves leaving the animals to feed for themselves in the pasture fields during dry season and following them up during the rainy season. Whenever animals were kept inside the confined fields during the dry season they provided plant leaves for them as animal feed.

The animals feed production is one of the agricultural production activities which are environmentally and economically sustainable. Fodder productions are intended to keep animals breeding at high level in term of sustainable agriculture. Cow production ($p > 0.001$) and composting from livestock wastes ($p > 0.001$) were significantly related with a strong negative correlation among livestock production system in study areas.

Table 6.9: Logit Regression Results of Livestock Production

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Beef production	-1.744	0.434	16.117	0.000***
Goat production	-0.745	0.422	3.111	0.078
Sheep production	-0.530	0.457	1.341	0.247
Dairy	-21.431	21758.353	0.000	0.999
Hides commerce	-0.041	1.509	0.001	0.978
Compost livestock	-4.112	1.054	15.214	0.000***
Constant	**1.923**	**0.320**	**36.067**	**0.000**

Note: *** significant at 1% level.

These parameters were looked for the livestock production capacity by households. Results showed that cattle (-1.744), goats (-0.745), sheep (-0.530), dairy produce (-21.431), peel commerce (-0.041) and compost (-4.112) had a strong negative correlation with location. If $= 0 + \quad + \quad + \quad + \quad + \quad + \quad +$ so the variables in equation were

$$= 1.923 \quad - 1.744 \quad - 0.745 \quad - 0.530 \quad - 21.431 \quad - 0.041 \quad - 4.112$$

6.3.10 Descriptive Statistics of Agroforestry

Timber wood production was practiced by 17 respondents which represented 8.5% among study population. Those who did not practice timber wood production were 183 representing 91.5% of the respondents in the study areas. In the non-mining site, there were 10 people who practiced timber wood production against 7 from the mining site. Those who did not practice timber wood production activities were 90 from the non-mining site and 93 from the mining site. The calculated Chi-Square of timber wood production was (χ^2 = 0.57) with the significance level of (p = 0.613).

Table 6.10: Agroforestry in Tangandougou Commune

	Freq.	**%**	**N = 200**		**χ^2 Value**	**P Value**
			Non-Mining	**Mining**		
Timber Wood						
No	183	91.5	90	93	**0.579**	**0.613**
Yes	17	8.5	10	7		
Poles						
No	192	96.0	94	98	**2.083**	**0.279**
Yes	8	4.0	6	2		
Charcoal						
No	160	80.0	66	94	**24.500**	**0.000**
Yes	40	20.0	34	6		
Hunting						
No	185	92.5	88	97	**5.838**	**0.029**
Yes	15	7.5	12	3		
Honey						
No	169	84.5	76	93	**11.033**	**0.001**
Yes	31	15.5	24	7		
Herbal						
No	183	91.5	93	90	**0.579**	**0.613**
Yes	17	8.5	7	10		

The number of the respondents who engaged in the production of wood for construction was 8 representing 4% of study population. Those who were not involved in this activity were 192 (94 from the non-mining site and 98 from the mining site) representing 96% of the respondents' population in study areas. The distribution was 6 are engaged in this activity from the non-mining site against 2 from the mining site Negative answers were observed for. The Chi-Square for this activity was (χ^2 = 2.08) with the significance level of (p = 0.279).

Charcoal production was practiced by 40 households among the respondents representing 20% of study population. The activity was not practiced by 160 household which represented 80% of total respondents in study areas. On non-mining site, they were 34 people against 6 on mining site who practiced charcoal production. In contrast, those were not practicing charcoal production were 66 from the non-mining site and 94 people from the mining site. The Chi-Square was (χ^2 = 24.50) with the significance level of (p = 0.000).

Hunting as a traditional activity in study areas was practiced by 15 households representing 7.5% of the respondents' population. There were 185 households representing 92.5% who did not practice hunting. The distribution was of the households that practiced hunting was 12 respondents from the non-mining site and 3 from the mining site. Those who did not practice hunting were 88 from the non-mining site and 97 from the mining site. The Chi-Square calculated for the hunting activities was (χ^2 = 5.83) with the significance level of (p = 0.029) in study areas.

Honey production as traditional service from forests was observed in 31 respondents' households representing 15.5% of study population. For instance, they were 169 households representing 84.5% in which people did not practice that activity in study areas. Those were practicing honey production were 24 respondents from the non-mining site against 7 from the mining site. The practice was not observed in 76 households from the non-mining site and 93 cases from the mining site. The Chi-Square of that observation was (χ^2 = 11.03) with the significance level of (p = 0.001).

Herbal medicine activity was observed in 17 households representing 8.5% of study population. There were 183 households representing 91.5% in which people were not practicing herbal medicine as a form of lucrative activity. On non-mining site, there were 7 households against 10 on mining site in which people practiced herbal medicine production as a lucrative activity. In contrast, there were 93 households on non-mining site and 90 on mining site in which people were not practicing herbal medicine as lucrative activity. The Chi-Square of herbal medicine production was (χ^2 = 0.57) with significance level of (p = 0.613).

Table 6.11: Plant Trees Observed (+) and none Observed (-) in Tangandougou Commune

Trees Species	Common Name	Scientific Name	Mining Site	Non-Mining
1	Papaya	*Carica papaya*	-	+
2	Mango	*Mangifera indica*	-	+
3	Sweet Orange	*Citrus sinensis*	-	+
4	Bitter Orange	*Citrus aurantium*	-	+
5	Baobab	*Adansonia digitata*	-	+
6	Karite	*Vitellaria paradoxa*	-	+
7	Eucalyptus	*Tereticornis globulus*	+	+

Agroforestry was practiced for local production for most of households within the site. Agroforestry activities were not a primary targeted production for households but rather due to the limited allowance to use resources from forests such as honey, timber wood and charcoal. Additionally, horticulture was limited to some fruits production such as oranges, mangoes, papaya. There was not beekeeping in terms of lucrative activity among households or an experience reported by Heckle *et al.,* (2018) emphasized the significant advantages of beekeeping for smallholder farming communities in Kenya.

6.3.11 Correlations Results of Agroforestry

The activities that were considered under agroforestry services included timber wood production, construction wood production, charcoal production, hunting activity in households, honey production by households and herbal medicine practiced by households as a form of lucrative activity. For instance, results showed that there were significant strong negative relationships between charcoal production and location ($r = -0.35$; $p > 0.01$), hunting activity versus location ($r = -0.17$; $p > 0.05$) and honey production versus location ($r = -0.23$; $p > 0.01$). The significant positive relationships were observed between construction wood and timber wood production ($r = 0.39$; $p > 0.01$), charcoal and timber wood production ($r = 0.20$; $p > 0.01$), herbal medicine and timber wood production ($r = 0.16$; $p > 0.05$); honey and charcoal production ($r = 0.269$; $p > 0.01$) and honey versus hunting activity ($r = 0.29$; $p > 0.01$) (Table 6.12 below).

Table 6.12: Pearson's Correlations of Agroforestry Activities

	Location	Timber wood	Poles	Charcoal	Hunting	Honey	Herbal medicine
Location	1						
Timber wood	-0.054	1					
Poles	-0.102	0.395**	1				
Charcoal	-0.350**	0.206**	0.089	1			
Hunting	-0.171*	-0.019	0.039	0.095	1		
Honey	-0.235**	0.117	0.124	0.269**	0.298**	1	
Herbal medicine	0.054	0.164*	0.121	-0.018	0.117	0.068	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

6.3.12 Logit Model of Agroforestry Activities

Gold Mining activities are always linked to forest resources exploitation in Mali. For example, the housing use more wood for construction and there is no distinction between wood, because of indiscriminate cutting tree in mining areas. This makes all forests in mining zones vulnerable to deforestation and thereby, it degrades the environment in the mining areas. As much as the government of Mali has the roles and responsibilities of protecting rare tree species, the full application and implementation of the laws and legislations in local areas may pose problems. In fact, there is some insufficient check-point for forestry's resources control including wood, charcoal and cooking wood. The gold-mining areas were free from that kind of control of forest resources which is significantly and negatively impacting charcoal production ($p > 0.001$).

Table 6.13: Logit Regression Results of Agroforestry Activities

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Timber wood	0.554	0.691	0.643	0.423
Construction wood	-1.333	0.997	1.790	0.181
Charcoal	-1.990	0.504	15.591	0.000***
Hunting	-1.263	0.737	2.937	0.087
Honey	-0.827	0.509	2.640	0.104
Herbal medicine	0.673	0.616	1.192	0.275
Constant	**0.477**	**0.179**	**7.073**	**0.008**

Note: *** significant at 1% level.

The parameters were run to find out which of them was mostly used by population in study area. The study found out that timber wood (0.554) and herbal medicine had a strong positive correlation to localities. The negatives strong correlation was given by the coefficient attributed to construction wood (-1.333), charcoal (-1.990), hunting activity (-1.263) and honey production (-0.827). If $= 0 + + + + + +$ so the variables in equation were $= 0.477 + 0.554 - 1.333 - 1.990 - 1.263 - 0.827 + 0.673$

6.3.13 Descriptive Statistics of Fisheries and Water Usage

They were 109 observed households representing 54.5% in which people used water from wells for their domestic services included drinking and cooking water in the study areas. Those who were not using water from wells were 91 representing 45.5% of study population. The distribution was 97 households from the non-mining area and 12 from the mining site in which people were using water from wells. In contrast, those were not using water from wells were 3 from the non-mining and 88 from the mining sites. The Chi-Square was (χ^2 = 145.68) with the significance level of (p = 0.000).

Table 6.14: Sources of Water Usage in Tangandougou Commune

	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
Wells						
No	91	45.5	3	88	**145.680**	**0.000**
Yes	109	54.5	97	12		
Backwater						
No	164	82	66	98	**34.688**	**0.000**
Yes	36	18	34	2		
Rivers						
No	185	92.5	85	100	**16.216**	**0.000**
Yes	15	7.5	15	0		
Water vendors						
No	192	96	100	92	**8.333**	**0.007**
Yes	8	4	0	8		
Fishing						
No	162	81	70	92	**15.724**	**0.000**
Yes	38	19	30	8		
Aquaculture						
No	195	97.5	98	97	**0.205**	**1.000**
Yes	5	2.5	2	3		

The use of backwater for basic services was stated by 36 households (34 from the non-mining site and 2 from the mining site) representing 18% of the respondents' population in study areas. In contrast, they were 164 households (66 from the non-mining site and 98 from the mining site) representing 82% in which people were not using backwaters for the domestic activity. The Chi-Square was (χ^2 = 34.68) with the significance level of (p = 0.000).

Fifteen (15) households interviewed (all from the non-mining site) representing 7.5% of observed populations in study areas were using water from the rivers for their domestic activities. Those who were not using water from the rivers were 185 representing 92.5% of the respondents interviewed on the study population whereby 85 were from the non-mining site and 100 from the mining site. The Chi-Square was (χ^2 = 16.21) with the significance level of (p = 0.000).

The number of the respondents who were involved in the water vending business was 8 representing about 4% of study population. Those were not interested to that activity were 192 representing 96% of observed population in study areas whereby 100 were from the non-mining site while 98 were from the mining site. There were zero positive response from the non-mining site and 8 responses from the mining site. The negative answers were 100 observed on non-mining site and 92 on mining site. The Chi-Square was (χ^2 = 8.33) with the significance level of (p = 0.007).

Fishing was practiced by 38 households representing 19% of study population. Those were not practicing this activity of fishing were 162 around 81% in study areas. The distribution was 30 people on non-mining site and 8 on mining site for those were practiced traditional peach. In contrast, those were not practiced that activity were 70 on non-mining site and 92 people on mining site. The Chi-Square was (χ^2 = 15.72) with the significance level of (p = 0.000).

The aquaculture as an activity was done in 5 households representing 2.5% in study areas. There were 195 households representing 97.5% in which people were not practicing aquaculture in study areas. For instance, they were 2 respondents from the non-mining site and 3 from the mining site who were practicing aquaculture as activity. Those who were not practicing aquaculture were 98 from the non-mining site and 97 from the mining site. The Chi-Square was (χ^2 = 0.20) with the significance level of (p = 1.000).

