Impacts of Industrial Park Development on the Environment and Livelihoods of the Surrounding Displaced Community in Ethiopia

The Case of Bole Lemi Industrial Park

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Dissertation Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Development Studies

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Impacts of Industrial Park Development on the Environment and Livelihoods of the Surrounding Displaced Community in Ethiopia:

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DECLARATION

I, the undersigned, declare that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation are fully acknowledged.

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This dissertation has been submitted for examination with my approval as University supervisor.

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ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DISSERTATION APPROVAL

This is to certify that the dissertation prepared by Fituma Lemessa entitled: "**Impacts of Industrial Park Development on the Environment and Livelihoods of the Surrounding Displaced Community in Ethiopia: The Case of Bole Lemi Industrial Park**" submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in Development Studies (Environment and Development Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Chair of the Center or Graduate Program Coordinator

DEDICATION

This dissertation is dedicated to my father, who made a significant and lasting contribution to the success of my academic career at all times and who passed away ten years ago. I thank my devoted wife Bonsitu Dulume and my kids for their unwavering support and the numerous services they rendered while I was studying.

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Fituma Lemessa

LIST OF PAPERS INCORPORATED IN THIS DISSERTATION

This thesis is structured based on articles-oriented dissertation compilation guideline of Addis Ababa University and emerged from articles already published in peer reviewed Journals and papers accepted for publication. The coauthors have made different levels of contribution to the publication of those articles on the basis of their area of specialty.\

1. Fituma Lemessa, Belay Simane , Assefa Seyoum , Girma Gebresenbet : Analysis of the concentration of heavy metals in soil, vegetables and water around the bole Lemi industry park, Ethiopia Heliyon, 2022 Dec 20; 8(12):e12429. DOI:10.1016/j.heliyon.2022.e12429. e Collection 2022 Dec, Elsevier.
2. Fituma Lemessa 1* ,Belay Simane 1,Assefa Seyoum 1 and Girma Gebresenbet 2 Assessment of the Impact of Industrial Wastewater on the Water Quality of Rivers around the Bole Lemi Industrial Park (BLIP), Ethiopia: *Sustainability* **2023**, *15*(5), 4290; **https://doi.org/10.3390/su15054290**, **Received: 24 December 2022 / Revised: 9 February 2023 / Accepted: 10 February 2023 / Published: 28 February 2023**
3. Fituma Lemessa, Belay Simane , Assefa Seyoum , Girma Gebresenbet : Investigation of compensation mechanisms and procedures relative to the displaced Community Preference.(Prepared as per standard Paper)
4. Fituma Lemessa, Belay Simane, Assefa Seyoum, and Girma Gebresenbet: Analyze the effects of industrial park development on the livelihood of local community. (Submitted to Journal & it's under Review)

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Head, Oromia Industry & Urban Development Zonal Offices (East Wollega & West Showa), 2098-2013

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ACRONYMS

ACG	Addis Ababa City Government
ADB	Asian Development Bank
AU	African Union
AWSSA	Addis Ababa Water Supply and Sewerage Authority
DIDC	Development Induced Displaced Community
DLC	Displaced Local Community
EDRI	Ethiopian Development Research Institute
EEC	Ethiopian Economic Commission
EEPP	Ethiopian Environmental Pollution Policy
EFP	Ecological Foot Print
EIA	Environmental Impact Assessment
EIC	Ethiopian Investment Commission
EIP	Ethiopian Industry Park
EIP	Eco Industrial Park
EIPDC	Ethiopian Industry Park Development Commission
EPM	Environmental Planning and Management
EPC	Ethiopian Plan Commission
FGD	Focal Group Discussion
ISD	Inclusive and Sustainable Development
UFL	Urban Farm land
IEG	Imperial Ethiopian Government
IPD	Industry Park Development
LCL	Local Community Livelihood
LUZ	Land Use Zoning
MoA	Ministry of Agriculture
MoC	Ministry of Construction
MoI	Ministry of Industry
MoWR	Ministry of Water Resource
MoUDH	Mistry of Urban development & Housing
MSMEs	Micro, Small & Medium Enterprises
SD	Sustainable Development
SEZ	Special Economic Zone
SMEs	Small and medium enterprises
ULUZ	Urban Land Use Zoning
UN	United Nations
UNIDO	United Nations Industrial Development Organization

ABSTRACT

In its first objective, this study analyzed heavy metal concentrations in soil and vegetables after irrigation with industrial wastewater from Bole Lemi Industrial Park. 24 samples from 8 stations were collected following APHA procedures in May and June 2021using a composite sampling method. Analysis included Pb, Cr, Cd, and Zn concentrations using statistical methods. Zn had the highest levels (7.82 mg/kg in vegetables, 5.12 mg/kg in soil). Bioconcentration factor, Estimated Daily Intake, and Target Cancer Risk were highest for Cd, Zn, and Cr, respectively. Hazard Index indicated no health effects. Soil concentrations showed strong positive correlations between Cr/Cd and Pb in vegetables, and Cd in water correlated with Pb. In its second objective, the study also assessed water quality in rivers near Bole Lemi Industrial Park. Data from six stations were collected between May and June 2021. In-situ and ex-situ measurements examined parameters like pH, EC, TSS, temperature, COD, TN, TDS, TP, and BOD. Water samples were evaluated using the weighted arithmetic water quality index. Statistical analysis revealed significant differences in water quality among stations. Temperature, EC, pH, TSS, TDS, COD, BOD, TN, and TP levels varied. pH exceeded the recommended ranges at two stations. The water quality index categorized samples as "unsuitable for consumption." Proper management and irrigation with treated wastewater are important. Findings can guide Addis Ababa in river protection and industry park management. This study, in its third objective, also assessed the impact of Bole Lemi Industry Park on the livelihoods of local communities in the peri-urban areas in Addis Ababa. A survey of 379 displaced household heads examined changes in income and employment opportunities. Descriptive statistics and regression models were used to analyze the data. Results showed deteriorating living conditions and increased poverty among the displaced. The study highlighted the imbalance between industrial development and local farming communities, recommending compensation, resettlement support, and livelihood diversification. Comprehensive and participatory approaches to industrial park development were deemed crucial for sustainable and equitable growth while protecting local communities. Finally, this study examined compensation for communities affected by the development of Bole Lemi Industry Park in Addis Ababa. A survey of displaced household heads explored various factors, including gender and marital status. Descriptive statistics and logistic regression were employed to analyze data on compensation rates, income distribution, and community participation. Findings revealed insights into compensation mechanisms, job creation perceptions, and preferences. The study identified gender disparities in compensation preferences and stressed the importance of transparency, accountability, and inclusive engagement for fair development outcomes. The study provided valuable information for stakeholders and promoted informed and equitable compensation approaches to development..

Keywords: *Heavy metals, Pollution, Industrial wastewater, Water quality assessment; Sustainable livelihood, Development-induced displacement, Inclusive development, Community compensation, Bole Lemi Industry Park, Addis Ababa*

Chapter I: General introduction

1.1. Background

In the early 1970s, the United Nations (UN) held an international conference to focus on fostering industrial development at the global level. The conference established many sector-based development programs and gave priority to industrialization. The conference also established the main principles of industrialization and the means of action to motivate the international community to work toward sustainable development through cooperation (UNIDO, 1973). In addition, the Lima Declaration reached a consensus on encouraging the industrialization of developing countries with the goal of increasing their fragile share in global industrial production. It also emphasized the need for strong integration of the industrial sector with other socio-economic sectors in order to achieve the comparative and competitive advantages of nations by adopting industrial clusters at the industrial park level. (UNIDO, 1974).

The idea of industrial park development is based on several principles, most notably the allocation of specialized infrastructure in selected development zones (Abelo et al., 2020; Trang et al., 2021). This is done with the aim of reducing the costs associated with building infrastructure and enhancing a country's ability to attract new investors. This would eliminate the economic, social, and environmental impacts caused by industrial production. (Stucki et al., 2019). Beyond their label, industrial parks are regarded as a helpful tool for luring capital, encouraging technological learning and innovation, and generating jobs, with the ability to produce comparative and competitive advantages. (Ramos & Fernando, 2016). Industrial parks attract innovative businesses, leading to both more jobs and a larger tax base. They also support startups, new enterprise incubation, and the development of knowledge-based businesses, and offer an environment where local and international firms can interact with a particular center of knowledge creation for mutual benefit. (ECARC on IPD, 2022).

An industrial park is philosophically based on the integration of relatively different functions, including production, services, relaxation, and education, into an industrial area with high economic activity and employment (Midoun et al., 2019). It can help to overcome hurdles and accelerate economic development in general and the inclusive development of developing nations (Fekadie Bazie, 2021a and 2021b), such as Ethiopia, in particular.

The Ethiopian economy is characterized by the least industrial development. In many respects, the industrial sector exhibits a low quality of products, a small workforce, and limited export capacity. It is also the least developed country in the world (EIC, 2015). In addition, it is structurally unbalanced and dependent on imports for intermediate inputs and capital goods. As a result, the development of other sectors of the economy is hampered by the lack of a dynamic, modern, clustered, and structured industrial sector (MoI, 2016). In light of these challenges, the government has envisaged the development of industrial parks in the country for economic prosperity and environmental quality verification as a whole (Linnenluecke and Griffiths, 2013; Lei Shi et al., 2014; EEC, 2017).

So far, the Ethiopian government has established and launched fifteen industrial parks (IPs) at the national level. These IPs specifically target manufacturing industries, with a main focus on the four regional states of Oromia, Tigray, SNNP, and Amhara and the two city administrations of Addis Ababa and Dire Dawa (Ethiopian Economic Commission, 2017). Worldwide experience has shown that Industrial Park Development (IPD) can be used as a policy tool to address development gaps and help achieve broader national and regional economic development goals (Tarantini et al., 2017; UNIDO, 2019). The successful implementation of IPDs depends on a number of key factors, including clear objectives, a sound governance system, appropriate policy preferences, effective administrative procedures, active investment promotion, and strong linkages to the rest of the economy (Begum et al., 2016). In line with these factors, it is essential to examine the process and implementation of IPD in Ethiopia while also drawing on development lessons from other countries, such as China's Special Economic Zones (SEZs) (EDRI, 2016). Industrial park (IP) development is a key policy instrument for enhancing economic transformation. It can attract investment, promote technological learning, upgrade innovation, and generate stable and decent employment (UNIDO, 2002). To achieve these goals, countries need to implement feasible policies and vibrant directives. These policies and directives should consider the specific features of each country (Alebel et al., 2017).