Fisheries were practiced by a few households linked to ethnic group “Bozo” fishermen. These households resided near rivers and backwaters for fishing. However, these rivers and backwater were poor in terms of resources, especially fish species. The residents need to turn to fish breeding artificially in ponds which could help much for subsistence and commercial needs of fisheries and fisheries resources. There were enormous potentials for fish breeding through water conservation with small bridges on backwaters in these areas of mining.

6.3.14 Correlations of Fisheries and Water Usage

The parameters considered under fisheries and water use for the study included water use from wells, backwaters, rivers, water vending activities and traditional peach, fish-breeding and about location of study area. Results showed that they were significands strong negative relationships between water used from wells and location ($r = -0.85$; $p > 0.01$), the use of backwater and location ($r = -0.41$; $p > 0.01$), water from rivers ($r = -0.28$; $p > 0.01$), fishing ($r = -0.28$; $p > 0.01$) and water vending activity versus wells ($r = -0.22$; $p > 0.01$). In contrast, there were significant strong positive relationships between water vending activity and location ($r = 0.20$; $p > 0.01$), backwater and wells ($r = 0.40$; $p > 0.01$), rivers and wells ($r = 0.26$; $p > 0.01$), fishing and wells ($r = 0.31$; $p > 0.01$), rivers and backwaters ($r = 0.50$; $p > 0.01$), fishing and backwater ($r = 0.40$; $p > 0.01$) and fishing versus rivers ($r = 0.39$; $p > 0.01$).

Table 6.15: Pearson's Correlations of Water Sources and Usages

	Location	Wells	Backwater	River	Water vendor	Fishing	Aquaculture
Location	1						
Wells	-0.853**	1					
Backwater	-0.416**	0.402**	1				
River	-0.285**	0.260**	0.509**	1			
Water vendor	0.204**	-0.223**	-0.096	-0.058	1		
Fishing	-0.280**	0.315**	0.403**	0.394**	-0.099	1	
Aquaculture	0.032	-0.047	0.092	0.076	-0.033	0.086	1

**. Correlation is significant at the 0.01 level (2-tailed).

6.3.15 Regression Results of Fisheries and Water Usage

Fisheries are one of the most important aquaculture activities in the sub Saharan Africa. In Mali, fishing activities are mostly based on traditional fishing methods, due to climate change over the years. Rivers and lakes become contaminated with different chemical products through anthropogenic activities in artisanal gold mining areas. Water mostly used by majority of the households was collected from wells, backwater, rivers and these sources serve other economic activities like water vending activity, fishing and aquaculture. For instance, water used from wells was significantly and negatively related to location ($p > 0.001$) and influenced households' water consumption for different domestic activities.

Table 6.16: Logit Regression of Water Usage by Community

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Wells	-5.098	0.687	55.002	0.000***
Backwater	-1.358	1.006	1.819	0.177
River	-18.716	10129.712	0.000	0.999
Water vendor	17.920	14210.361	0.000	0.999
Fishing	0.465	0.722	0.415	0.519
Aquaculture	0.290	2.603	0.012	0.911
Constant	**3.283**	**0.594**	**30.540**	**0.000**

Note: ***significant at 1% level.

These parameters were run so as to fund out which amongst the different sources of water mostly maintained households for different domestic activities. The results shown that water from wells (-5.098) had a strong negative correlation to localities of study areas. This means that wells were the common source of water used by households in these areas. It may affect population health if there is no control of wells' water for usages. Backwaters (-1.358) and rivers (-18.716) were negatively correlated to localities but not strong in term of regression significance. The explanation was that populations already knew that water from these sources were slowly being contaminated by artisanal gold-mining activity hence it was not safe for households' domestic activities. If $= 0 + \quad + \quad + \quad + \quad + \quad + \quad +$ then variables in equation were $= 3.283 \quad - 5.098 \quad - 1.358 \quad - 18.716 \quad + 17.920 \quad + 0.465 \quad + 0.290$

6.3.16 Descriptive Statistics of Land Tenure

The community land property right was recognized and worked in the land were 167 households interviewed representing around 83.5% of study population. Those who did not work on community land were 33 representing 16.5% of the respondents. The distribution was 69 respondents who worked on the community land were from the non-mining site and 98 from the mining site. Those who did not work on the community land were 31 from the non-mining site and 2 from the mining site. The Chi-Square was (χ^2 = 30.52) with the significance level of (p = 0.000).

Table 6.17: Land Property Rights in Mining Zone

	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
Community right						
No	33	16.5	31	2	**30.521**	**0.000**
Yes	167	83.5	69	98		
Private						
No	137	68.5	42	95	**65.091**	**0.000**
Yes	63	31.5	58	5		
Public						
No	104	52	99	5	**177.003**	**0.000**
Yes	96	48	1	95		

The private right of land was quoted by 63 interviewed households (58 from the non-mining site and 5 respondents from the mining site) represented by 31.5% of study population. There were 137 households (42 from the non-mining site and 95 from the mining site) represented by 68.5% who did not own private right of land among the study population. The Chi-Square was (χ^2 = 65.09) with the significance level of (p = 0.000).

The number of the respondents who worked on or had the right on the public or government land was observed in 96 interviewed households represented by 48% of population. There were 104 households represented by 52% in which people were not working on the public land. The distribution of the respondents was 1 from the non-mining site and 95 from the mining site who gave positive responses. There were 99 respondents from the non-mining site and 5 from the mining site who gave negative responses. The Chi-Square was (χ^2 = 177.00) with the significance level of (p = 0.000).

Land tenure issues were affected populations surrounding Farabacoura artisanal gold mining area. These land issues were such as lack of management policy and official ownership which are unsustainable socio-economic and agricultural development pathways. For instance, the importance of land policy in agricultural transformation in Africa was developed by Jayne *et al.* (2016) in which the economic growth inclusivity depend on good policy framework of land for Africa. In addition, the land related disputes in term of intra-household affecting women in rural Rwanda was documented by Kloos *et al.* (2016), they were underlying more than 400 cases of peaceful resolution of land conflict issues with the consideration of gender. Furthermore, land tenure insecurity in Mali was reported by USAID (2010) in which there were issues such as demographic growth, unsustainable land and natural resources management practices, climate change, lack of good governance and competence within the land administration affected smallholders, women and youth, migrant populations, investors and fisherman. All those parameters highlighted above are land uses optimization which affects crop farmers (Abah *et al.,* 2016).

6.3.17 Correlation of Land Property Right

The correlation of land property right included community right, private right, government or public right and about locality. Results showed that there were significant strong negative relationships between private right and location ($r = -0.57$; $p > 0.01$), private right and community right ($r = -0.65$; $p > 0.01$) and between government versus private right ($r = -0.60$; $p > 0.01$). In addition, there were significant strong positive relationships between community right and location ($r = 0.39$; $p > 0.01$), government right and location ($r = 0.94$; $p > 0.01$) and between government versus community right ($r = 0.40$; $p > 0.01$).

Table 6.18: Pearson's Correlations of Land Property Right

	Location	Community right	Private right	Government/ Public right
Location	1			
Community right	0.391**	1		
Private right	-0.570**	-0.656**	1	
Government/Public right	0.941**	0.400**	-0.608**	1

**. Correlation is significant at the 0.01 level (2-tailed).

6.3.18 Regression of Land Property Right

Land right is declining to be for government generally in Mali (Constitution, 1992). Indeed, there are two others property rights which include community and private. In fact, artisanal gold mining exploitation is under community right in term of common resources in the country. There is a type of exploitation called "draguage" meaning excavator system which is a contract between private investors and the government of Mali. These private investors are exploiting gold directly on rivers and backwaters with government licenses or authorization over the country.

Land monitoring in the Republic of Mali is by three types of right. The first right is for government which includes all the territory of the country, all aspect of defense, questions linked to boundaries and community conflict. The second is all about the traditional laws and rights of communities. These are usually called accustomed laws and rights. In other words, they are first occupants, inhabitants, settlers at the place. Ordinarily, these rights and laws are includes follow-ups and monitoring by traditional chief of villages, sub-counties and counties undertaking the government right (Constitution, 1992).

Table 6.19: Logit Regression of Land Property Right in Tangandougou

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Community right	0.819	1.239	0.437	0.509
Private right	0.433	1.027	0.178	0.673
Government	7.587	1.230	38.061	0.000***
Constant	**-3.851**	**1.439**	**7.161**	**0.007**

Note: *** significant at 1% level.

The parameters run about the property right were checking the ownership of land used on gold-mining and non-mining sites. These were attributed to community right, private right and government or public right of land. They were all positively and strongly correlated to localities with the coefficient of community right (0.819), private right (0.433) and government right (7.587). If $= 0 + \quad + \quad + \quad +$ so the variables in equation were $= 0.819 \quad + 0.433 \quad + 7.587 \quad - 3.851$

6.3.19 Descriptive Statistics of Traditional Environmental Knowledge

There were 190 respondents (representing 95%) who acknowledged the understanding of the deteriorating environmental conditions especially water quality in study areas. Only 10 respondents representing 5% of study population failed to acknowledge the deteriorating environmental conditions. In the non-mining site, there were 97 positive responses observed against 93 from the mining site. The negative responses on the acknowledgement of the environmental conditions were 3 from the non-mining site and 7 from the mining site. The Chi-Square was (χ^2 = 1.68) with the significance level of (p = 0.181).

The understanding and acknowledgment of the functions of the aquatic ecosystem was quoted by 168 respondents from the households representing 84% of population in study areas. There were 32 respondents (7 from the non-mining site and 25 from the mining site) household (16%) in which people did not acknowledgement of the aquatic ecosystem. The distribution was 93 from the non-mining site and 75 from the mining site had a positive response. The Chi-Square was (χ^2 = 12.05) with the significance level of (p = 0.001).

The pollution of water by AGM was recognized by 139 respondents representing 69.5% of the entire study population. Those that had limited ideas about water pollution were 61 represented by 30.5% of target population. On non-mining site, there were 92 positive responses 47 from the mining site about the information on water pollution by the artisanal gold mining. On the other hand, there were 8 respondents from the non-mining site against 53 from the mining site with negative responses on the connection between artisanal gold mining and water pollution. The Chi-Square was (χ^2 = 47.76) with the significance level of (p = 0.000) in study areas.

They were 185 households (97 from the non-mining site against 88 from the mining site) representing 92.5% in which the respondents confirmed the occurrence of land degradation. However, 15 households (3 from the non-mining site against 12 from the mining site) represented by 7.5% of people interviewed who did not confirm land degradation was taking place. The Chi-Square was (χ^2 = 5.83) with the significance level of (p = 0.029).

They were 112 households interviewed represented by 56% in which people accepted that mining affects water available for agriculture. Those who did not recognize the effects of mining on the agricultural water were 88 respondents (44%) of study population. From the non-mining site, they were 85 positive responses against 27 from the mining site. There were 15 negative responses on the effects on mining on agricultural water from the non-mining site and 73 from the mining site. The Chi-Square was (χ^2 = 68.26) with the significance level of (p = 0.000).

The perceptions of community about labor transfer from the other sectors of the economy especially the agricultural production to the artisanal gold mining was179 respondents which were represented by 89.5% of the interviewed population. The contrary was 21 respondents representing 10.5% (comprising 4 from the non-mining site and 17 from the mining one) in study areas. The distribution was 96 people from the non-mining site against 83 from the mining site for the acknowledgement of the labor transfer. The Chi-Square was (χ^2 = 8.99) with the significance level of (p = 0.005).

Table 6.20: Community Perception on Environmental Changes

	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
Water Quality						
No	10	5	3	7	**1.684**	**0.331**
Yes	190	95	97	93		
Ecosystem						
No	32	16	7	25	**12.054**	**0.001**
Yes	168	84	93	75		
Pollution						
No	61	30.5	8	53	**47.765**	**0.000**
Yes	139	69.5	92	47		
Land degradation						
No	15	7.5	3	12	**5.838**	**0.029**
Yes	185	92.5	97	88		
Crop water						
No	88	44	15	73	**68.263**	**0.000**
Yes	112	56	85	27		
Labor spoliation						
No	21	10.5	4	17	**8.992**	**0.005**
Yes	179	89.5	96	83		
Livestock pasture						
No	13	6.5	5	8	**0.740**	**0.568**
Yes	187	93.5	95	92		
Livestock water						
No	68	34	7	61	**64.973**	**0.000**
Yes	132	66	93	39		
Livestock procreation						
No	38	19	5	33	**25.471**	**0.000**
Yes	162	81	95	67		

The impact of artisanal gold-mining on pasture was testified by 187 respondents (93.5%) of study population. Those who did not recognize the impact of artisanal gold mining on the pasture were 13 respondents which were represented by 6.5% of the total individuals interviewed. They were 95 positive responses from the non-mining site and 92 from the mining site. Those who felt that artisanal gold mining had no impacts on the pasture were 5 from the non-mining site against 8 from the mining site. The Chi-Square was (χ^2 = 0.74) with the significance level of (p = 0.568).