Therefore, this thesis has assessed world experiences by reviewing different literature, particularly the fast-growing Asian tiger countries. An economy is sustainable only if it simultaneously meets human needs, particularly the essential needs of the world's poor, and accepts the limitations imposed by the requirement to sustain the environment's ability to meet present and future needs (Bekele, F., 2010; Gebregziabher, 2014; Debela et al., 2020). This perspective enables us to grasp the techniques and strategies that led to their dramatic economic growth over the last four and five decades while also adopting sustainable industry development (SID) practices in our context. Hence, a clear understanding of the concept of SID and what it envisions to achieve in the medium- and long-term is essential among key stakeholders (government bodies, investors, entrepreneurs, universities, and local communities). This understanding should be defined and directed through refined, workable policies and strategies.

In addition, it is essential to explore the rationality of the IP development process (planning, implementation, monitoring, and evaluation) to transform productivity and systematically reverse development gaps through scientific research at the highest levels of intervention (federal, regional, and local governments, as well as grassroots societies). This helps to clarify the individual and shared roles and responsibilities of each entity in achieving development goals in general and sustainable industrial park development (SIPD) in particular. Therefore, it is imperative to investigate the impacts of the new emerging industrial park development on defined socioeconomic and environmental elements, with strong consideration for the livelihood of the local community (Goswami & Mohammed, 2020; Dires et al., 2021). The integration of SMEs with IPs (Marshall, 2019) and the region of the park would also need to be well-elaborated while contributing to an inclusive and sustainable IPD that benefits the surrounding community.

Industry parks are also supposed to establish strong linkages with research institutions and universities to implement new technologies and transfer knowledge and skills. (Kim, 2013; Joo et al., 2018; Mohammed, 2020; Rodriguez et al., 2022). In this regard, different studies argue that there is a need to enhance collaboration among academia, industries, governments, private institutions, and communities to strengthen EIP and the environmental planning strategy toward sustainable development. (Fang et al., 2007; Stucki et al., 2019).

Furthermore, the United Nations (UN) has demonstrated the viability and benefits of Eco-Industrial Park approaches (EIPA) in scaling up resource productivity and improving the economic, environmental, and social performance of businesses in developing nations (UNIDO, 2018). EIPAs are environmentally friendly. Since 2012, the Ethiopian government has been developing industry parks as special economic zones. The government's primary focus is on the national economic benefits of the program, with less consideration for environmental factors, the livelihood of the local community, or a sound strategy for integrating these issues into the industry parks (World Bank, 2017). Fifteen industrial parks have been established in some large cities of the country (Addis Ababa, Hawassa, Dire Dawa, Mekele, Adigrat, Bahir Dar, Kombolcha, Adama, and Jimma). Among them, the Bole Lemi Industrial Park in Addis Ababa was selected for this study. The major factors that led the candidate to choose this site were:

- Its location is in the capital city, where a large number of people live.
- It has the potential to have adverse effects on the surrounding area, such as waste discharges, unemployment, displacement, marginalization, and harassment (Walakira, P., 2011; Serrat & Vanclay, F., 2017; Rouzet & Shaw, 2019).
- Its vigorous measures, such as a workforce center and technology, access to infrastructure and markets, security, and peace, within the locality and the region of the park These measures have ranked the site as a potential study hub for inclusive, sustainable local and industrial park (IP) development.

Thus, this dissertation, in line with its academic goal, would like to make an effort to address the IPD gaps that have bottlenecked sustainable eco-industrial park development (SEIPD) in the country in general (Paudel et al., 2017; Coulibaly, 2020) and the research site in particular. To this end, the dissertation has investigated the impacts of industrial park development on the environment and the livelihood of the displaced community around Bole Lemi industry park.

The study used a socioeconomic survey and laboratory examinations to investigate the industrial impacts, factors, and magnitude of the environmental elements and livelihood of the surrounding community. The results would benefit policymakers by demonstrating the development gaps and providing recommendations for reversing the negative impacts.

1.2. Statement of the problem

The Ethiopian economy faces a challenge in ensuring income growth generated from a developing industrial sector while also maintaining environmentally sustainable production processes. Evgeniy et al. (2018) stated that, while industrial growth is mainly a function of market forces, governments actively pursue policies and activities to accelerate industrialization throughout the economy of a country. Therefore, promoting development in a balanced way requires the integration of the three dimensions of sustainable development, such as economic, social, and environmental issues. This is not a choice for most developing nations but rather a compulsory task, particularly for Ethiopia (UNIDO, 2013).

According to Alebel et al. (2017), governments assert that industrial activities directly or indirectly affect the natural environment. It is a difficult task to either set or enforce environmental standards that do not have some negative impact on industrial development options, or to formulate industrial policies that take environmental issues fully into account. Therefore, optimizing welfare and attaining economic, social, and environmental objectives requires studying the relationship between industrial policies and the potential for industrial pollution (UNIDO, 2019). In this context, the extent to which environmental policies and management have prevented or mitigated pollution resulting from effluents is going to be investigated and addressed as a research question.

The majority of manufacturing industries in Ethiopia are old and use outdated technology (Abreha et al., 2017). For example, 90% of the industries located in Addis Ababa discharge their wastewater without any treatment into nearby water bodies and open spaces. This has exposed streams flowing across Addis Ababa to serious pollution (AAMPPO, 2017). Although a limited number of assessment reports have been conducted to assess pollution's impact on human health.The reports show that there was a direct release of untreated industrial effluents into the water bodies, resulting in a negative impact on human health.

The following studies have been conducted to assess the impact of industrial pollution on human health in Ethiopia:

- The AWSSA Project (2004) found that people living near industrial areas were more likely to suffer from respiratory diseases, skin diseases, and diarrhea.
- The Wastewater Master Plan Study (1993) found that industrial wastewater was a major source of pollution in Ethiopia's water bodies.
- The AACEPA Five-Year Strategic Plan (2010–2014) identified industrial pollution as a major threat to human health in Ethiopia.

These studies suggest that industrial pollution is a serious problem in Ethiopia and that it is having a negative impact on human health (Abrha et al., 2017). The government of Ethiopia needs to take steps to reduce industrial pollution and protect the health of its citizens. As indicated in the EPA's Amare’s A. (2019) environmental studies, a considerable amount of waste, particularly in Addis Ababa, ends up in open dumps or the drainage system. This threatens both surface and groundwater quality, providing a breeding ground for disease-carrying pests that impact human and animal health as well as the environment.

The flourishing of manufacturing industries in the country, which is a major source of pollution and waste, has also congested the way people think and live through changes in technology, environment, and culture. Assefa et al. (2014) state that most communities surrounding industrial zones have been complaining about the health and environmental impacts of factories. Waldt (2015) argues that governments have a moral and legal obligation to intervene in society in order to direct, regulate, facilitate, and act as a catalyst for economic prosperity, social justice, and ecological sustainability. Even though there are laws and regulations at the federal and regional levels, their implementation and enforcement mechanisms for regulating waste and pollution have become unviable due to weak management. Consequently, the problem has become serious for human and animal health as well as ecological elements. Therefore, research on industrial wastes and their related impacts on the environment (water, soil, and vegetation) has been given a paramount and significant position, alongside the socio-economic impacts of the displaced indigenous community due to the park development programs (Waldt, 2015).

The World Bank has played a vital role in conducting studies on development-induced displacement and resettlement (DIDR). The term DIDR first appeared in scientific publications in the mid-to-late 1980s (Bogumil, 2013). Although international institutions have recognized development-induced displacement (DIDR), the phenomenon continues to affect urban and rural grassroots residents around the world, particularly in the Bole Lemi Industry Park locality of Ethiopia. According to Terminski & Bogumil (2013) and Sabar (2010), dislocations can lead to a number of potential risks, including landlessness, unemployment, homelessness, increased morbidity and mortality, food insecurity, loss of access to common property, social disarticulation, and impoverishment. Marginalization can exacerbate these risks, leading to further declines in health, well-being, and economic opportunity. It is important to address the root causes of dislocations and provide support to those who have been displaced in order to mitigate these risks.

The growth of Addis Ababa City's population from about 2.1 million in 1994 to about 2.7 million in 2007 (or 2.1% annually) has been primarily horizontal, occurring in peripheral areas. Many farmers in the peri-urban periphery have been dispossessed of their agricultural land, which is the basis of their livelihoods. The city's expansion program is neither participatory nor supportive of farmers in the periphery and thus has negative effects on people's livelihoods, with women and youth being the most affected (Feyera & Terefe, 2017). This phenomenon has again shown that the residents around Bole Lemi Industrial Park are the members of the community most directly affected by the project.

Moreover, the increased demand for land for development projects, such as industrial parks, has exacerbated the miseries of displaced societies. These societies have been forced to give up their homes, assets, and means of livelihood (Wen, Z., et al., 2019). As a result, land policy, compensation, and rehabilitation strategies with funding are not viable for sustaining the livelihoods of societies in general and the community at the research site, Bole Lemi Industry Park, in particular. Moreover, previous studies have been conducted (Tahoma, 2014; Diriba, 2016), mostly on land conversion and farmer's facilities. Those studies were focused on the scattered industries, with little or no attention paid to the impacts of industrial parks.

Therefore, in this study, we examined the hypothesized major industrial park impacts on the environment and the livelihood of the displaced community as follows:

- The quality of River Water around the BLIP deteriorates with industrial effluents released from IP into the rivers.
- Excess Heavy metal concentrations from discharges of industrial wastes may contaminate environmental attributes (Soil, vegetables, and Water) and human health.
- Compensation mechanisms and procedures lacks legal liability (transparency, equity, fairness, and inclusiveness).
- Development-induced displacement (DID), due to an insignificant rehabilitation strategy or program, affected the livelihood of the displaced community.

1.3. Objectives of the study

1.3.1. General objective

The overall objective of the study was to analyze the impacts of industrial Park development on the environment and livelihood of the local community around the Bole Lemi industry park in Ethiopia.