The contamination of the water for livestock production was responded by 132 households which were represented by 66% of study population. There were 68 households representing about 34% of entire study population who did not accept that the water quality for livestock was a problem in study areas. In non-mining site, there were 93 positive responses against 39 observed from the mining site. In contrast, they were 7 negative responses from the non-mining site against 61 observed from the mining site. The Chi-Square was (χ^2 = 64.97) with the significance level of (p = 0.000).

The impact of AGM on livestock production and rearing was acknowledged by 162 households representing 81% of study population. Those who did not recognize the problem of livestock production was due to artisanal gold mining were 38 households (19%) of the study population. It was not equally distributed 95 positive responses from the non-mining site and 67 from the mining site. On the hand, there was 5 negative responses from the non-mining site and 33 observed from the mining site. The Chi-Square was (χ^2 = 25.47) with the significance level of (p = 0.000).

Community perceptions on environmental change were oriented towards water quality. Water pollution by artisanal gold mining was a major challenge to the community in study areas. Because of the rarity of rainfall, the quantities of water in rivers and backwaters have started to reduce gradually. Consequently, this lack of enough and quality water affected crops and livestock production. The community needs to adopt water collection strategies during the rainfall season to help during dry season for different activities. Garvin *et al.* (2009) reported that community members and gold mining extractive companies in terms of impact whereby mining undertaken place in Ghana. Similarly, the perceptions of Tangandougou commune differ according to the relationships between miners and authorities, farmers and many others.

6.3.20 Correlations Results on Community Perception

The correlation of community perception on traditional environmental knowledge was based on factors such as water quality, ecosystem management, land degradation, water for crops production, labor transfer, grazing pasture degradation, water for livestock, livestock rearing run about location. For instance, results showed that there were significant negative relationships between these parameters and location ecosystem management ($r = -0.24$; $p > 0.01$), pollution of water ($r = -0.48$; $p > 0.01$), land degradation ($r = -0.17$; $p > 0.05$), water for crops production ($r = -0.58$; $p > 0.01$), labor transfer ($r = -0.21$; $p > 0.01$), water for livestock production ($r = -0.57$; $p > 0.01$) and livestock rearing ($r = -0.35$; $p > 0.01$).

There were significant positive relationships between these variables and water quality such as ecosystem management ($r = 0.27$; $p > 0.01$), pollution of water ($r = 0.24$; $p > 0.01$), land degradation ($r = 0.45$; $p > 0.01$), water for crops production ($r = 0.16$; $p > 0.05$), labor transfer ($r = 0.44$; $p > 0.01$), grazing pasture ($r = 0.59$; $p > 0.01$), water for livestock ($r = 0.22$; $p > 0.01$), livestock rearing ($r = 0.29$; $p > 0.01$). There were also significant positive relationships between ecosystem management and these parameters which included pollution of water ($r = 0.24$; $p > 0.01$), water for crops production ($r = 0.27$; $p > 0.01$), labor transfer ($r = 0.16$; $p > 0.05$), grazing pasture ($r = 0.21$; $p > 0.01$), water for livestock ($r = 0.20$; $p > 0.01$) and livestock rearing ($r = 0.34$; $p > 0.01$).

In addition, results showed that there were significant positive relationships between pollution of water and water for crops production ($r = 0.52$; $p > 0.01$), labor transfer ($r = 0.23$; $p > 0.01$), grazing pasture ($r = 0.22$; $p > 0.01$), water for livestock ($r = 0.15$; $p > 0.05$) and livestock rearing ($r = 0.20$; $p > 0.01$). It was observed also that there were significant positive relationships between water for crops and labor transfer ($r = 0.22$; $p > 0.01$), water for livestock ($r = 0.51$; $p > 0.01$) and grazing pasture ($r = 0.44$; $p > 0.01$). There were significant positive relationships between labor spoliation and grazing pasture ($r = 0.37$; $p > 0.01$), water for livestock ($r = 0.30$; $p > 0.01$) and livestock production ($r = 0.16$; $p > 0.01$). It was also observed that there was a significant positive relationships between grazing pasture and water for livestock ($r = 0.23$; $p > 0.01$) and livestock procreation ($r = 0.28$; $p > 0.01$). The last significant positive relationship was between water for livestock and livestock production ($r = 0.37$; $p > 0.01$).

Table 6.21: Pearson's Correlations of Community Perception on Environmental Change

	Location	Quality water	Ecosystem	Pollution water	Land degradation	Water for crops	Labor Spoliation	Grazing pasture	Water for livestock	Livestock procreation
Location	1									
Quality water	-0.092	1								
Ecosystem	-0.245**	0.275**	1							
Pollution of water	-0.489**	0.247**	0.244**	1						
Land degradation	-0.171*	0.457**	0.083	0.100	1					
Water for crops	-0.584**	0.166*	0.273**	0.529**	0.092	1				
Labor spoliation	-0.212**	0.445**	0.162*	0.234**	0.336**	0.222**	1			
Grazing pasture	-0.061	0.591**	0.217**	0.222**	0.387**	0.134	0.373**	1		
Water for livestock	-0.570**	0.223**	0.205**	0.464**	0.156*	0.512**	0.305**	0.239**	1	
Livestock procreation	-0.357**	0.298**	0.345**	0.427**	0.201**	0.444**	0.167*	0.286**	0.379**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

6.3.21 Logit Model on Community Perception of Environmental Change

Basically, majority of the people understands fully that nature is changing as depicted in the Tangandougou commune. For example, they have testified within this study that environmental parameters have been shifting with time. The parameters that majority of the respondents appreciated are the ones which affected them directly through the environmental conditions surrounding them. This can be supported by the results from households survey which showed that water pollution ($p > 0.010$), water for crops production ($p > 0.001$) and water for livestock production ($p > 0.001$) are significantly and negatively impacted by artisanal gold mining activities. This confirms their environmental knowledge about phenomena surrounding their agricultural productivity namely, the socio-system and ecosystem.

As much as it may be difficult for the locals to state with clarity the degree of significance of the impacts due to difficulties in evaluation, they all acknowledge that these impacts are anthropogenic in nature and could make them more uncomfortable in the future. However, some believe that change is coming from God and humans cannot do anything about it. So the philosophy of fatality and myth are behind rural comprehension in this study area. But rarity of raining is known and also natural vegetation and forest cover are degrading gradually. These are some few signs which were observed by respondents as it was discussed during the focus group discussions.

Table 6.22: Logic Regression Results on Environmental Change

Explanatory Variables	**Coeff.**	**S.E.**	**Wald**	**Sig.**
Quality water	1.703	1.272	1.792	0.181
Ecosystem	-0.912	0.634	2.069	0.150
Pollution of water	-1.422	0.556	6.554	0.010**
Land degradation	-1.528	0.821	3.464	0.063
Water for crops	-1.607	0.455	12.493	0.000***
Labor spoliation	-0.214	0.828	0.067	0.796
Grazing pasture	2.048	1.141	3.219	0.073
Water livestock	-2.412	0.578	17.392	0.000***
Livestock procreation	-0.273	0.694	0.155	0.694
Constant	**2.803**	**1.132**	**6.133**	**0.013**

Note: ***; ** significant at 1% and 5% levels respectively.

These parameters were run with the idea to know if the populations in study area have knowledge about environmental change. The strong correlations were given by the positive coefficients to the quality of water (1.703) and to the destruction of grazing pasture (2.048). The negative strong correlations were given by the coefficients to ecosystem (-0.912), pollution of water (-1.422), land degradation (-1.528), water for crops (-1.607), labor transfers (-0.214), water for livestock (-2.412) and livestock rearing (-0.273). If $= 0 + \quad + \quad + \quad + \quad + \quad + \quad + \quad + \quad + \quad +$ so variables in equation were $= 2.803 \quad + 1.703 \quad - 0.912 \quad - 1.422 \quad - 1.528 \quad - 1.607 \quad - 0.214 \quad + 2.048 \quad - 2.412 \quad - 0.273$

6.3.22 Descriptive Statistics of Social Change

The impact of artisanal gold mining about increasing living cost was admitted in 198 (100 people from the non-mining site and 98 from the mining site) households representing 99% of the respondents. Those who did not admit the impacts of artisanal gold mining on the living standards were 2 households (from the mining site) represented by 1% of study population. The Chi-Square was ($\chi^2 = 2.02$) with the significance level of ($p = 0.497$).

The proliferation of prostitution within the mines and the other businesses connected to gold mining was quoted by 198 households which were represented by 99% of the respondents within the study population. Those who did not quote that there was proliferation of prostitution in the area were 2 (each from the mining and the non-mining sites) representing 1% among interviewed population. There were 99 households each from the mining and the non-mining sites who accepted that there was proliferation of prostitution. The Chi-Square was ($\chi^2 = 0.00$) with the significance level of ($p = 1.000$).

The occurrence of conflicts between miners and crops farmers was accepted by 102 households which were represented by 51% of study population. However, 98 households (21 from the non-mining site against 77 from the mining site) represented by 49% of the study population did not acknowledge that existence of any conflicts. Those who accepted the existence of conflicts were 79 respondents from the non-mining site against 23 from the mining site. The Chi-Square was ($\chi^2 = 62.74$) with the significance level of ($p = 0.000$).

Table 6.23: Gold Mining Impacts on Social Changes

	Freq.	%	N = 200 Non-Mining	Mining	χ^2 Value	P Value
Living cost increasing						
No	2	1	0	2	**2.020**	**0.497**
Yes	198	99	100	98		
Prostitution						
No	2	1	1	1	**0.000**	**1.000**
Yes	198	99	99	99		
Miners & Farmers						
No	98	49	21	77	**62.745**	**0.000**
Yes	102	51	79	23		
Miners & livestock Famers						
No	129	64.5	36	93	**70.947**	**0.000**
Yes	71	35.5	64	7		
Miner & Natives						
No	69	34.5	30	39	**1.792**	**0.234**
Yes	131	65.5	70	61		
Miners & Authorities						
No	107	53.5	33	74	**33.786**	**0.000**
Yes	93	46.5	67	26		
Miners & Miners						
No	66	33	5	61	**70.918**	**0.000**
Yes	134	67	95	39		
Traditional Management						
No	34	17	8	26	**11.481**	**0.001**
Yes	166	83	92	74		
Classic Management						
No	106	53	51	55	**0.321**	**0.671**
Yes	94	47	49	45		

The conflict between miners and livestock farmers was acknowledged by 71 households (64 people who accepted from the non-mining site against 7 from the mining site), represented by 35.5% of study population. There were 129 households represented by 64.5% (36 people from the non-mining site against 93 from the mining site) in which people did not accept that there were conflicts between miners and livestock farmers. The Chi-Square was (χ^2 = 70.94) with the significance level of (p = 0.000). The conflict between miners and natives was quoted by 131 households, represented by 65.5% of study population. There were 69 households, represented by 34.5% in which people did not quote conflict between miners and natives. On non-mining site, there were 70 observed households against 61 from the mining site in which there were acceptance of the existence of conflicts between the miners and the natives within the study sites. There were 30 households from the non-mining site and 39 from the mining site where the respondents gave contrary response. The Chi-Square was (χ^2 = 1.79) with the significance level of (p = 0.234).

The existence of conflicts between miners and authorities were acknowledged by 93 respondents, represented by 46.5% of study population. Those who did not recognize that there were emerging conflicts were 107 interviewed households representing 53.5% of the respondents within the study areas. The distribution was 67 households from the non-mining site against 26 from the mining site for those who gave a positive response. Those who gave negative responses were 33 respondents from the non-mining site against 74 from the mining site. The Chi-Square was (χ^2 = 33.78) with the significance level of (p = 0.000).

The existence of the usual business and economic conflicts amongst the miners was accepted by 134 respondents' households, which were represented by 67% of the study population. Those who did not acknowledge the recognition of the conflicts amongst the miners were 66 households representing about 33% of observed population. From the non-mining site, there were 95 households against 39 from mining site who gave positive responses. Those who did not recognize the existence of the conflicts amongst the miners were 5 from the non-mining site and 61 from the mining site. The Chi-Square was (χ^2 = 70.91) with the significance level of (p = 0.000).

The management of conflict with traditional using the traditional systems was accepted by 166 respondents' households, represented by 83% of study population. Those who did not the use of the traditional conflict management systems were 34 (17%) of the study population. The distribution of the respondents was 92 households from the non-mining site against 74 from mining site were among those who gave the positive response. However, those who gave a negative response were 8 from the non-mining site and 26 from the mining site. The Chi-Square was (χ^2 = 11.48) with the significance level of (p = 0.001).

Classic resolution of conflict was testified by 94 respondents representing 47% of observed population. Those who did not testify were 106 (53%) of the study population. There were 49 respondents from the non-mining site against 45 from the mining site who gave positive responses. There were 51 respondents from the non-mining site and 55 from the mining site for negative answers. The Chi-Square was ($\chi^2 = 0.32$) with the significance level of ($p = 0.671$).

The preoccupations of social changes were mostly oriented towards conflict between miners and crops farmers, livestock farmers, and natives amongst the miners themselves (Coulibaly, 2017; Urkidi and Walter, 2011). These social factors were potential barrier which affected all development activities. In fact, the most conflicts observed were about land use between natives but also different farmers and miners. Authorities should classify and allocate all lands in Mali for different purposes. That identification of lands has to resolve the problems of property right of natural resources exploitation hence promoting sustainability.

6.3.23 Correlations of Gold Mining Impacts on Social Change

The social change correlation was a concern due to effects like the increased of cost of living, the proliferation of prostitution, conflicts between miners and crops farmers, livestock farmers, native people, authorities, miners and type of conflicts resolution based on the application of both the traditional and modern management methods among others. For instance, there were significant negative relationships between location and miners-crops farmers ($r = -0.24$; $p > 0.01$), miners-livestock farmers ($r = -59$; $p > 0.01$), miners-authorities ($r = -0.41$; $p > 0.01$), miners-miners ($r = -0.59$; $p > 0.01$) and traditional management ($r = -0.24$; $p > 0.01$).

There were significant positive relationships between prostitution proliferation and increased cost living ($r = 0.49$; $p > 0.01$), conflicts of miners versus prostitution proliferation ($r = 0.14$; $p > 0.05$), traditional management and prostitution ($r = 0.22$ $p > 0.01$), conflicts between miners-livestock farmers and crops farmers ($r = 0.72$; $p > 0.01$), miners-natives and miners-crops farmers ($r = 0.40$; $p > 0.01$), miners-authorities versus miners-crops farmers ($r = 0.41$; $p > 0.01$), amongst the miners and miners-crop farmers ($r = 0.52$; $p > 0.01$), traditional management and miners-crop farmers ($r = 0.27$; $p > 0.01$) and classic management versus miners-crop farmers ($r = 0.18$; $p > 0.05$). There were also significant positive relationships between miners-natives and miners-livestock farmers ($r = 0.42$; $p > 0.01$); miners-authorities versus miners-livestock farmers ($r = 0.52$; $p > 0.01$), miners-miners and miners-livestock farmers ($r = 0.52$; $p > 0.01$) and traditional management versus miners-livestock farmers ($r = 0.19$; $p > 0.01$). In addition, there were significant positive relationships between miners-natives and miners-authorities ($r = 0.23$; $p > 0.01$), miners-miners ($r = 0.16$; $p > 0.05$) and traditional management ($r = 0.28$; $p > 0.01$). The significant positive relationships were observed also between miners-authorities and miners-miners ($r = 0.42$; $p > 0.01$) and traditional management ($r = 0.26$; $p > 0.01$). The last significant positive relationships were between miners-miners and traditional management ($r = 0.39$; $p > 0.01$) and classic management ($r = 0.25$; $p > 0.01$).

Table 6.24: Pearson's Correlations of Social Change

	Location	Increase living	Increase prostitution	Miners & farmers	Miners & livestock	Miners & natives	Miners & authorities	Miners & miners	Traditional manag.	Classic manag.
Location	1									
Increase living	-0.101	1								
Increase prostitution	0.000	0.495**	1							
Miners & farmers	-0.560**	0.103	0.103	1						
Miners & livestock-farmers	-0.596**	0.075	0.075	0.727**	1					
Miners & natives	-0.095	0.033	0.138	0.404**	0.429**	1				
Miners & authorities	-0.411**	0.094	0.094	0.412**	0.523**	0.234**	1			
Miners & miners	-0.595**	0.036	0.143*	0.525**	0.521**	0.162*	0.420**	1		
Traditional management	-0.240**	0.088	0.222**	0.275**	0.197**	0.288**	0.262**	0.390**	1	
Classic management	-0.040	-0.006	0.095	0.182*	-0.008	0.072	0.086	0.256**	-0.027	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

6.3.24 Logit Regression of Gold Mining Impacts on Social Changes

Artisanal Gold mining has multi-dimensional social impacts on communities surrounding the sites. Usually, it increases the cost of living through the price inflation of items in local markets. This local market is also opportunities for sex workers and drug dealers. Whenever, the individuals are carrying on with their daily activities conflicts of any kind may arise, others based on the nature of activity involved. For example, miners and natives farmers' conflicts are based on the limit of the site for mining activities and farm exploitation methods. This kind of conflict is very frequent between livestock farmer and miners. The most common form of the conflict is the personal and selfish interests from traditional land owners, the other stakeholders and the government authority. This makes the site to be operated with limited regards to the laid down control and management rules.

Table 6.25: Logit Regression Results of Gold Mining Impacts on Social Changes

Explanatory Variables	Coeff.	S.E.	Wald	Sig.
Increase living cost	-40.305	33620.410	0.000	0.999
Increase prostitution	22.848	23773.208	0.000	0.999
Miners & farmers	-1.577	0.586	7.247	0.007
Miners & livestock farmers	-1.745	0.654	7.127	0.008
Miners & natives	1.776	0.571	9.662	0.002**
Miners & authorities	-0.716	0.471	2.308	0.129
Miners & miners	-2.735	0.701	15.234	0.000***
Traditional management	-0.344	0.712	0.233	0.629
Classic management	0.610	0.476	1.644	0.200
Constant	**20.153**	**23773.232**	**0.000**	**0.999**

Note: ***; ** significant at 1% and 5% levels respectively.

The social impacts due to artisanal gold mining at Farabacoura are escalating with time. The negative social impacts outweigh the positives as they are accompanied with criminality and delinquency of youth and women in communities surrounding mining site. It is also a vector that could set couples to be divorced. For example, the Mayor of Tangandougou stated that they handled fifty (50) divorce cases during the last two years (2014 – 2016). That is due to rural migration, money and materials temptation. All these factors explained above are disturbances of households' productivity. Results showed that the conflicts between miners and crops farmers ($p > 0.007$), miners and livestock farmers ($p > 0.008$), miners and natives ($p > 0.002$) and between miners ($p > 0.001$).

The social change had a strong positive correlation to localities given by the coefficient for prostitution (22.848), conflict between miners and natives (1.776) and classic management of conflict (0.610). The negative strong correlation was given by the coefficients for the increasing cost living (-40.305), conflict between miners and crops farmers (-1.577), conflict of miners and livestock farmers (-1.745), conflict between miners and authorities (-0.716), conflict between miners (-2.735) and the traditional management of conflict observed (-0.344). If $= 0 + \quad + \quad + \quad + \quad + \quad + \quad + \quad + \quad + \quad +$ so the variables in equation were $= 20.153 \quad - 40.305 \quad + 22.848 \quad - 1.577 \quad - 1.745 \quad + 1.776 \quad - 0.716 \quad - 2.735 \quad - 0.344 \quad + 0.610$

6.3.25 Descriptive Statistics of Community Preference

Crops production was preferred by 119 households (77 from the non-mining site against 42 from the mining site) represented by 59.5% of observed population. Those who did not prefer crops production were 81 or about 40.5% of the study population. It was observed that 23 negative responses emanated from the non-mining site and 58 from the mining site. The Chi-Square was (χ^2 = 25.41) with the significance level of (p = 0.000).

Livestock production was carried out by 67 households represented by 33.5% of study population. Those who did not practice livestock production were 133 households represented by 66.5% of observed population. The activity of livestock rearing was reported by 42 households from the non-mining site and 25 from the mining site. In contrast, there were 58 households from the non-mining site against 75 from the mining site in which negative responses were observed in study areas. The Chi-Square was (χ^2 = 6.48) with the significance level of (p = 0.016).

Fisheries as an economic activity were practiced by 14 respondents' households or about 7% of the study population. There were 186 households represented by 93% in which people did not prefer fisheries. From the non-mining site, it was observed by 8 households against 6 from the mining site in which respondents preferred fisheries. The contrary was 92 respondents from the non-mining site against 94 from the mining site who were not involved in the fisheries activities. The Chi-Square was (χ^2 = 0.30) with the significance level of (p = 0.783).

Table 6.26: Community Preferences among Agriculture Activities in Tangandougou

Crop production	Freq.	%	N = 200		χ^2 Value	P Value
			Non-Mining	Mining		
No	81	40.5	23	58	**25.418**	**0.000**
Yes	119	59.5	77	42		
Livestock						
No	133	66.5	58	75	**6.486**	**0.016**
Yes	67	33.5	42	25		
Fisheries						
No	186	93	92	94	**0.307**	**0.783**
Yes	14	7	8	6		
Beekeeping						
No	193	96.5	93	100	**7.254**	**0.014**
Yes	7	3.5	7	0		
Agroforestry						
No	138	69	45	93	**53.857**	**0.000**
Yes	62	31	55	7		

There were 7 households all from the non-mining site represented by 3.5% of study population in which people preferred beekeeping. It was observed that 193 households represented by 96.5% of the respondents who did not prefer beekeeping. In contrast, there were 93 households observed from the non-mining site against 100 from the mining site in which people did not prefer beekeeping. The Chi-Square was (χ^2 = 7.25) with the significance level of (p = 0.014).

Agroforestry production was preferred by 62 interviewed households represented by 31% of the study population. Those who did not prefer agroforestry within the study area were 138 households represented by 69% among study population. There were 55 households from the non-mining site against 7 from the mining site who gave positive responses. The contrast was 45 interviewed households from the non-mining site against 93 from the mining site with negative responses. The Chi-Square was (χ^2 = 53.85) with the significance level of (p = 0.000).

6.3.26 Correlations of Community Preferences

The correlation analysis included crops production, livestock production, fisheries, beekeeping and agroforestry. Results showed that there were significant negative relationships between location and crops production (r = -0.35; p > 0.01), livestock production (r = -0.18; p > 0.05), beekeeping (r = -0.19; p > 0.01) and agroforestry (r = -0.51; p > 0.01).

There were also significance positive relationships between crops production versus beekeeping (r = 0.15; p > 0.05) and agroforestry (r = 0.17; p > 0.05). It was observed that livestock production was significantly and positively related to fisheries (r = 0.22; p > 0.01), beekeeping (r = 0.26; p > 0.01) and agroforestry (r = 0.23; p > 0.01). The last significant positive relationships were between fisheries and beekeeping (r = 0.48; p > 0.01) and beekeeping versus agroforestry (r = 0.22; p > 0.01).

Table 6.27: Pearson's Correlations of Community Preferences

	Location	Crops production	Livestock production	Fisheries	Beekeeping	Agroforestry
Location	1					
Crops production	-0.356**	1				
Livestock production	-0.180*	0.132	1			
Fisheries	-0.039	0.027	0.220**	1		
Beekeeping	-0.190**	0.157*	0.268**	0.481**	1	
Agroforestry	-0.519**	0.179*	0.234**	0.113	0.225**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

6.3.27 Logit Regression Results of Community Preferences

Results showed that community preferences about agriculture activities such as crops production (p > 0.001) and agroforestry (p > 0.001) were significantly and positively accepted in most of households among observed population in study areas. The main crops produced included cereals and vegetables plus agroforestry were the principal agriculture activities in Tangandougou commune during the period of this study. Livestock, fisheries and beekeeping should be more promoted so as to ensure revenues diversification in these areas.