1.3.2. Specific objective

The specific objectives of the study are to:

1. Analyze the concentration of Heavy Metals in Soil, Vegetables, and Water around the Bole Lemi Industry Park, Ethiopia.
2. Evaluate the Impact of Industrial Wastewater on the Water Quality of Rivers Around the Bole Lemi Industrial Park, Ethiopia
3. Investigate compensation Mechanisms and procedures relative to the displaced community's preference during DIDR execution.
4. Measure and analyze the effects of industrial park development on the livelihoods of displaced local communities.

1.4. Research questions

1. What hazardous effluents are discharged from IPs into environmental attributes (Water quality and horticulture), and what is their implication on human and animal health as toxins? And to what magnitude is it polluting;
2. What were the living assets and plans of the local community before and after post-park development? How and to what extent does it affect their livelihood?
3. What are the compensation mechanisms? Is it eligible and acceptable with the stakeholder's preference, and how far from gorgeous options is it?
4. To what extent is the implementation of IPD as a policy tool farsighted towards inclusive and sustainable eco-industry development? To meet its initial goals?
5. To What scale are the policy issues and strategies designed to integrate or link IPs with relevant development actors, particularly technology centers and Research institutes as well as environmental groups??

1.5. Significance of the study

The outcome of this study is expected to benefit different development stakeholders, including policymakers, researchers, investors (companies), universities, and research institutes, as it is expected to come up with relevant information with regard to the consequences of the establishment and running of the park in the area and on the lives of the people. It is also expected to benefit the IPDs in considering sustainable local and regional development approaches and eco-friendly industrial development strategies (Sertyesilisik et al. 2016).

Therefore, this research would be focused on filling the gap in modernizing industrialization from a dispersed and disconnected settlement approach to a clustered, integrated pattern and structure at the level of collective park development with assimilation of the livelihood of the surrounding community. This could again empower and enforce management efficiency and utilization of scarce resources (Land, Capital, labor, and infrastructure) to maximize social, economic, and environmental benefits for the sake of comparative advantage at the national level and competitiveness at a global level as well. So that this proposal, in this regard, gives priority to investigating specific to Bole Lemi industry park, which is the primary Ethiopian SEZ to practice and attain Sustainable eco-industry development, which may contribute to the new coming park development (the 14^{th} remaining IP) practices at the national level as a whole.

Last but not least, the dilemma of the industry sectors and industry Parks on the marginalized nearby community would be scientifically investigated, and finally, multi-spiraling policy-based recommendation options towards local sustainability (grassroots community, life stability) via sustainable industrial park development would be derived and contributed.

1.6. Scope of the study

Since the issues of industry park development, sustainability, and impact evaluation are vast, it is difficult to deal with all aspects at once. This research, therefore, limits itself to certain aspects of IP and local sustainability simultaneously. It mainly focuses on the three main dimensions of sustainability: economic, social, and environmental. Under economic impact, this research evaluates only the impact of the park on the income of residents, the creation of new businesses, and other related topics. The social aspect deals with the social impact that the park had on the locality. These include the impact the park had on the livelihoods of the residents (job creation, change in livelihood, displacement, impact on access to school, health facilities, impact on children's and youth’s lives, gain or loss of capital assets, migration, exposure to a new culture, linkage of the park with local institutions such as Federal TVETs, Research centers, and relevant Universities). The environmental aspect is also captured by evaluating the impact of the park on water pollution, soil, and horticulture around the industrial park.

The data regarding the themes of the research objectives were collected within a defined spatial territory (within a 5km and 10 km radius). The 5 km radius is chosen because it represents the walking distance in town planning (Ethiopian MOUD, 2016). It represents those people who are primarily obstructed by the industrial park. This is important for comparison and to evaluate how the park affects the lives of local residents in the first place. In addition, communities that live beyond this distance should also be approached to see how impacts dissipate as one gets further from the industrial park.

1.7. Limitations of the study

Budget shortages, logistical services (Transport, shelter, and food), Time, and data are some of the expected limitations during the research work. Thus, the economic use of scarce resources would be planned and implemented.

1.8. Organization of the dissertation

This dissertation is organized into six chapters. Chapter One discusses the background, statement of the problem and fundamental research questions, objectives of the study, rationale of the study, scope of the study, literature, concepts, and theories, description of the study area, and dissertation organization.

Chapter’s two to six are incorporated into independent publications and manuscripts with an abstract, introduction, materials, methods, data settings, results and discussions, conclusion, and recommendations.

Chapter two and a chapter have discussed the impacts of industrial waste water-caused pollutants (physicochemical parameters) and hazardous heavy metals and their effect on living organisms, exploring them with laboratory examinations.

Chapter Four articulated the effect of the DIDR program on the livelihood of displaced and marginalized communities around the industry park using statistical software modeling. Chapter Five also detected and evaluated the compensation viability, procedures, and mechanisms relative to the displaced community's preferences. This chapter explores the community's attitude, willingness, and perception toward investments by measuring inclusiveness and sustainability in the locality.

The authors have discussed the major findings and results of the dissertation in the final chapter, Chapter Six. This chapter concisely summarizes the study's rational contributions to policy implications and directions for scientific communities in the future.

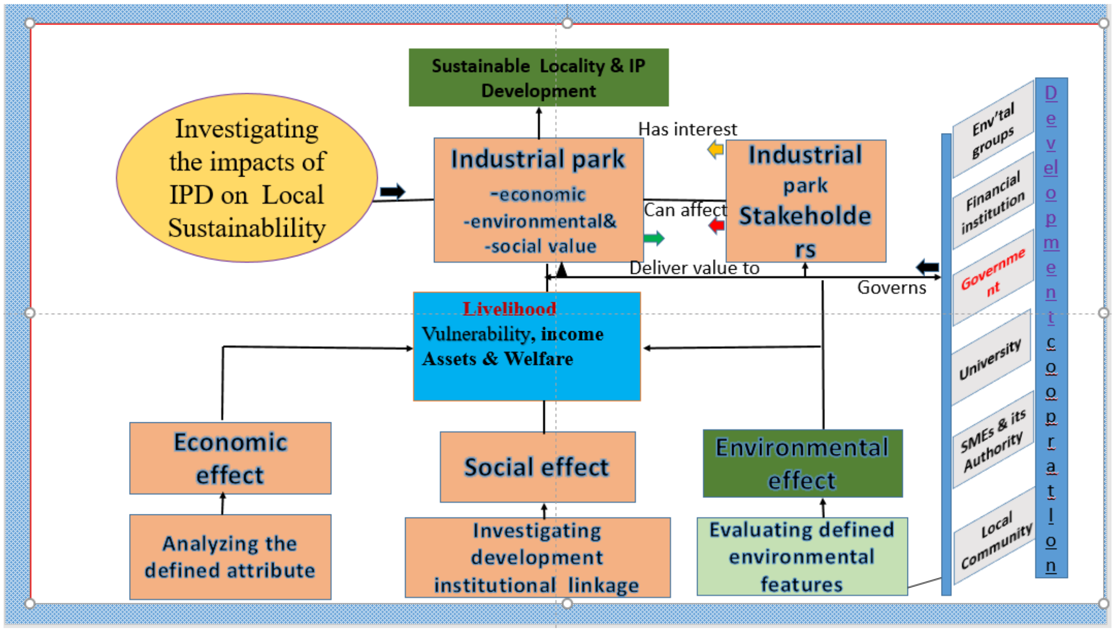
2. Conceptual Framework of the Research

An industrial park is a set of businesses that share resources in order to increase profitability and reduce environmental impact. The implementation of industrial parks may significantly contribute to the creation of a sustainable economy. Despite this prospect, the actual development of industrial parks is challenging, as a variety of factors must be considered. Not only technical, economic, and environmental factors are relevant but numerous stakeholder relationships as well, such as between firms, governmental bodies, and local communities (France, Research and Education Institute, a conceptual framework for industrial park development, 2015).

Therefore, effective measures towards inclusive and sustainable industrial development should encompass and enhance productive capacities in a way that supports the structural transformation of the economy, encourages economic growth and the creation of decent jobs, enhances productivity and development through the transfer and absorption of technology on mutually agreed terms, infrastructure, and technological innovation, and advances development, particularly in the small and medium-sized enterprise sectors (UNIDO, 2013, Lima Declaration).

Therefore, this paper presents a conceptual framework that is used to capture these diverse aspects and the relationships between them. The Unified Modeling Language (UML) is used for modeling its concepts and relationships. First, based on a literature survey, relevant concepts of industrial parks are identified. One central concept is "industrial park development". A novel value-based interpretation of industrial park development is presented. Second, the park’s economic, environmental, local, and regional development contexts, as well as its internal technical components and their relationships, are modeled. Finally, the framework is used for modeling a concrete IPD towards eco-industrial park development (Andreas Makoto Hein, 2016). Thus, this research has intervened in the subsequent conceptual frame to promote the Bole Lemi industry park towards the EIP standard.

Figure 1.1: Industrial Park Development Analytical Framework



Source, Own, adopted from Andres M. Hein et.al 2015, Boston, Massachusetts, USA

3. Research methodology

3.1. Description about the study area

Bole Lemi Industry Park (BLIP), which is the research site, is found in Addis Ababa. It is located in the southeastern Suburb of Addis Ababa, at a distance of about 15–20 km from the City Center. The industry park is located at **X and Y** Coordinates of 8° 55' and 90° $^{05\ north}$ latitude and 380° 40' and 380° 50' East longitude. The park is found in one of the ten sub-cities (Bole Sub-City Administration) of Addis Ababa, with a coverage area of 156 ha of land.