Table 6.28: Logit Regression Results of Community Preferences

Explanatory Variables	**Coeff.**	**S.E.**	**Wald**	**Sig.**
Crops production	-1.485	0.372	15.965	0.000***
Livestock production	-0.288	0.402	0.512	0.474
Fisheries	0.628	0.996	0.398	0.528
Beekeeping	-19.595	14409.267	0.000	0.999
Agroforestry	-2.711	0.471	33.142	0.000***
Constant	**1.692**	**0.335**	**25.580**	**0.000**

Note: *** significant at 1% level

Crop production (-1.485) and agroforestry (-2.711) were significantly negative among the various practiced agricultural activities. They had best explanatories than livestock production (-0.288), fishing (0.628) and beekeeping (-19.595). More importantly, these populations should be more orientated on crops production and agroforestry so as to ensure food security in this area. If $= 0 + \quad + \quad + \quad + \quad + \quad +$ so the variables in equation were $= 1.692 \quad - 1.485 \quad - 0.288 \quad + 0.628 \quad - 19.595 \quad - 2.711$

6.4 Conclusion and Recommendations

Artisanal gold-mining negatively affects agricultural development in the study area. A number of residents have abandoned agriculture for gold mining hence impacting negatively on agroforestry, fisheries, crops and livestock production. For agriculture to be developed, emphasize should be on small and proximity irrigation, collection of rainfall water, livestock breeding and agribusiness enterprises so as to increase farmers' profits. These should be organized as integrated system for sustainable agriculture (ISSA) under functional units of system theory. This strategy has to be supported by national and local government policies.

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CHAPITER SEVEN

SOURCES OF HOUSEHOLDS INCOMES IN TANGANDOUGOU COMMUNE

7.1 Introduction

Mining activities generate incomes through direct employment for households in rural areas but it has also negative impacts on human societies and the environment (Zhang and Moffat, 2015). Apart from gold mining activities the communities in Tangandougou were usually based on such crops and livestock production, agroforestry and fisheries. These activities were characterized by research of incomes so as to cover households' expenditure in Tangandougou community. In most of the cases for households, the incomes were done from these economic activities for substance food, health care and many others. Tenkorang and Osei-Kufuor (2013) reported that most of these leases were for surface mining displacing the original owners from large arable land needed for their livelihoods. This situation makes the local people vulnerable to local economic shock which were undertaken in crops and livestock production, agroforestry and fisheries (Hilson, 2016). The real benefits accruing to the ordinary local communities is simply taken, for granted as monetary compensation is paid to affected community members in case of industrial exploitation, but not for artisanal mining that may poses household incomes distribution from others activities (Adu *et al.,* 2016; Tenkorang and Osei-Kufuor, 2013) . Even though, such palliative payments to people displaced by mining activities do not address the existing vulnerabilities of these mining communities (Tenkorang and Osei-Kufuor, 2013). On both the mining and the non-mining sites, the sources of households' incomes comprised of gold mining, crops and livestock production, agroforestry and fisheries in Tangandougou Commune. Agriculture is the backbone of the country's economy, especially cereals crops and livestock production. In Malian rural areas, the majority of household depend on agriculture for their livelihoods. Yet, food insecurity remains important in rural Mali, although agricultural development was promoted by national government and international donors since 2006. This fact of food insecurity motivates rural populations to be engaged in artisanal gold mining in Mali. Similarly, Cartier and Bürge (2011) documented the case of Sierra Leone by "the ongoing lack of viable livelihood opportunities for rural populations is a serious issue in post-conflict Sierra Leone, and it has meant that many individuals and communities have no choice but to turn to (informal) gold or diamond mining as a source of income in their efforts to combine food security and generate revenue". In addition, the impacts of artisanal gold mining was summered by Meisanti *et al.* (2012) to three principals' parameters in Indonesia (social, economic and environmental), which were influenced farmers and communities surrounding mining in term of daily activities. As a matter of fact, the presence of the gold mining changed the social structure of the farming society and affected their social interactions. This kind of situation was made the local people vulnerable to economic uncertainties in Ghana (Tenkorang and Osei-Kufuor, 2013). This objective was conceived to determine different sources of households' incomes in Tangandougou commune, Sikasso region in Mali. Thus would like to know more on which sources of incomes have to be improved so as to enhance food security and nutrition in Sikasso region.

7.2 Materials and Methods

7.2.1 Methods for Data Collection and Analysis

Structured questionnaires were used for households head or representative interviews. In addition, three focus group discussions were conducted plus key informant interviews and observation check-list. The data collected was analyzed using the Statistic Packages for Social Sciences (SPSS) while ArcGIS was used to come up with study area map.

The study used exploratory and descriptive research designs with random sampling of 200 households. The questionnaires were administrated on mining site of Farabacoura and none mining site of Tiéguècourouni. The two study sites were approximately 45 km apart. The proportionality of 100 samples was used for household survey between the two sites. Data was analyzed using descriptive and inferential statistics such as Chi-square, correlation and multiple linear Regressions.

In contrast to linear simple regression which uses a simple predictor variable x to explain the response variable y, the multiple linear regression describes how a dependent variable y is explained by more than one explanatory variables x (Liebscher, 2012).

A MLR model with n explanatory variables X_1, X_2, …X_n and a dependent variable Y, can be written as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ...\beta_n x_n + u_n = \left[\beta_0 + \sum_{n=1}^{r} \beta_n x_n + u_n \right] \text{……………….………Eqn xiv}$$

Whereas y is dependent variables; x is the independent variables; β_0 is the intercept; and β_1, β_2,.. β_n are coefficient of regression.

The MLR may consist of exponential of one or more explanatory variables as:

$y = \beta_0 + \beta_1 x_1 + \beta_2 x^2 + ...\beta_n x_n + u$ ....Eqn xv

The MLR can also have within the equation the interaction effects among two or more variables as:

$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 ..\beta_n x_n + u$ ....Eqn xvi

The study assumes neither interaction effects nor exponential ones among variables, thus the choice of equation (a) for further analysis. This equation is specified as follows:

$y = \beta_0 + \beta_1 \text{ var}\textit{iablename} + \beta_2 \text{ var}\textit{iablename} + .\beta_3 \text{ var}\textit{iablename}. + ... + \beta_n \text{ var}\textit{iablename} + u_n$

In this equation, the regression curve is not in a line, hence the preference of names "Non-Linear Regression Model" or "Polynomial Regression Model". The model requires the number of observation be bigger than the number of variables in the equation (Bremer, 2012).

The maximum likelihood estimation of MLR is similar to as the same as in simple linear regression model:

$y = X\beta + u$ ....Eqn xvii

Where the error term (u) is independent and identically distributed, $N(0, \sigma^2)$. The decision to be made in MLR is about the good fitness of the model for the data and whether all the explanatory variables are needed in the model. To handle the first issue, Quick (2013) suggested a test of relationship among variables and its significance. In MLR, the interpretation of R^2 which is a simple square of the correlation between dependent variables and independent variables is no longer valid since the more the variables the higher the R (Bremer, 2012). Therefore, the second issue is handling by using the adjusted R^2 because it is not automatically proportional to the increase of in number of variable, and it higher value shows the model better fitness (Bremer, 2012).

7.3 Results and Discussions

7.3.1 Incomes from Artisanal Gold Mining in Tangandougou

Results showed that 61 households represented by 30.5% of study population were not gaining from artisanal gold mining. Among this population, 52 respondents' households were from the non-mining site and 9 from the mining site. The households which were gaining 100 Dollars per year from artisanal gold mining were 100 represented by 50% of study population (comprising of 33 households from non-mining site and 67 from the mining area). Within the study area, it is only 33 respondents' households (13 from the non-mining area and 20 households from the mining site) represented by 16.5% who were earning above 200 Dollars annually. The largest amount of 300 Dollars per annum as an earning from artisanal gold mining was observed in 6 respondents' households represented by 3% of the study population and the distribution was 2 respondents' households from the non-mining site and 4 from the mining area of Farabacoura village.

Table 7.1: Incomes from Artisanal Gold Mining in Tangandougou Commune

			N = 200	
Incomes in $	**Freq.**	**%**	**Non-Mining**	**Mining**
00	61	30.5	52	9
100	100	50	33	67
200	33	16.5	13	20
300	6	3	2	4
Likelihood Ratio	**47.486**	**0.000**		

The distribution of amount of income from artisanal gold mining was not adequate to support the connected families on mining site over the year. Furthermore, the workforce used in the mining activities limits the available manpower to support agricultural production back in their family at home (Bryceson and Geenen, 2016). Therefore, food insecurity is currently impacting Malian rural populations in mining areas, which necessary has to be eradicated through the intensification of crops production as a function of sustainable food security (Friedrich and Kassam, 2016). The importance of mining is generally local and regional as longer it is not sustainable to replace the basic incomes from crops, livestock, agroforestry and fisheries (Aroca, 2001).

7.3.2 Incomes from Crops Production in Tangandougou

The households which were not gaining any amount from crops production were 51 respondents represented by 25.5% of the total study population in the area. The distribution was for 10 respondents' households from the non-mining site and 41 from the mining site of Farabacoura village. There were 58 household who earning about 100 Dollars per year from crops production which represented by 29% of total households interviewed in the study area (17 households from the non-mining site and 41 from the mining site). The agricultural crop production income of 200 Dollars per annum was earned by 53 households (36 from the non-mining site and 17 from the mining area) which represented by 26.5% of total interviewed households in the study area. Additionally, those who earned about 300 Dollars per annum were 36 respondents' households represented by 18% of interviewed households with a of distribution of 35 from the non-mining site and 1 household from the mining area. The highest earners of 4oo Dollars per year were 2 respondents' households from the non-mining site representing 1% of total representation in study area.

Table 7.2: Incomes from Crops Production in Tangandougou Commune

Incomes in $	Freq.	%	N = 200	
			Non-Mining	**Mining**
00	51	25.5	10	41
100	58	29	17	41
200	53	26.5	36	17
300	36	18	35	1
400	2	1	2	0
Likelihood Ratio	**80.961**	**0.000**		

The study revealed that crops production in mining areas were not possible as evidenced in the above (Table 7.2). The community had concentrated its energy and workforce to mining and other associated production activities such as business. For households in non-mining area, the major sources of income were from crops production which denoted that crops production and artisanal gold mining are not compatible. Consequently, crops production was influenced by artisanal gold mining and its associated activities as depicted by the poor incomes from crops production. The same analysis was done by George-Laurentiua *et al.* (2016) in Romania, which was confirmed that at present the agriculture is limited by the degraded lands in Ciudanovita mining area. This situation was as a result of limited workforce geared towards crops production by the populations in the study area, especially in the artisanal gold mining one (Bryceson and Geenen, 2016).

7.3.3 Incomes from Livestock Production in Tangandougou

The incomes from livestock production were null in 66 interviewed households represented by 33% of the study population. These were was 8 interviewed households from the non-mining site and 58 from the artisanal gold mining area of Farabacoura village. The households which were gaining about 100 Dollars from livestock production were 37 (12 from the non-mining area of Tieguecourouni village and 25 from the mining area of Farabacoura village) represented by 18.5% of total interviewed household in the study area. The income of about 200 Dollars per annum from livestock production was realized by 40 interviewed households represented by 20% of total respondents' population in the study area. The 40 households comprised of 33 from the non-mining site and 7 from the mining area. Those households which earned about 300 Dollars annually from livestock production were 47 (38 households from the non-mining area and 9 from the mining site) which was represented by 23.5% of the total households interviewed in the study area. The highest earners received about 400 Dollars annually. However, they were only represented by 10 interviewed households whereby 9 were from the non-mining area and 1 from the mining site representing 5% of the total household interviewed in the study area.

Table 7.3: Incomes from Livestock Production in Tangandougou Commune

Incomes in $	Freq.	%	N = 200	
			Non-Mining	**Mining**
00	66	33	8	58
100	37	18.5	12	25
200	40	20	33	7
300	47	23.5	38	9
400	10	5	9	1
Likelihood Ratio	**92.373**	**0.000**		

Those who were gaining more than 100 Dollars per year in mining area kept cattle, goats and sheep for business. In contrast, households in non-mining area were practicing substance livestock production so as to supplement household diet from crops production and to cover different domestic needs which include ceremonial and cultural aspects of family. Danquah *et al.* (2017) reported that livelihood resources in Amansie West, Ghana were exposed to the detrimental impact of mining and its activities, hence making it difficult for livelihood outcomes to be achieved by rural households. “The resulting illegality, along with the sector’s numerous social ills and environmental impacts, has overshadowed its importance, in particular how many subsistence farmers now rely on ASM for their disposable incomes” (Hilson, 2016).

7.3.4 Incomes from Agroforestry in Tangandougou

Out of the total study area respondents, 122 interviewed households with a distribution of 45 from the non-mining area of Tieguecourouni and 77 from the mining site of Farabacoura which is represented by 61% of total interviewed household in the study area earned no income from agroforestry. Those whose income was about 100 Dollars annually from agroforestry activities were 44 household (29 households from the non-mining area and 15 from the mining site) which represented 22% of the population observed in Tangandougou commune. Those who earned about 200 Dollars per year from agroforestry were 21 households distributed as 17 from the non-mining site and 4 from the mining site which represented 10.5% of interviewed households. For the income of 300 Dollars annually, there were 10 interviewed households with 6 from the non-mining area and 4 from the artisanal gold mining site which represented 5% of households interviewed in study area. The highest level of income of about 400 Dollars per annum was earned by 3 households from the non-mining area against represented by 1.5% of total respondents in the study area.

Table 7.4: Incomes from Agroforestry Activities in Tangandougou Commune

Incomes in $	Freq.	%	Non-Mining	Mining
			N = 200	
00	122	61	45	77
100	44	22	29	15
200	21	10.5	17	4
300	10	5	6	4
400	3	1.5	3	0
Likelihood Ratio	**26.249**	**0.000**		

Trees production was limited to fruit tree production in Tangandougou commune. The goods and services from trees were sourced from the natural forests exploitation such us charcoal production, timber wood, construction wood, hunting and honey production. The pressure on natural forests has made them less dependable by the communities in study area. The two major goods from forests include charcoal and fire wood production for commercial and domestic consumption within the study area. The overexploitation of the forests to get the aforementioned goods has made the natural forests surrounding artisanal gold mining area to be vulnerable from the shock. Generally, populations in gold mining areas usually exploit forests without replacement which posed the issues of vegetation regeneration (Moyo, 2017).

7.3.5 Incomes from Fisheries in Tangandougou

The incomes from the exploitation of fisheries were null in 159 interviewed households (70 from the non-mining area and 89 from the mining site) which represented 79.5% of total household interviewed in study area. However, there were 39 households which were earning about 100 Dollars per year from fisheries with a distribution of 28 from the non-mining site and 11 households from the mining area which represented 19.5% of study total population. Those who earned about 200 Dollars annually were 2 households both from the non-mining which represented 1% of total interviewed household.

Table 7.5: Incomes from fisheries in Tangandougou Commune

Incomes in $	Freq.	%	N = 200	
			Non-Mining	Mining
00	159	79.5	70	89
100	39	19.5	28	11
200	2	1	2	0
Likelihood Ratio	**200**	**0.002**		

The explanation of low incomes from fisheries was due to the rarity of fish and fisheries resources in the rivers and backwaters in study area. Furthermore, rivers were contaminated by chemical products in form of effluents from the artisanal gold mining activities (Rasheed and Amuda, 2014).

7.3.6 Correlation Results on Households Incomes

The households' sources of incomes included gold mining activity, crops and livestock production, agroforestry and fisheries production. There were significant negative relationships between locality and incomes from crops (r = -0.573; p > 0.01), incomes from livestock production (r = -0.610; p > 0.01), incomes from forests (r = -0.302; p > 0.01) and incomes from fisheries (r = -0.242; p > 0.01). There were also significant negative relationships between incomes from artisanal gold mining and incomes from crops (r = -0.203; p > 0.01), incomes from livestock production (r = -0.243; p > 0.01) and incomes from fisheries (r = -0.144; p > 0.05).

The results showed that there were significant positive relationship between locality and incomes from artisanal gold mining (r = 0.353; p > 0.01), incomes from crops and incomes from livestock production (r = 0.549; p > 0.01), incomes from crops production versus incomes from forest (r = 0.322; p > 0.01), between incomes from livestock production and incomes from forest (r = 0.395; p > 0.01), incomes from fisheries (r = 0.292; p > 0.01) and between incomes from forests and incomes from fisheries (r = 0.330; p > 0.01).

Table 7.6: Pearson's Correlation of Income Sources in Tangandougou Commune

	Location	Incomes gold	Incomes crops	Incomes livestock	Incomes agroforestry	Incomes fisheries
Location	1					
Incomes artisanal gold mining	0.353**	1				
Incomes crops production	-0.573**	-0.203**	1			
Incomes livestock production	-0.610**	-0.243**	0.549**	1		
Incomes agroforestry	-0.302**	-0.101	0.322**	0.395**	1	
Incomes fisheries	-0.242**	-0.144*	0.115	0.292**	0.330**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

7.3.7 Multiple Linear Regressions of Households Incomes

The results showed that socio-economic parameters were influenced by different sources of households' incomes in the study area of Tangandougou Commune in Sikasso region, Mali. The parameters considered were profession under agricultural productivity, nativity of respondents during household's survey, gender of respondents, age of interviewees, education level, children presence on gold mining site and the size of the family in the study area of Tangandougou Commune.

Profession under agricultural productivity: results showed that profession influenced significantly and positively artisanal gold mining incomes (0.119). However, they significantly and negatively influenced crops production, livestock production, agroforestry and fisheries (-0.192, -0.237, -0.147, -0.045) respectively (Table 7.7).

Nativity of respondents: the result significantly and negatively influenced the nativity of the respondents in the study areas for artisanal gold mining incomes (-0.294) but significantly and positively influenced by incomes from crop production (0.807) and livestock production (1.086) as showed in (Table 7.7).

Gender of interviewees: gender influenced significantly and negatively the incomes from artisanal gold mining (-0.294) and it was influenced significantly and positively by incomes from agroforestry (0.369) and incomes from fisheries (0.145) (Table 7.7).

Ages of respondents of households: there were significant and positive influence in characters of age of the interviewees' incomes from crops production (0.189) and incomes from livestock production (0.152) in study area as shown in Table 7.7.

Education level of respondents: the levels of none, primary, secondary, college or University influenced significantly and negatively the incomes from agroforestry production (-0.234) in study area of Tangandougou commune (Table 7.7).

Children presence on gold mining: household's children involved in gold mining significantly and negatively influenced incomes from fisheries (-0.403) in study area.

Family size of interviewees: the number of people in family significantly and negatively influenced the incomes from artisanal gold mining (-0.215) (Table 7.7).

Table 7.7: Multiple Linear Regression Results of Households Incomes

Explanatory Variables	Incomes Gold Mining		Incomes Crops		Incomes Livestock		Incomes Agroforestry		Incomes Fisheries	
	Coeff.	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
(Constant)	0.982	0.320	0.700	0.389	1.171	0.462	0.821	0.403	0.498	0.189
Profession	0.119***	0.038	-0.192***	0.047	-0.237***	0.055	-0.147**	0.048	-0.045*	0.023
Nativity	-0.329**	0.117	0.807***	0.142	1.086***	0.169	0.241	0.147	0.108	0.069
Gender	-0.294***	0.128	0.211	0.155	0.462	0.184	0.369**	0.161	0.145*	0.075
Age	0.068	0.066	0.189**	0.080	0.152**	0.095	0.061	0.083	-0.040	0.039
Education Level	0.003	0.085	-0.064	0.103	-0.067	0.123	-0.234*	0.107	-0.053	0.050
Marital Status	0.365	0.282	0.228	0.343	-0.399	0.407	-0.001	0.355	-0.269	0.167
Children Presence	-0.004	0.305	0.049	0.371	-0.553	0.440	-0.087	0.384	-0.403**	0.180
Family Size	-0.215**	0.096	-0.085	0.116	-0.063	0.138	-0.072	0.120	0.047	0.056
Number	200		200		200		200		200	
R^2	0.427		0.631		0.640		0.425		0.345	
F	5.328		15.774		16.595		5.267		3.219	
P	**0.000**		**0.000**		**0.000**		**0.000**		**0.002**	

Note: ***; **; * Significant at 1%, 5% and 10% respectively

Like many developing nations within the Sub-Saharan Africa region, Mali has limited arable land that faces a lot of pressure from the competing interests including subsistence crop, livestock production and mining (Djibril, *et al.,* 2017; Papworth, *et al.,* 2017).

The results showed that profession, nativity, gender and family size influenced households' participation in artisanal gold mining activities in Tangandougou commune. The parameter profession was only positive which means that individuals who are professional earn more income artisanal gold mining and the associated commercial activities. In contrast, nativity, gender and family size negatively and significantly influenced households' incomes from artisanal gold mining in Tangandougou commune. The non-local people faces more expenses arising from taxes, rents, land lease housing among others as compared with the locals in these mining communities of Tangandougou. Concerning gender, artisanal gold mining demands more physical energy a situation which locks out most of the female gender from being engaged equally as males in artisanal gold mining. Family size was negatively significant, because of the characteristics of artisanal gold mining which forces the miners to keep migrating to new sites in search of the gold due to its rarity, hence a challenge to moving large families (Tenkorang and Osei-Kufuor, 2013).

Crops production was influenced by profession, nativity and age in Tangandougou commune. The profession negatively and significantly affected incomes from crops due to the non-specialization of the community in substance crops production system. The nativity positively and significantly affected incomes from crops production as the households were primarily engaged in crops production for subsistence purposes. The priority of these households is for domestic consumption leading to the declined crops production and deviation from crops productions as the principal income generating activity for them (Danquah *et al.,* 2017). Age also positively and significantly affected incomes from crops production due to the high demand of the energetic workforces for production (Hilson, 2016). Crops production was mainly dominated by women and youth and usually reflected the production capacity of households in this area.

The incomes from livestock production were affected by profession, nativity and age in Tangandougou commune. Profession negatively and significantly affected the incomes from livestock hence the need for the households to integrate livestock production in their agricultural production system (Sîrbu, 2014). Nativity positively and significantly affected incomes from livestock production a situation which gives them an advantage over the non-locals in livestock production. The age positively and significantly affected incomes from livestock production in the sense that energy production is necessary to realize this agricultural activity. The nature of livestock production was mainly extension system which implicates youth intervention in most of the cases in livestock production in this area of study.

The incomes from agroforestry were affected by profession, gender and education level in Tangandougou commune. The profession affected negatively and significantly incomes from agroforestry which denotes the insufficiency of specialization in this area of agricultural production system. The different products from forests were naturally exploited without households' intervention in terms of agroforestry production system. The gender positively and significantly affected incomes from agroforestry, because of female gender intervention in this agricultural activity. Women were the dominant in agroforestry system through the supply of food products, earning from fire wood and charcoal. There were a few men who were produced fruits such as mango, banana, papaya and many others under the agroforestry production systems. The education level affected negatively and significantly the incomes from agroforestry which was characterized the literacy in most of the households (Moyo, 2017).

The incomes from fisheries were affected by profession, gender and children presence on site in Tangandougou commune. The profession negatively and significantly affected fisheries due to the limited specialized production methods and capacities in these areas. The female gender affected positively and significantly fisheries which was attributed to women intervention in fishing and aquaculture supported by association and NGOs. For instance, children presence in study areas affected negatively and significantly fisheries, denoting that fisheries requires adults' intervention than children for it development.

7.4 Conclusion and Recommendations

The different sources of incomes were all negatively and significantly affected by profession but not the incomes from artisanal gold mining. The second factor which affected households' incomes was nativity followed by gender, age, education level and family size respectively. Therefore, the study recommends national and local intervention, particularly on artisanal gold mining so as to develop agricultural production systems through the integrated system of sustainable agriculture. This system should be focused on rainfall water collection for proximity irrigation purposes, livestock production to supply crops and agroforestry production which have to facilitate aquaculture in the region and specifically in Mali. These are pathways to ensure environmental health, food security, nutrition and above all increase the households’ level of income.