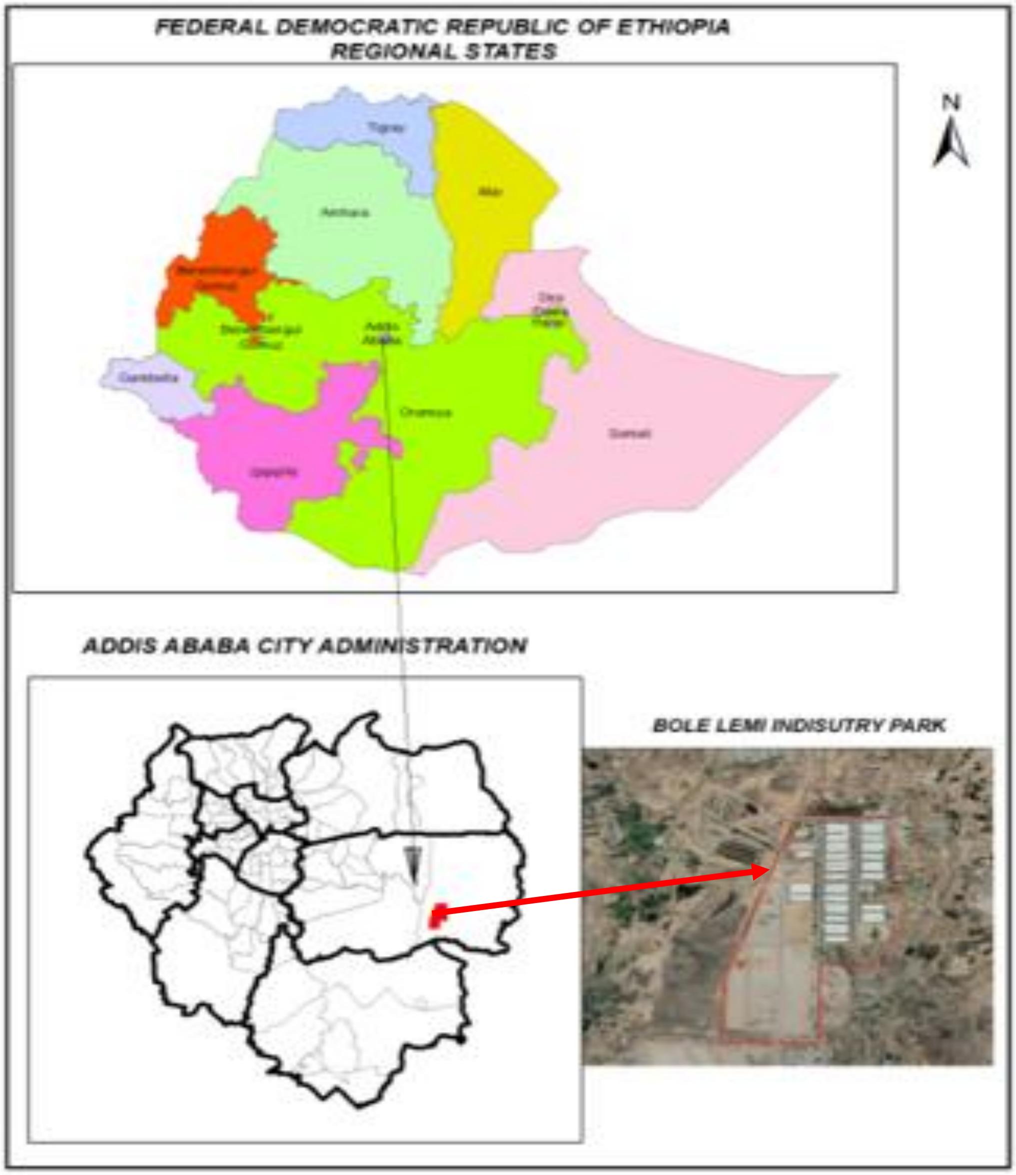
The Industrial Parks Proclamation 886/2015 provides that industrial parks can be developed by any profit-making public, public-private, or private enterprise. Three mechanisms are in place for the establishment of IPs and SEZs: (a) fully developed by the federal or regional government; (b) developed by PPPs with the IPDC; and (c) by private developers only. Bole Lemi IP is the first public park established and owned by the federal government (EIPDC, 2017).

Bole Lemi Phase I (covering 156 hectares) is the first IP operating under the IP development strategy. It was established in 2012 with the help of a World Bank loan and started its operations in 2014. It now consists of some 20 pre-erected factories (185,000 square meters of factory space) rented out to more than 10 foreign-owned manufacturing companies producing and exporting leather and apparel goods.

The Park site is surrounded by vast farming lands and quarry sites in the south and southeast, by condominiums in the form of built city expansion in the north and northwest, and by the Akaki River and its small tributaries on the east. The existing land use type in Bole Lemi IZ is mainly characterized by cultivated agricultural lands and scattered settlements. Quarry sites are very commonly found in and around the site in large numbers, according to the Addis Ababa City Structure Plan Project Office (AACSPPO, 2017).

The site is drained from north to south. It is drained by the Great Akaki River and its tributaries, such as the Beshale River. The Great Akaki River also drains large parts of Addis Ababa city in its eastern and southeastern directions and is highly loaded by waste generated from upstream.

Figure 1.2: Location of Bole Lemi Industry Park, Addis Ababa City



Source Own ,2019

3.2.Research design and sampling frame

This study has planed to draw appropriate methodological paths. Hence, based on the nature and characteristics of the research objectives, this study would mostly employ a correlational and quasi-experimental research design.

Causal research aims to determine the cause-and-effect relationship or association between several independent variables and one or more dependent variables without any experimental manipulation (Cipani 2009). Tharenou et al. (2007) state that the aim of causal design is to assess the extent or magnitude of the relationships between the independent variables and dependent variable(s). Therefore, this study is going to evaluate the determinants of IP that carry the surrounding potential resources while securing the environment and livelihood of the local community. Furthermore, in the meantime, the integration of IP with SMEs, community participation, and its inverse or diverse effect on inclusive and sustainable development processes would be well analyzed.

According to Jackson (2014), the quasi-experimental research design is also interested in evaluating the effects of a particular project or program, while dealing with the quantitative aspects of the study would entail comparing participant groups that are produced naturally or occur through intervention by other agents. Tharenou et al. (2007) also added that quasi-experimentation is applied to investigate events that naturally occured . Therefore, this research is aimed at investigating the impact of IPD on the environment and livelihood of the Bole Lemi industry park territory.

In this regard, Bole Lemi was selected using a purposive sampling method. The first task done in this regard was to obtain the sampling frame, which is a complete list of industrial parks throughout the country (Ministry of Industry and EIPDC, 2016). There are a total of fifteen industrial parks in the country, from which the research site was selected as a case study. The site was selected due to its significant potential to affect the environment and the livelihood of surrounding residents through its untreated effluent enlargement.

Case studies are important because they offer a deep insight into the subject to be studied. A case study gives solid knowledge about the case that is believed to represent the group.

It also saves a great deal of time and money. That is why the case study method was employed. This research intends to study the selected attributes of the economic, social, and environmental impact of the industrial park on residents that live within a 5 to 10 km radius of this park. The 5 km radius is specifically considered a walking distance in planning (MOUD & AACPPO, 2016). Hence, in this study the word "local" presents the people who live within the defined radius from the center of the park compound.

After delineating the radius, the study addressed the number of households who was living within the perimeter using Survey and official data. A sample survey has been conducted with these residents to evaluate the impact of the industrial park on their livelihood and the environment. A structured questionnaire would be developed to conduct a sample survey of these residents. The three core issues are mentioned here on purpose. They are specifically included in the research to capture the three basic pillars of sustainable development. According to UN-Habitat (2012), sustainable urban development is about the local economy, society, and the environment. Hence, variables that measure the impact of the industrial park on people's economies, social lives, and the environment would be accessed by the community.

3.3. Data types, sources, and methods of data collection

3.3.1. Data types and sources

Primary and secondary data have been collected using appropriate collection tools from identified data sources.

Primary data would be collected from the displaced and the attached neighborhood selected grass-root communities, industry parks -investors, managers, and concerned employees that are found in the industry Parks. Government bodies like City Administrations, managers, and experts from environmental protection and conservation offices, investment Commissions, Urban planning institutes and commissions, urban land development, and management offices, and the mayor's office also visited.

Similarly, at the Federal level, the Ministry of Industry, Ethiopian Investment Commissions, Industry Parks Development Corporation (EIPDC), Ministry of Urban Development and Construction, and Federal Plan Commission Regional government leaders are also being visited (Bottom UP interface). Likely, three professional experts and a top manager (the leader) of each organization would have been touched. Small and Medium-scale enterprise (SME) agencies and financial institutions at the Federal government and Addis Ababa City Central level are potential resources.

Secondary data sources are Literature, Ethiopian Central Statistics Agency documents, United Nations, Ph.D. dissertation papers, articles, publications, and federal, regional, and Woreda sector offices are used as a secondary data sources

3.3.2. Methods and techniques of data collection

3.3.2.1. Quantitative data collection tool

The study would use a custom quantitative data-gathering method, including the Experimental method. The Experimental method made the researche task more concrete and realistic. To address the specific objectives, Primary data were collected with enumerators using different data collection techniques, including survey questionnaires and semi-structured interviews.

Thus, household heads from the local communities, investors, selected public and private organizational setups, top leaders, and middle and bottom managers took part in this regard purposefully.

Thus, it generates statistics through the use of large-scale surveys using questionaries' (Closed-ended, Open-ended, or a combination of the two) or structured interviews.

The questionnaire was directly asked by enumerators for local residents and filled out. The major reason was**:** that, first**,** the researcher expected that some respondents might not be able to read and write.**Second,** It would be important to avoid the risk of collecting incomplete and wrong information particularly when the respondents become unable to understand questions properly. **Third,** to get reliable data within a short period of time.

3.3.3.2. Qualitative data collection method

Qualitative data collection tools are used to perform in-depth factual analysis. And it helps to provide answers for the how part of each study objective. Hence, Interviews **(**Structured and semi-structured interviews), Focal group discussions, Key informant interviews, and Observations (Insight, photography, Documentary film, and Recording) had been implemented.

Focus group discussion is important as it allows study participants to share a common range of knowledge. Therefore, the information generated through this method had a wider margin and depth of validity (Creswell, 2009). In this study, 3–6 focus group discussions, of which each group is composed of 8–12 members, were conducted with the surrounding targeted resident households. So, the information gathered through this technique supplements the data collected by means of questionnaires.

The method also enables us to explore the attitude, behavior, beliefs, perception, and experience of the people. And it attempts to get in-depth participants' Opinions.

3.3.3.3. Mixed research approach

Here both Quantitative and Qualitative types are stimulated interchangeably, and "triangulation "is also used due to the use of both inquiries.

3.4. Population and sampling

3.4.1. Target population

The urban and farmer households that were displaced from their origin homes prior to the IP plantation program by 2012 and the hinterland households within the delineated boundary of the research site have been considered the target population of this study. Hence, Addis Ababa City Administration and Oromia National Regional State Areas are the potential data sources.