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CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

i. Artisanal gold mining is one of the human activities that influences household to be engaged in other activities apart from agricultural production, especially in the study area. The influencing factors ranged from professions, nativity, gender, ages, education levels, marital status and family size. These factors are driving rural population from agriculture to artisanal gold mining and in turn leading to food insecurity and vulnerability.

ii. Water quality is being compromised slowly in mining zones due to heavy metals and chemical products used by miners. The cadmium and lead concentration in Sankarani River and tributaries have exceeded European Communities and World Health Organization standards of drinking water. Without continuous monitoring of surface waters, it will be useless water very soon for crops and livestock production, fishing and drinking.

iii. Crops production system is impacted by artisanal gold mining. People are leaving agricultural production to mining with expectation to gain quick financial returns. This situation affects crops production through reduced workforces of households. Currently, households are supported only by ageing people in terms of crops production. Gold mining has captured the energetic youth and women or these are major workforces of agriculture production in rural areas.

   Livestock production is practiced traditionally and on a small scale and therefore mainly for household consumption. The households kept a few animals such as cattle, goats and sheep for cultural and social circumstances. That possession is not enough to develop livestock production, moreover to ensure food security and nutrition through meat production. These animals are not raised for meat consumption but to prevent cultural and social aspects in rural areas.

   Fishing is one of the most important activities in agricultural production system in the study area. So it is affected by climate change and artisanal gold-mining activities through the slow contamination of rivers and backwaters surrounding mining areas. That effect is driving people focused on fishing out of production, because of the rarity of fish in these waters due to the chemical products contamination from gold-washing in mining areas.

Agroforestry is practiced in the global system of agricultural production in small-scale farming. The agroforestry products mostly come from natural forests which include timber wood, charcoal, honey, construction wood and herbal medicine. The agricultural systems of production undertaken in agroforestry are based mainly on fruits such as orange, papaya and mango. The biomass production for domestic purposes is on starting stage in these mining zones.

Land ownership in gold mining areas is still unclear because of the type of exploitation. Gold mining is taking place under government or community ownership of land. The private land ownership is very few in Mali. Consequently, miners are always in conflict with farmers, livestock farmers, native people and authorities. These conflicts are revolved traditionally or using modern ways.

Traditional environmental knowledge is based on changing natural environmental and climatic parameters which can be observed by community every year. Generally, it is focused on water quality, biomass regression, forests and pasture degradation, cultivable land loss and rarity of rainfall. This environmental change is considered as natural phenomena. Nevertheless, the community accepts the impacts of human activities as fundamental causes of change.

Gold mining affects social aspects of local natives. Farabacoura mining site is also greatly affected with impacts including increased cost of living, prostitution, alcoholism, increase of criminality and conflict. These phenomena were linked to weak security and the fact that artisanal mining is free from formal regulations. That social change has impacted youth and women studies as they have abandoned school earlier for gold-mining, prostitution and others activity as mining is going on.

iv. The study found evidence of negative effects of mining on household income sources in Tangandougou Commune. Results also indicate that once the income from artisanal gold mining is reducing that effect heavily those were gained from mining activities. In the case of household welfare, the revelation from research results is that households were vulnerable to food insecurity, because of the large population surrounding mining area. Finally, artisanal gold mining activity does not only reduce income and wellbeing, further increases inequality in the distribution of income and the overall wellbeing of households.

8.2 Recommendations

i. For food security to be enhanced emphasis should be on youth and women involvement in agriculture and promotion of its modern and related technologies. The government and agriculture chamber should train farmers on agribusiness enterprises and to grantee accessibility to credit for them.

ii. Water quality monitoring should be carried out in all water sources surrounding mining areas by the water commission of Sankarani River so as to protect human and environmental health. The traditional environmental knowledge has to be integrated in all projects, programs and plans implemented in rural areas.

iii. Crops and livestock production should be promoted more by the government and agriculture chamber so as to ensure food security and nutrition through meat production. It should be organized under integrated sustainable agriculture. The government should identify and certify all land of the territory for different purposes. Fishing and agroforestry should be more promoted by the government and agriculture chamber so as to imply more farmers in production.

iv. The researcher recommends testing and use of Integrated System of Sustainable Agriculture (ISSA) in agricultural production systems so as to improve the system in question, environmental and food security.

8.3 Further Suggested Areas for Research

Further studies are recommended in the following areas:

i. Underground water quality in gold-mining areas.

ii. Heavy metal contamination of fish from Sankarani River and tributaries as well as their impacts on human health.

APPENDICES

Appendix 1: Household Questionnaire

I am Mahamadou Moussa Keita a Ph.D. student at the Department of Environmental Science, Faculty of Environment and Resources Development, Egerton University. I am also a Teacher/Researcher for the Rural Polytechnic Institute of Katibougou. I am conducting a research on **"Environmental and socio-economic impacts of artisanal gold mining on agricultural productivity in Sikasso Region, Mali".**

This household survey is for research purpose, and the findings will be used for academic purpose. You are kindly requested to provide honest answers regarding small-scales gold mining impact on physical environment, agricultural production, and human health. Your responses will be held in confidence and used for the above mentioned purposes. Thank you in advance for your cooperation.

Contacts: (+223) 76 03 63 31, E-mail: mahamadou77@yahoo.fr

Survey Date………/……/………

Section A: socio – economic characteristics of the household

Personal detail of respondents

1. Location……………………Survey site…..……………………Village..…………….
2. Respondent Name (optional)…………………………….Profession…………………

For the following questions tick appropriately, please.

3. Are you native of this village?

Yes [] No []

4. Respondents' gender:

A. Male [] B. Female []

5. Respondents' age in bracket:

A. 15-25 [] B. 26-36 [] C. 37-47 [] D. 48-58 [] E. 59 +[]

6. Level of education:

A. None [] B. Primary [] C. Secondary [] D. College/University []

7. Marital status:

A. Married Yes [] No [] B. Father Yes [] No [] C. Mother Yes [] No [] D. Child Yes [] No [] E. Employee Yes [] No []

8. Number of people in the household:

A. 1-5 [] B. 6-10 [] C. More than 10 []

9. Principal Occupations?

A. Crop production Yes [] No []

B. Livestock production Yes [] No []

C. Gold mining Yes [] No []

D. Agro-Forestry Yes [] No []

E. Fisheries Yes [] No []

10. How long have you been living on this site of artisanal gold mining?

Section B: Household questionnaire

1. These activities in the table provide a number of benefits to local communities. In this question you are requested to tick the activity from which you obtain more income. Please, if you could estimate the relevant income?

Activities	Potential source of incomes	Estimation/amount per year
Artisanal Gold mining	Gold Commerce Yes [] No []	[……………..…......………]
	Petty business Yes [] No []	[………………....…...………]
	Construction works Yes [] No []	[…………………...….….….]
	Selling food Yes [] No []	[……………………..……..]
	Selling water Yes [] No []	[…………….………...……...]
	Daily work Yes [] No []	[………………..…………..]
	Transport Yes [] No []	[…………………..………..]
Crop production	Cereals production Yes [] No []	[………...……...…………..]
	Gardening Yes [] No []	[…………...………...……...]
	Folders production Yes [] No []	[……………….....………….]
	Compost from crops Yes [] No []	[……………….....………….]
Livestock production	Cow production Yes [] No []	[…………………..…....…...]
	Goat production Yes [] No []	[………………......………...]
	Sheep production Yes [] No []	[…………………......……...]
	Dairy produce Yes [] No []	[…………………......……...]
	Peel commerce Yes [] No []	[…………………..………..]
	Compost livestock Yes [] No []	[…………………..………..]
Water sources	Wells Yes [] No []	[………………..…………..]
	Backwater Yes [] No []	[………………..…………..]
	River Yes [] No []	[……………….....………….]
	Water commerce Yes [] No []	[……………….....………….]
Fisheries	Traditional peach Yes [] No []	[………………..……...…..]
	Fish breeding Yes [] No []	[………………..……...…..]
Forest	Timber wood Yes [] No []	[……………….……....…...]
	Construction wood Yes [] No []	[……………….……....…...]
	Charcoal Yes [] No []	[……………….……....…...]
	Hunting Yes [] No []	[……………….……....…...]
	Honey Yes [] No []	[……………….……....…...]
	Herbal medicine Yes [] No []	[……………….……....…...]

2. Properties right of Land?

Comminatory right Yes [] No [] Private/Individual right Yes [] No [] Government Yes [] No []

3. What activity do you prefer between below mentioned?

A Crop production Yes [] No [] B. Livestock production Yes [] No [] C. Fisheries Yes [] No [] D. Apiculture/beekeeping Yes [] No [] E. Agro-Forestry Yes [] No []

4. Where do you graze your livestock?

A Farm Yes [] No [] B. Pasture Yes [] No []

5. What impacts does artisanal gold mining on water?

A Degrade the quality of water Yes [] No [] B. Degrade aquatic ecosystem Yes [] No [] C. Pollute surface and groundwater Yes [] No []

6. What impacts does artisanal gold mining on crops production?

A Degrade land/soil Yes [] No [] B. Pollute water use in crops production Yes [] No [] C. Spoiled crops production labor Yes [] No []

7. What impacts does artisanal gold mining on livestock production?

A. Degrade livestock pasture Yes [] No [] B. Pollute livestock watering Yes [] No []

C. Degrade livestock procreation Yes [] No [] D. Other [] specify

8. What impacts does artisanal gold mining on cultural values?

A. Increase cost of living Yes [] No [] C. Increase sex market Yes [] No []

9. What kind of conflicts have you usually got between people below mentioned?

A. Miners and Farmers (Crop) Yes [] No [] B. Miners and Farmers (Livestock) Yes [] No [] C. Miners and natives Yes [] No [] D. Miners and authorities Yes [] No [] E. Miners and miners Yes [] No []

10. How did you resolve these conflicts?

A Traditional management of conflicts [] B. Classic management of court []

Appendix 2: Focus Group Discussions Photos and Topics

Focus group discussions on Farbacoura artisanal gold-mining *impact*

Date………/……/………

"Evaluation of Environmental and Socio-economic Impacts of Artisanal Gold Mining on Agricultural Productivity in Sikasso Region, Mali".

1. What activities increasing more your income?

…………………………………………………………………………………………

2. What evaluation of the impacts on environment degradation related to artisanal gold mining have you done?

………………………………………………………………………………………….

3. What evaluation of the impacts on crops production related to artisanal gold mining have you done?

…………………………………………………………………………………………

4. What evaluation of the impacts on livestock production related to artisanal gold mining have you done?

…………………………………………………………………………………………

5. What evaluation of impacts on socio-economic aspects related to artisanal gold mining have you done?

…………………………………………………………………………………………

6. What kinds of conflicts related to land use in mining zones?

…………………………………………………………………………………………

7. What kinds of conflicts related to water resources use in mining zones?

…………………………………………………………………………………………

8. What kinds of diseases related to gold mining have you observed?

…………………………………………………………………………………………

9. What characterize the displacement of labor from agricultural sector to mining?

…………………………………………………………………………………………

10. What characterize vulnerability and risk of food insecurity in your community?

…………………………………………………………………………………………

11. Which disposals of food security have you?

…………………………………………………………………………………………

Water and sanitation

What are the sources of drinking water?

…………………………………………………………………………………………………

Water for household usage? …….………………………………………………………...

What are the treatment methods? .……………………………………………………

Is water accessible? ..………………………………………………………………...

Distance to source? ……………………Hours spent? ……………………………......

Quality of water use? ....

Quantity of water use? ....

Household water management:

Storage (what kind of storage pots?) ……………………………………………….

Covering storage containers? ....

Are there any rainwater harvesting methods?

Small-Bridge irrigation system …………………Domestic system…...………………...

Occupational safety and Health

The use of Personal Protective Equipment (PPE) by the workers at the mines:

Goggles…………………Nose mask…………………… Gloves……………………….

Occupational hazards

Uncovered pits…………………………..…..Collapsing tunnels………….……………..

Wet grounds and unfenced………………………….……………………………………….

Water areas (open cast pits)………………………………………………………...

Mosquitoes breeding grounds? ……………………………………….………………….

Solid waste management:

Types of solid waste ……………………………………………………………..

Disposal of the solid waste …………………………………………………………...

Impacts on environment ..……………...…………………………………………

Liquid waste management

How is it disposed of? ….……………………………………………………………...

Is there a treatment facility? ……………………………………………………………..

How is the human excreta disposed of?

Pit latrines? ………… Use of bushes? …………. How persons per toilet? ....

Impacts of human excreta on environmental and handling (water related diseases)

……………………………………………………….……………………………

Hygiene

Food preparation and handling? ………………………………………………………

Methods and impacts on human health? ….…………………………………………..