Furthermore, the target population for the study is involved with the disregarded Local Community and manufacturing industries (Apparel, textile, garment, leather, and leather product industries) investing and found in the park of the defined study site (Bole Lemi Industry Park).

The displaced communities and hinterland households, Government Officials and employees, industry owners, and workers that are selected are also among the basic targets.

3.4.2. Sampling framework

This study attempts the following standard sampling thoughts and formulas: According to Yemane (1967), for a larger population whose size is known, the sample size can be determined using the following formula: n = N/1+N (e2), where n is the sample size, N= Population size, and e= the margin of error.

On the other hand, Kothari states that sampling design primarily aims at increasing the representation of the population by reducing sampling error at the minimum possible cost (Kothari, 2004).

Kothari (2004) defines research design as the arrangement of conditions for collecting and analyzing data in a manner that aims to combine relevance to the research purpose. Consequently, Kothari (2004) conventionally argued to use sampling and a sample size determination model for deciding the households to be addressed from the total population of the local community, as verified below.

Formula: -

$$n = \frac{N.z^2 . p. q}{e^2 (N-1) + z^2 .p.q}$$

$$n = \frac{(600)(1.96)^2 (0.5)(0.5)}{(0.05)^2 (600-1) + (1.96)^2 (0.5)(0.5)}$$

n= 401hh

Where:

n= sample size

z= 95% confidence interval under normal curve (1.96)

e= a sample or margin error (0.05)

p= proportion of sampled population of sample population (0.5)

q= is the estimates of the proportion of sample size (0.5)

N= total population (960)

p.q=0.25 .therefore; 401 respondents selected

Purposive and random sampling method was used to select samples form the local community, companies in the IPs, and the respective SMEs population conditionally.

Therefore, the sample survey questionnaires, in-depth interviews were conducted with key informants, operators in the industrial park, managers of the park, higher official in the Ethiopian Industry Park Corporation, Ministry of Industry, and Federal SMEs Authority. This provides a bottom-up and tops down perspective on the issue under investigation. The research mainly adopts a bottom-up approach as residents are placed at the center of the evaluation. Such a bottom-up perspective is important because it is inclusive. It also evaluates certain top-down issues such as policy issues and other aspects (managerial) that are mostly top-down in nature.

3.4.3. Variables

The scientific research variables of any scientific experiment or research process are factors that can be manipulated and measured. Any factor that can take on different values is a scientific variable and influences the outcome of experimental research (Rajkot, 2018). And these variables could be classified into two measure categories: independent and dependent Variables (Cohen et al., 2007).

Generally, there has been a relationship of cause and effect between dependent and independent variables, where the independent variable acts as a cause and the dependent variable as an effect on the research objectives. To summarize, the variables employed for this research are listed below with respect to the research objectives.

3.5. Methods and models of data analysis

This study employed different analytical models to deal with each specific objective. **Laboratory tests** and multiple statistical models (like logistics and the multinomial logistic regression model, as well as descriptive and inferential analysis) would be used.

Furthermore, based on the nature of the data, a mixed method (qualitative and quantitative technique analysis) was performed. And statistical software like **SPSS and STATA** was used **as such** for coding, editing, and the tabulation process. Hence, the most basic form of statistical analysis, like descriptive statistics to describe the row data and an impact analysis model to examine the impact, has been used so far to calculate the mean, median, mode, and percentages to demonstrate impact significance during the data process.

Findings and results would be discussed and presented through tables, bar graphs, and pie charts. Model maps, descriptive, explanatory, and exploratory papers are also demonstrated scientifically as parts of the result.

3.5.1. Models used

The inferential statistics mainly evaluate the impact of the industrial park on the local household economy using multiple regression models. The multiple linear regressions showed the quantitative effect of the independent variables on the dependent variable (the household income of residents living around the Industrial Park). The household income of residents is regressed as a function of independent variables, to show how independent variables impact household income (HHI). Some of these independent variables that need to be considered in such instances are the proximity of the residents to the industrial park (X1), the availability of household members who have a job in the industrial park (X2), new businesses created as a result of the industrial park (X3), farming land lost due to the industrial park (X4), providing inputs for the park (X5), etc. Such variables are captured using the model specified below.

HHI = f (X1, X2, X3, X4......)

The model can therefore be specified as

Thereafter, the formula for multiple linear regressions is written as follows.

$$HHI = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + ... +e)$$

Where HHI = Household Income; α = constant; β = coefficients; Xs= independent variables

The simplified multinomial logistic regression model relates the log of odds (or logit) of Y to the explanatory variables X, in a linear form:

$$\text{Logit } (Pj) = \log(\text{odds}) = \frac{Pj(Y=i)}{P1(Y=1)} = \beta 0i + \beta 1iX1 + \beta 2iX2 + \beta\, 3iX3 + \beta 4iX4 + ...BpXp + \varepsilon$$

where Pj(Yi)/P1(Y1) is the odd ratio of each dependent variables; Pj represent the probabilities of dependent variables (y1, y2, y3, y4, and y5) p1, p2, p3, p4 and p5; Yi iβ_{0i}, β_{1i}, β_{2i}, β_{3i} and β_{4i}, parameters to be estimated or regression line coefficients or slops; X_1, X_2, X_3 and X_4 are independent variables; demographic, socio economic and environmental aspects, adopted from Akalu (2014)

Table 1.1: Summary of research design and approach

S. N	Specific Objectives	Variables Demographic, Eco. ,Social & Environmental Variables	Data Sources	Analytical Method /Model/	Hypotheses
1	To Analyze the Concentration of Heavy Metals in Soil, Vegetables and Water around the Bole Lemi Industry Park.	***Heavy Metals,*** ***Zn, Cr, Cd & Pb***	*- Near Streams, Rivers along the park (Lemi, Beshale)* *-Addis Ababa city Beautification & waste management agency* *- City Environmental management Office*	*Laboratory test*	*-The water sources are negatively affected and its effect leads the water quality beyond the Global & National standard. And therefore it affects human ,animals &vegetation health*
2	To Evaluate the Impact of Industrial Wastewater on the Water Quality of Rivers around the Bole Lemi Industrial Park.	*- PH, Temperature. BOD5 & COD,* *-Total Suspended solids(TSS),* *-Total dissolved solids (TDS). -Total nitrogen (as N),* *Total phosphorus (as P) & other Organic & non organic elements*	*- Near Streams, Rivers along the park (Lemi, Beshale)* *-Addis Ababa city Beautification & waste management*	*Experimental* *(Laboratory test)*	" " " " "

			agency - *City Environmental management Office*		
3	To measure the effects of industrial park development on the livelihood of surrounding urban and the hinterland Farming community	***Independent Variables*** - *Age of household in years* -*Sex of household in years* -*Household head education level* -*Religion of household head* -*Marital status of household in years* -*Area of land per hector per household head* ***Dependent Variables*** *Job opportunity created for household in number in IP* -*Income generated per household head before & late IPP* -*Expenditure released per household head before & late IPP* - *life status per household **head** before & late IPP*	- *Nearby Residents & sampled heads* -Surrounding affected Community -Defined SMEs associations -EIPDC -Policy Makers -Experts, Managers & higher officials of defined organizations - **Laws** (Declarations, Directives and regulations) limitations	Multinomial Regression	-*The local community welfare & asset is dominantly affected due to industrial park development* - Development integration and Institutional linkage has fragmented and stresses inclusive & SEIPD program

4	To Investigate compensation mechanisms and procedures relative to the displaced Community Preference & Rehabilitation strategy.	**Compensation Mechanism** -Compensation choice in type per household head - Compensation received n kind per household head -Compensation preference per household head -Opportunity of new business plan & rehabilitation forms per household head - Participation per household head in new development program - Reflection per household head, while presence of compensation & rehabilitation Options -Life status per household before & after compensation. - Sense of **Laws** (Declarations, Directives and regulations) , with compensation procedure per household head.	- Marginalized community -City Gov't -AA City Compensation & rehabilitation management Agency and -Relevant Federal institutions	Multinomial Regression	***Compensation instrument*** *-Compensation tool is not well distinguishable, and it lacks the community participation prior to its announcement.* *-The un-separation of Property removing & compensation estimating authority make the process biased & unfair projection out come* *-Thus it does not meet the affected welfare of the community .*

Table 1.2: Variables defined to analyze the effects of industrial park development on the livelihood of the displaced local community

Variable	Description	Measurement	Expected effect
Dependent Variable (1)	**Mean Before 2012 & 2020 Late**		
Total income	Income per household head per year	Continuous(ETB)	+/-
Total expenditure			
	Expenditure per household per year	Continuous(ETB)	+/-
Independent Variable			
SHHH	Sex of Household head	Dummy	+/-
AGRHHH	Age of house hold head	Continuous (year)	+/-
MARSHHH	Marital status of household head	Categorical (Type)	+/-
EDUHHH	Educational level of household head	Continuous (Number)	+/-
TTFAMSIZ	Total Family Size of household head	Continuous (Number)	+/-
Dependent Variable(2)			
TTLUE2012	Land owned per household early 2012	Continuous (Hector)	+/-
TTLUE2020	Land owned per household at 2020	Continuous (Hector)	+/-
Independent Variable			
AGHHH	**Age of household head**	**Continuous (year)**	**+/-**
			+/-
TTFAMSIZ	**Total family size of household head**	**Continuous (Number)**	**+/-**
			+/-
EDUHHH	**Educational level of household head**	**Categorical (Number)**	**+/-**
			+/-
NDFSIZ	**Household head dependent family**	**Continuous (Number)**	**+/-**
Dependent Variable (3)	**size**		
Growth Trend HHH		**Categorical (Ordinal)**	**+/-**
Independent Variable	**House hold head growth trend**		**+/-**
TTNLIVST2012		**Continuous (Number)**	**+/-**
TTNLIVST2020	**Livestock per household early 2012**	**Continuous (Number)**	
ANNU Income	**Livestock per household late 2020**	**Continuous (Number)**	**+/-**
	Annual income per household head		
Dependent Variable (4)			
Perception		**Categorical (Ordinal)**	**+/-**
Independent Variables	**Household head choice**	**Categorical (Nominal)**	
Dependent Variable (5)	**Respondents response, feeling**		
Job opportunity created		**Categorical (Nominal)**	
	Employment opportunity created		**+/-**
Explanatory variable	**since IDP (2012-2020)**		
Dependent Variable (6)			
Progress in life standard		**Categorical(Ordinal)**	**+/-**
	Respondents response(choice)		

Table 1.3: Variables defined to investigate compensation mechanisms and procedures relative to the displaced community preference

Varia bles	Variable discription	Measurment	Expected effect
Explained Variable (1)			
HHH awareness	*Compensation awareness per household head*	Categorical(nominal)	+/-
Explanatory	***Determinant factors***		
AGHHH	Age of household head	Continuous (in year)	+/-
EDUHHH	Educational level of HHH	Continuous (in number)	+/-
SEXHHH	Sex of household head	Dummy	+/-
RELHHH	Religion of household head	Dummy	+/-
ETNHHH	*Ethnicity of household head*	Dummy	+/-
Explained Variable (2)			
HHH Comp Cho.			
Explanatory	Compensation Choice per Household head	Categorical (Type)	+/-
Explained Variable (3)			
Preference	Compensation preference per household head	Categorical (kind)	+/-
Explanatory			
AGRHHH	Age per household head	Continuous (in year)	+/-
TTFAMSIZ	Total family size	Continuous (in number)	+/-
EDUHHH	Educational level of HHH	Categorical(Ordinal)	+/-
NDFSIZ	Number of dependent family size	Continuous (in number)	+/-
Explained Variable (4)			
Satisfaction in DIDR			
Explanatory	Household heads reflection on compensation formulation and implementation during DIDR	Categorical(Nominal)	+/-
Explained Variable (5)			
HHHs Asset loss			
Explanatory	A- Amount of money paid, Birr/ M^2 of land per HHH.	Continuous (in number)	+/-
	B-Total amount of money paid for total land & property right	Continuous (in number)	+/-
	C- Government land sells price, for Investors in Birr/M^2	Continuous (in number)	+/-

Source, adopted from UN-HABITAT. (2012)

4. Ethical issues

At every stage of the investigation, the following ethical concerns had been taken into account: Citations had been made for all sources used, information would only be provided with consent, and any data collected from them would be kept private. The thesis wouldn't contain any biased or improper reporting.

Chapter II: Assessment of the impact of industrial wastewater on the water quality of rivers around the bole lemi industrial park (blip), Ethiopia

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Abstract: The discharge of industrial waste into water bodies without significant treatment can be a source of water pollution. This study was conducted to assess the impact of industrial wastewater on the water quality in rivers around the Bole Lemi Industrial Park (BLIP). Data were collected from six sampling stations in midstream, downstream, and upstream locations between May and June 2021. In situ (pH, electrical conductivity [EC], total suspended solids [TSS], and temperature) and ex situ (chemical oxygen demand [COD], total nitrogen [TN], total dissolved solids [TDS], total phosphorus [TP], and biological oxygen demand [BOD]) determinations of water quality were conducted. The quality of the water samples was examined using the weighted arithmetic water quality index (WQI) method. A statistical analysis showed that there are significant differences in the water quality parameters among the sampling stations along the river. The results showed different levels of temperature, EC, pH, TSS, TDS, COD, BOD, TN, and TP. The pH values were higher than the pH ranges (6.5–8.5) of USEPA, EU, CES, and WHO at two sampling stations. The results of the WQI showed that the analyzed water samples were in the "unsuitable for consumption" water quality category. These results will be useful for the city administration of Addis Ababa in crafting strategies for the protection and sustainable management of the Bole Lemi River.

Keywords: water quality assessment; industrial wastewater; physicochemical parameters; river; Ethiopia

1. Introduction

Freshwater resources are critical ecosystems that support human and animal life [1]. However, they are the most threatened ecosystems in the world as a result of anthropogenic activities [2] which impair their natural stability [3]. Rivers are important components of freshwater resources with beneficial effects on human beings as they require water for various uses [4]. As a natural resource, rivers are essential for human survival and development [5]. They provide resources (water, food, etc.) and livelihood to mankind [6]. Their water is used for various purposes, such as drinking and other human consumption, animal drinking, agricultural irrigation, industry, recreation, etc. [7,8]. According to the 2018 United Nations World Water Development projection, nearly six billion people in the world may face severe water shortages by 2050 [9]. However, globally, many rivers are polluted with chemicals [10,11]. The water quality in rivers can be changed by various anthropogenic factors. These include the accidental or intentional emission of industrial wastes. According to [12], many developing countries face pollution from industrial discharge, which triggers eutrophication [13]

Urban rivers play an important role in supporting economic and social development [6,14]. Rapid urbanization and industrialization have attracted large numbers of people to cities, resulting in large amounts of industrial wastewater and domestic sewage pollution increasing the pollutant load on these water bodies [6,15,16]. These problems deteriorate their water quality and weaken their ecosystems [17–19]. Due to urbanization and industrialization, river water pollution has become a severe problem in developing countries, impacting the sustainability of water resources [20] and impacting human health [21]. This has led to a high incidence of harmful diseases in humans and will harm sustainable economic development in the long run [22].

Water quality is a general term used to describe the characteristics (physical, chemical, and biological) of water resources. It plays an important role in determining aquatic ecosystems and public health [23,24]. It is a concern across the world due to the widespread release of pollutants into freshwater ecosystems [25]. It plays a vital role in maintaining the ecological integrity of the river ecosystem [26]. As an important indicator of river health, water quality deterioration is a challenge to humanity [25] and is a critical challenge faced by many countries in Africa [9,27,28] and other regions [29]. With increasing economic and societal development, the deterioration of river water quality has become increasingly prominent [30]. Maintaining a good level of river water quality is crucial for sustainable development and human health [24,31]. Studies about the changing characteristics of water quality and their causes have become a hot issue in the field of water sciences [32]. River water quality is an important environmental concern that must be monitored [33]. With a rise in people's awareness of environmental protection, the monitoring of water quality in rivers has gained extensive attention for its use in sustainable urban development [34]. Physicochemical water quality parameters play significant roles in assessing and monitoring river water [35].

Strong economic growth and urbanization contribute to the increase in industrial and domestic waste [36]. Effluents can easily be discharged directly into rivers without wastewater treatment, resulting in reduced water quality [37]. Although rivers are essential natural resources that support socioeconomic development (human use, livestock drinking, irrigation, industries, transportation, recreation, etc.), they have largely been subjected to various anthropogenic sources of pollution [38]. These include industries, among other sources [39,40], that cause the deterioration of river water quality. According to Worku and Giweta [41], poorly treated and untreated industrial wastewater discharged into rivers has resulted in the pollution of rivers in Ethiopia. Although industrial parks provide economic benefits, their environmental costs—such as water pollution, loss of biodiversity, etc.—result in the degradation of ecosystem functions and services [42]. In this trade off, a well-developed and science-based management of aquatic ecosystems is required. Such management should include knowledge of water quality (physical, chemical, and biological) data and other information [43].

The city of Addis Ababa in Africa is undergoing rapid urbanization and industrialization. The city has an area of 540 km^2. The rivers of the city are heavily polluted by waste generated from various sources, mainly industrial and domestic. According to Tamiru et al. (2005) [44], between 90% and 96% of industrial waste is discharged without treatment into water bodies and open spaces in Ethiopia. There is a need for monitoring and assessing the water quality of aquatic ecosystems such as rivers. This study aimed to determine the Bole Lemi River's water quality status in Addis Ababa, Ethiopia, using water quality indicators and the water quality index (WQI) assessment methods. The levels of water quality indicators were evaluated based on the standards of USEPA, EU, CES, and WHO for water resources. A one-way analysis of variance (ANOVA) was conducted to determine the water quality parameters among the sampling stations. The assessment and monitoring of water quality provides empirical evidence to support decision makers and natural-resource managers in managing aquatic resources. Knowing the existing conditions of the Bole Lemi River through water quality analysis could help decision makers create plans for sustainably manage the river.

2. Materials and methods

2.1. Description of the study area

This study was conducted on the Bole Lemi River, which is found very close to the BLIP in the city of Addis Ababa, Ethiopia**.** The industrial park is located at the coordinates 8°58′17.2200″ N and 38°51′24.5088″ E (Figure 1).

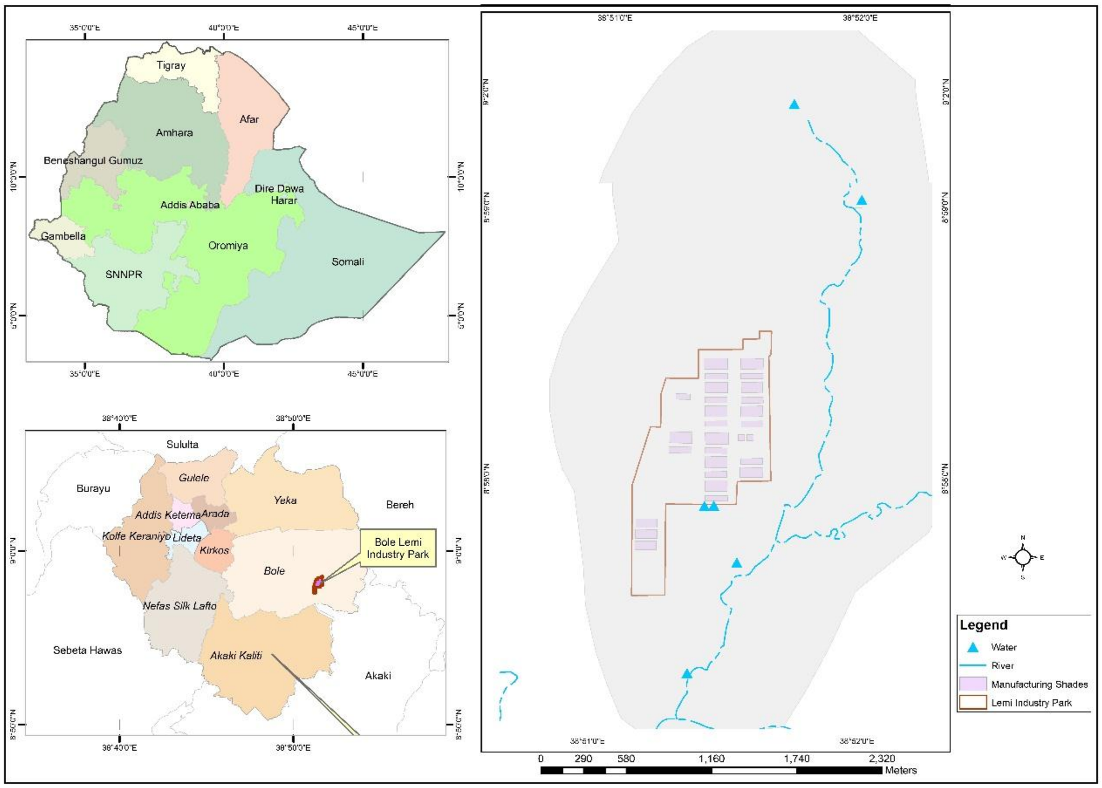

Figure 2.1: Map representing the BLIP and the sampling sites along the Bole Lemi River, Addis Ababa, Ethiopia.