Washing hands before eating? ….…………………………………………………..

Washing hands after visiting a toilet? …………………………………………………...

Conflict management strategies:

Prevention ……………………………………………………………………………….

Mediation ………………………………………………………………………......

Adjudication ……………………………………………………………………………..

Arbitration ……………………………………………………………………………….

Compromise ………………………………………………………………….......

Conciliation/Reconciliation …………………………………………………….......

Consolidation ……………………………………………………………………………

Appendix 3: Key Formant Interview

Subjects	Observations
. An evaluation of impact (social and environmental economic).	
. Artisanal gold-mining impacts on water sources.	
. Artisanal gold-mining impacts on crops production.	
. Artisanal gold-mining impacts on livestock production.	
. Artisanal gold-mining impacts on food security.	
. Artisanal gold-mining impacts on agroforestry.	

Appendix 4: Field Observation Check list

1. Types of gold mining ranging from open pit, underground tailings and placer.
2. State and conditions of gold mining sites
3. List of provisioning such as water and energy.
4. Settlements, production and commercialization of products on the sites.
5. Agricultural production, consumption and market on the sites.
6. Current threats to the drinking water related to gold mining (potential sources of surface and groundwater pollution).
7. Ongoing activities around gold mining sites.
8. Status of land use by mining and agricultural activities.
9. Management of solid and liquid wastes produces on the sites.

Appendix 5: List of Publications

Keita, M. M., Owuor**,** G. and Ogendi, G. M. (**2018). Drivers of Participation in Artisanal Gold Mining and its Effect on Agriculture in Mali**. ADRRI Journal of Agriculture and Food Sciences, Ghana: Vol.4, No. 1 (3), Pp. 1-16, E-**ISSN**: 2026-5204, 30 September, 2018.

Keita MM, Ogendi GM, Owuor G, et al. **Impacts of Artisanal Gold Mining on Water Quality: A Case Study of Tangandougou Commune in Sikasso Region, Mali**. J Environ Health Sustain Dev. 2018; 3(4).

Keita, M. M., Ogendi, G. M. and Owuor, G. **(2018). Socio-economic Factors That Influence Household Incomes in Artisanal Gold Mining Area of Tangandougou Commune, Mali.** ADRRI Journal of Agriculture and Food Sciences, Ghana: Vol.4, No. 2 (3), Pp. 1-19, E-ISSN: 2026-5204, 31st October,

Appendix 6: List of Presentation in International Conferences

Keita, M. M., Owuor, G. and Ogendi, G. M. (2018). Effects of artisanal gold-mining on crop production in Tangandougou Commune, Mali. *Egerton University 12th International Conference, 27th – 29th March 2018. FEDCOS Complex, Njoro Campus, Kenya. pp 118*

Keita, M. M., Ogendi, G. M. and Owuor, G. (2018). Water Usages in Tangandougou in Sikasso region, Mali. *Egerton University 12th International Conference, 27th – 29th March 2018. FEDCOS Complex, Njoro Campus. Kenya. pp 155*

Keita, M. M., Ogendi, G. M. and Owuor, G. (2018). Local Community Perception on the Impact of Gold-mining on Sustainable Agriculture in Tangandougou, Sikasso region, Mali. *Egerton University 12th International Conference, 27th – 29th March 2018. FEDCOS Complex, Njoro Campus. Kenya. pp 157*

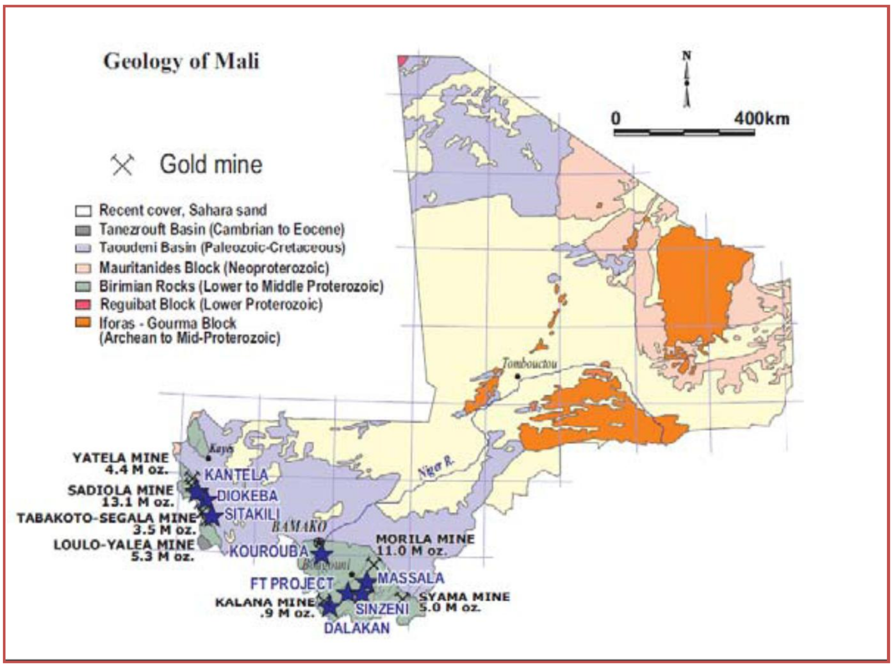
Keita, M. M. (2017). The Drivers of Participation in Artisanal Gold Mining against Agriculture: The Case of Tangandougou Commune, in Sikasso Region, Mali. *BHEARD 2nd Regional Conference, 2nd – 8th July 2017, Elementaita, Kenya.*

Keita, M. M. (2017). Impacts of artisanal Gold mining on Water Quality: A Case Study of Gold Mining at Farabacoura. *BHEARD 2nd Regional Conference, 2nd – 8th July 2017. Elementaita, Kenya.*

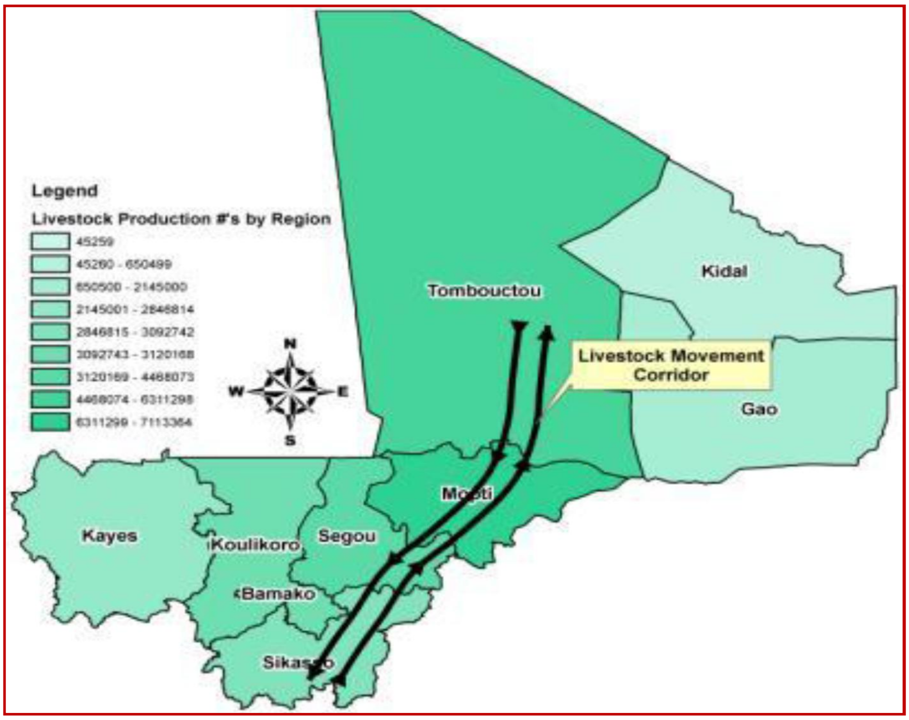
Keita, M. M., Ogendi, G. M. and Owuor, G. (2017). Impacts of artisanal Gold mining on Water Quality: A Case Study of Gold Mining at Farabacoura. *Egerton University 11th International Conference and Innovation Week, 29th – 31st March 2017. FEDCOS Complex, Njoro Campus. Kenya. pp 18*

Keita, M. M., Owuor, G. and Ogendi, G. M. (2017). The Drivers of Participation in Artisanal Gold Mining against Agriculture: The Case of Farabacoura Mining in Sikasso Region, Mali. *Egerton University 11th International Conference and Innovation Week, 29th – 31st March 2017. FEDCOS Complex, Njoro Campus. Kenya. pp 164*

Appendix 7: Gold mining Activity Sites Location and Livestock Movement in Mali



Gold-mining sites location in Mali; Source: (Drakenberg, 2010)



Livestock movement in Mali; Source: (USAID-Mali, Feed the Future, 2010)

Appendix 8: WHO Drinking Water Quality Guidelines

Parameters	Levels mg/L
Cadmium	0.003
Lead	0.01
Arsenic	0.01
PH	At 25^{o}c
Turbidity	0.3 NTU

Source: WHO, 2011

Appendix 9: Data Analysis Procedures

Descriptive Procedure

```
FREQUENCIES VARIABLES=location village profession native gender age education
married father mother child employee number people living time
  /ORDER=ANALYSIS.
CROSSTABS
  /TABLES=location BY village profession native gender age education married father
mother child employee number people living time
  /FORMAT=AVALUE TABLES
  /CELLS=COUNT
  /COUNT ROUND CELL.
CORRELATIONS
  /VARIABLES=location village profession native gender age education married father
mother child employee number people living time
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Logistic Regression Procedure

```
LOGISTIC REGRESSION VARIABLES location
  /METHOD=ENTER profession native gender age education married child number people
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
```

Multiple Linear Regression Procedure

```
GET
  FILE='C:\Users\User-
pc\Documents\Ph.D_Field_Research_KEITA_2016\Thesis_Ph.D_KEITA_Egerton_Unive
rsity_2015_2018\Data_Factors_Ph.D_keita_Egerton_2016.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT incomes gold
  /METHOD=ENTER profession native gender age education married child number
people.
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT incomes crops
  /METHOD=ENTER profession native gender age education married number people
community right private government location.
```

Appendix 10: Rainfall Data of Mali

Rainfall Annually Data			
Years		2014	2015
Stations	Stations		
2_cod_0	Kayes	673.4	661.7
2_cod_1	Nioro du sahel	436.9	452.6
2_cod_2	Yélimane	539.9	635.1
2_cod_3	Kenieba	1134.3	1512.4
2_cod_4	Kita	853.1	1032.4
2_cod_5	Diema	665.4	607.8
2_cod_6	Mahina	902.1	852.3
2_cod_7	Bafoulabe	719.7	930.7
2_cod_8	Bamako senou	819.3	952.1
2_cod_9	Bamako ville	1007.6	912.7
2_cod_10	Sotuba	843.8	832.9
2_cod_11	Koulikoro	692.4	813.2
2_cod_12	Katibougou	721.8	735.5
2_cod_13	Nara	566.4	446.9
2_cod_14	Kati	876.8	983.2
2_cod_15	Baguinéda	896	983.3
2_cod_16	Ouelessebougou	779.1	1004.1
2_cod_17	Selingue	981.4	1102.4
2_cod_18	Dioila	923.5	858.6
2_cod_19	Kolokani	730.3	755.3
2_cod_20	Didieni	661.7	669.3
2_cod_21	Banamba	390.9	755
2_cod_22	Kangaba	893.3	988.9
2_cod_23	Sikasso	1396	1021.9
2_cod_24	Bougouni	1128.5	1247
2_cod_25	Koutiala	1017.8	1149.3
2_cod_26	Yanfolila	1271	1057
2_cod_27	Kadiolo	1153	1127
2_cod_28	Kolondieba	1291	1089.5
2_cod_29	Yorosso	910.9	824.5
2_cod_30	Ségou	520.4	599
2_cod_31	San	604.2	899.6
2_cod_32	Bla	718.6	824.5
2_cod_33	Baraoueli	779.5	615.4
2_cod_34	Bonobougou	723.5	875
2_cod_35	Niono	428.6	617.4
2_cod_36	Ke-macina	494.2	593.6
2_cod_37	Tominian	483.6	812.1
2_cod_38	Mopti	564.1	585.3

Source: http://countrystat.org/home.aspx?c=MLI&tr=56