2.2. Description of sampling sites

The sampling sites along the river were purposively selected to assess the impacts of the BLIP's wastewater discharge on the water quality of Bole Lemi River. Six sampling sites were considered for the study. The sites were classified as being midstream, downstream, or upstream of the river (see Table 1).

Table 2. 1: Description of Sampling Sites for Water Sampling Stations.

Sample Site	X-Coordinate	Y-Coordinate	Altitude	Brief Description of the Site
Site 1	0481164	1001030	2660	Upper stream (Wendraide station).
Site 2	0485375	0992975	2261	At Gabriel Church, where the river is polluted with domestic wastes, runoff, etc.
Site 3	0484305	0990893	2244	The site at which effluents were released from the BLIP to the inside compound of the treatment plant.
Site 4	0484369	0990895	2242	The site at which effluents were released from the BLIP to the outside of the treatment plant.
Site 5	0484525	0990508	2218	The site at which effluents released from the BLIP join the Lemi River.
Site 6	0484187	0989757	2202	The site downstream of the Bole Lemi River where local communities use the wastewater for irrigation purposes.

2.3. Method of data collection

In situ and ex situ determination was performed to assess water quality. Water samples were collected from upstream, midstream, and downstream sites from the six sampling points (Figure 1) along the Bole Lemi River between May and June of 2021. This period was chosen for data collection because, in Ethiopia, it represents a transition between the dry and wet seasons. The analyses were carried out on nine water quality parameters. For the determination of water quality, the parameters collected for in situ included pH, water temperature, electrical conductivity (EC), and total suspended solids (TSS), and the parameters for ex situ included chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), total dissolved solids (TDS), and biological oxygen demand (BOD). The in situ parameters were collected using a portable device. For ex situ parameters, water samples from the three sites were collected and submitted for laboratory analysis using standard protocols (Table 2).

Water sample collection for the physicochemical analysis was performed according to the standards of the American Public Health Association [45]. Accordingly, twelve water samples were collected using the composite sampling method. The samples were collected in clean 2 L plastic bottles, each labeled with full information regarding the sample's code, date, time, source, and type and the name of the sample's collector. They were then preserved in a refrigerator at 4 °C. The collected samples were submitted as quickly as possible to the Oromia Environmental Laboratory Center in the town of Burayu to avoid the deterioration of the samples. The samples were analyzed using standard methods, such as COD and TN using the HACH-DR6000 UV—VIS spectrophotometer, and total phosphorous (TP) using the HACH-DR3900 UV spectrophotometer (Table 2).

Table 2.2. Water quality parameters and types of analysis methods employed.

Parameters	Water Quality Technique/Method Used for Analysis
pH	pH meter
Temp. (°C)	EC meter
EC (μS/cm)	EC meter
BOD (mg/L)	Standard method
COD (mg/L)	HACH-DR6000 UV VIS—Spectrophotometer
TN (mg/L)	HACH-DR6000 UV VIS—Spectrophotometer
TP (mg/L)	HACH-DR3900 UV Spectrophotometer
TSS (mg/L)	Gravimetric method
TDS (mg/L)	EC meter

Water quality estimation using the water quality index (WQI) method: The water quality index (WQI) assessment method can be used to determine the quality of water in a single value [20,46] and is used to evaluate the quality of river water and gather information about the state of the river [47–50]. The WQI was calculated using the weighted arithmetic index method, developed following the three steps of [51].

The weighted arithmetic WQI was used for estimating the water quality in the river using nine water quality variables (Table 3). For this estimation, the standard values of the different water quality parameters were used, as recommended by the World Health Organization (WHO) and USEPA.

Table 2.3: Water quality parameters recommended by WHO and USEPA.

Parameter	Standard Value	Recommended Agency
pH	8.5	WHO
Temp. (°C)	15	WHO
EC (μS/cm)	400	WHO
BOD (mg/L)	60	WHO
COD (mg/L)	150	WHO
TN (mg/L)	10	USEPA
TP (mg/L)	1	USEPA
TSS (mg/L)	60	WHO
TDS (mg/L)	500	WHO

WQIs of the collected water samples were calculated using the following three steps [51]:

(a) Unit Weight (Wn) Calculation

The unit weight (Wn) of the n^{th} parameter is inversely proportional to the recommended standards value (Sn) and can be calculated using the following formula:

$$Wn = \frac{K}{Sn} \quad (1)$$

where Sn = standard permissible value of the n^{th} parameter and K = proportional constant. K can be estimated from the following relation:

$$K = \frac{1}{\sum(\frac{1}{Sn})} \quad (2)$$

(b) Estimation of Quality Rating (Sub-index) (qn)

Sub-index, i.e., water quality rating, refers to the relative value of the n^{th} parameter concerning the standard value set by the recommending agencies.

$$K = \frac{100(Vn - Vio)}{(Sn - Vio)} \quad (3)$$

where K = quality rating (sub-index), Vn = estimated value of the n^{th} parameter in a sample, Vio = desirable value of the n^{th} parameter in a sample for it to be considered "pure," and Sn = standard permissible value of the n^{th} parameter.

(c) Estimation of WQI

A WQI is a numerical expression used to show the quality of a water source for human use as indicated in Table 4. The WQI of a sample can be calculated using the following mathematical relationship:

$$Wi = K/Sn \quad (4)$$

$$WQI = \frac{\sum_{n=1}^{n} qnWn}{\sum_{n=1}^{n} Wn} \quad (5)$$

where WQI = water quality index, Wn = unit weight of a parameter, and qn = quality rating or sub-index.

Table 2.4: Weighted arithmetic WQI values used as presented by Brown et al. (1972).

WQI	Water Quality Status
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very Poor
>100	Unsuitable for Consumption

2.4. Data analysis

The collected water quality data were compared to the existing water quality standards of WHO and USEPA. The data analysis included descriptive statistics and fundamental statistical measures for the studied water quality indicators that were analyzed. A one-way analysis of variance and descriptive statistics were used to verify the changes to the collected water quality parameters. A significant difference in the water quality parameters among sample sites was determined using a level of significance set at $p < 0.05$. A statistical analysis of the data was performed using the SPSS software, version 25.0.

3. Results and discussion

Investigating the concentration of water quality parameters is important for future river water quality monitoring [16], which is an essential task because rivers are a source of water for any community [52]. The regular assessment of water quality helps in formulating policies and taking appropriate measures to alleviate the health impacts of water pollution [53]. The water samples collected from different sampling stations were analyzed for water quality parameters such as water temperature, pH, EC, TSS, TDS, COD, BOD, TN, and TP using mean and standard deviation. The mean and standard deviation values of the physicochemical parameters recorded at the six sampling stations are shown in Table 5.

Table 2.5: Analysis of water sample results for physicochemical parameters (mean ± SD).

	Water Quality Parameters								
Study Site	**pH**	**EC (μS/cm)**	**BOD (mg/L)**	**COD (mg/L)**	**TN (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**	**TDS (mg/L)**	**Temp. (°C)**
Site 1	7.90 ± 0.57	262.67 ± 3.77	8.00 ± 8.49	146.50 ± 37.01	31.33 ± 2.83	4.27 ± 0.28	25.50 ± 34.65	155.30 ± 0.85	15.25 ± 4.17
Site 2	8.20 ± 0.04	575.00 ± 66.93	15.50 ± 19.09	132.83 ± 3.54	21.48 ± 8.27	4.02 ± 0.12	31.50 ± 14.85	347.00 ± 40.55	14.70 ± 4.24
Site 3	8.84 ± 0.23	650.00 ± 6.60	28.00 ± 32.1	139.17 ± 13.91	15.65 ± 0.03	4.74 ± 1.18	13.50 ± 4.95	389.67 ± 8.49	15.45 ± 4.17
Site 4	8.92 ± 0.16	644.33 ± 18.38	7.50 ± 7.78	112.50 ± 12.02	15.03 ± 0.03	3.89 ± 0.12	13.50 ± 10.61	389.50 ± 9.19	16.45 ± 2.76
Site 5	8.24 ± 0.19	437.17 ± 125.16	22.5 ± 17.68	105.67 ± 4.24	17.28 ± 8.27	3.95 ± 0.31	50.50 ± 0.71	332.33 ± 22.63	15.25 ± 4.45
Site 6	8.35 ± 0.17	570.83 ± 65.76	21.50 ± 2.12	121.34 ± 3.30	15.78 ± 0.78	5.35 ± 0.17	170 ± 147.79	336.67 ± 43.84	16.65 ± 1.63

pH: pH is one of the most important water quality parameters that can affect the suitability of water for various uses [54,55]. The pH value of water is closely related to its concentrations of carbon dioxide (CO_2) and alkaline substances [56]. In this study, the pH values were found to be alkaline, ranging from 7.90 to 8.92 (Figure 2). The maximum pH value was recorded at Sampling Site 4, where industrial effluents are discharged from industrial treatment plants (Table

5). This indicates a slightly alkaline river water, possibly due to untreated industrial wastewater discharge [54,57]. In addition, a higher pH value indicates a higher alkalinity, which indicates the presence of $CO^{3+}{}_2$, Ca^{2+}, and Mg^{2+} in the river [58]. The lowest pH value was recorded at Sampling Site 1, an upstream sample site. This may be attributed to a relatively low anthropogenic influence.

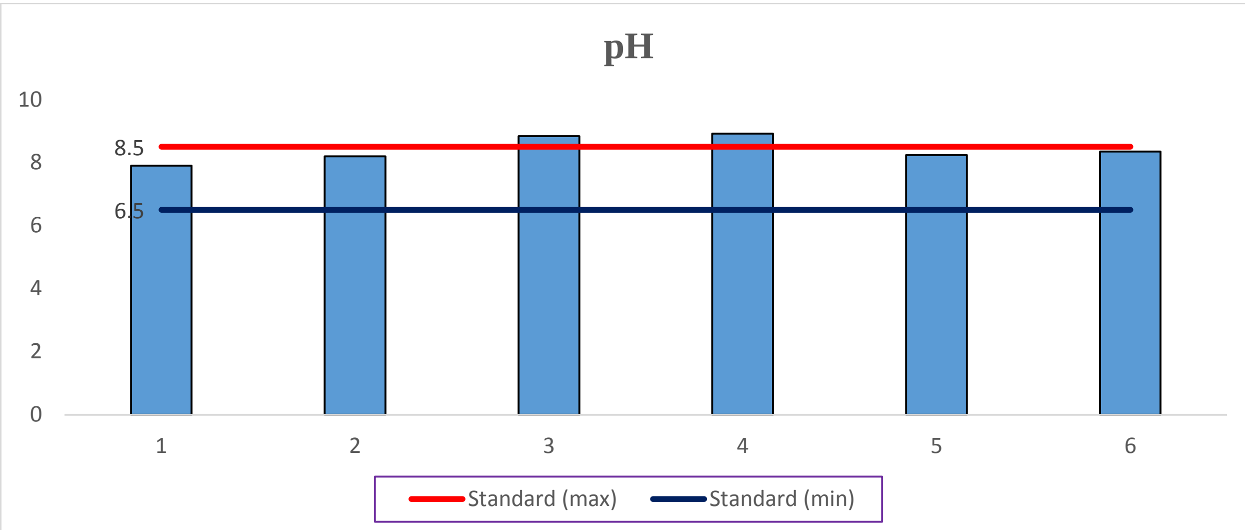

Figure 2.2. pH values recorded at the six sampling sites.

Other factors, such as temperature, oxygen levels, available anions, and cations, can affect pH value [56]. The optimum pH to support aquatic life is 6.5–8.2 [59]. However, the detected pH value was not significantly different among all sampling sites ($p = 0.06$). According to this study, the pH values for all sites except Site 3 (8.84) and Site 4 (8.92) were within the range of 6.5 to 8.5 as recommended by the USEPA (2009), EU (1998), CES (2013) and WHO (2011) standards and guidelines for drinking water and FAO (2013) for water irrigation. Similarly, all the pH values analyzed during this study in all the sampling stations were within the UNU-EHS/UNEP (2013) recommendations, which have standard values ranging from 6.5 to 9.0 for the water quality of an ecosystem. An increase or decrease in the pH levels of water could be due to either natural or anthropogenic activities. Surface runoff containing carbonate minerals in the soil may cause an increase in the pH levels of water during the rainy season. Wastewater discharge that contains chemicals such as detergents and soap-based products can increase water pH levels (Fondriest Environmental Inc., Fairborn, OH, US, 2013). The high levels of pH in the Site 3 and

Site 4 sampling stations may indicate an alkalinity in the wastewater due to the discharge of contaminated effluents by industries near these sampling points.

Water temperature: Water temperature affects the water quality parameters and plays an important role in aquatic life. Temperature is an important physical measure of water quality that affects the amount of dissolved oxygen (DO) in water ([57]. The temperature of polluted water may significantly affect its DO concentration [60]. The Lemi River receives wastewater from industrial parks, which may release warm water into the river system. The direct discharge of warm water from industries elevates water temperature [61]. This may raise the temperature of the river alongside its direct exposure to sunlight. The lowest and highest mean water temperature levels detected during the wet season of 2021 were 14.70 °C at Site 2 and 16.65 °C at Site 6, respectively. Yet, there was no significant difference (p = 0.99) in water temperature among the sampling stations (Figure 3). This deviates from the findings of [62]who reported that the highest water temperature in various water bodies in Nigeria was 28 °C, but is very similar to those of a study conducted in the town of Bahir Dar (15–20 °C) and to the Canadian recommended level of 15 °C [63].

There is slight temperature variation due to variation in altitude, which effects solar radiation and levels of pollution in water [64]. Similar findings were also reported in Ethiopia for the Modjo River (21.50–24.93) [65] and Kebena River (17–21) [66]. However, lower values were reported in India for the Hindon and Garra Rivers (15.6 to 34.70 and 28.70 to 31.1, respectively) [57,67]. Riparian trees maintain low water temperatures by providing shade, which reduces light and, in turn, photosynthesis [68].

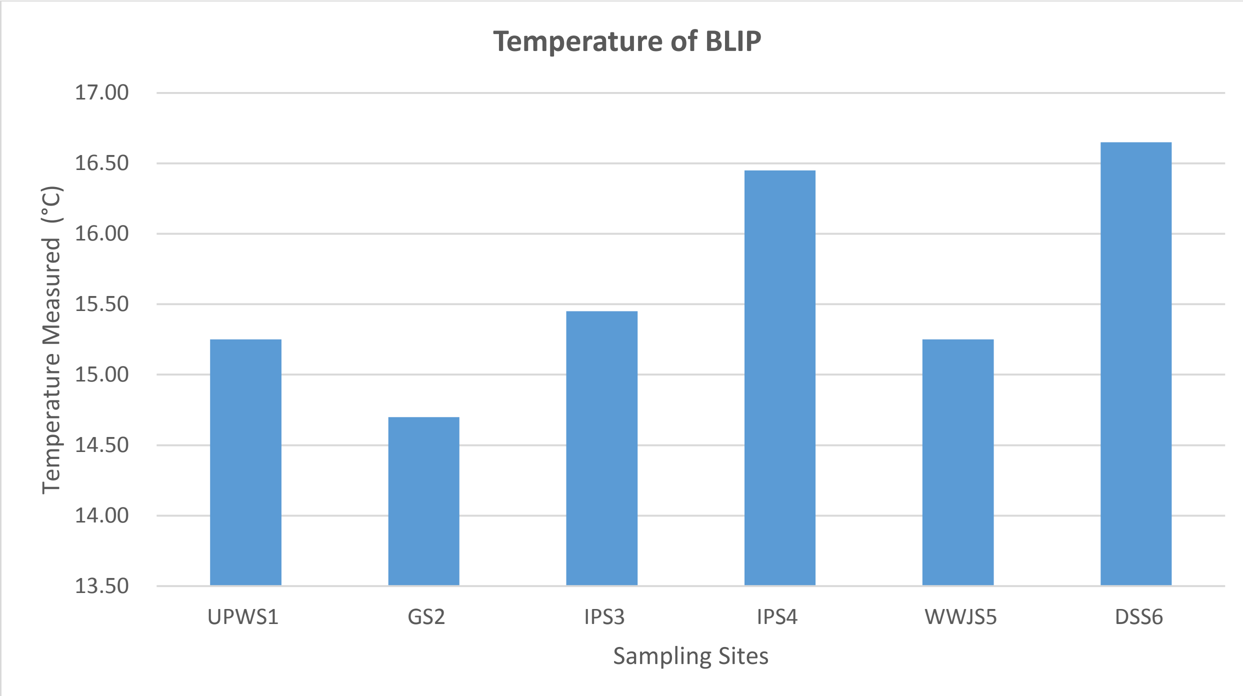

Figure 2.3:Temperature records (°C) at the sampling points along the river.

Electrical conductivity (EC): This is an indicator of the number of salts and carbonates in water. EC is a measure of the ability of a solution to conduct the flow of current depending on the presence of ionic particles [69]. Like TDS, EC denotes the salinity nature of the river water [50]. It is affected by the presence of inorganic dissolved solids, such as chlorides, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum ions [70,71]. Inorganic ions have an important effect on water conductivity. The more ions present in a body of water, the higher its conductivity level. EC refers to the number of dissolved salts and minerals in the water, which indicates the pollutants released into the river system [54]. Water turbidity is an important parameter that affects the penetration of sunlight into the bottom of the water, affecting aquatic life [55,56]. High turbidity reduces the amount of sunlight reaching underwater phytoplankton by scattering sunlight and obstructing incoming light with suspended fine particulate matter, such as mud, algae, detritus, and fecal material clay. A sudden increase or decrease in the conductivity level of water can indicate pollution.

The mean EC recorded in this study was between 262.67 and 650 µS/cm (Figure 4). The lowest mean EC value was detected at the Site 1 sampling station, while the highest was recorded at Site 3. This may be due to the discharge of industrial and domestic waste in the area. Water turbidity can be caused by fine organic and inorganic matter [72]. High levels of suspended solids and turbidity impair the recreational use of river waters because they reduce visibility and cleanliness in the water body and affect the safety and aesthetics of recreational waters [73]. The analysis revealed statistically significant differences (p = 0.01) in EC among the sampling stations. The average EC values recorded were within the EU standard for drinking water (1998), which is 2500 µS/cm at 20 °C, the FAO standard for irrigation water (2013), 700 to 3000 µS/cm, and the WHO standard of 400 µS/cm. According to the United States Environmental Protection Agency (USEPA), a body of water that can support fisheries should have a range of 0.15 mS cm^{-1} to 0.50 mS cm^{-1}. Based on the collected data, the conductivity of the Seven Lakes is suitable for aquaculture.

River water conductivity may be controlled by various factors, such as watershed geology, watershed size, wastewater from point sources, runoff from nonpoint sources, atmospheric inputs, evaporation rates, and bacterial metabolism [74].Agricultural runoff and sewage leakage can increase conductivity as a result of their chloride, phosphate, and nitrate ions [75].

Total suspended solids (TSS): Like TDS, TSS can also affect surface water quality. TSS are one of the most widely used indicators of surface water quality, which has both indirect (toxicity) and direct (physical, biological, and ecological) effects on aquatic environments [76]. High rates of TSS affect light transmission and aquatic life [77]. Total suspended solids (TSS) are a measure of the specific suspended solids in a body of water and are used to describe the level of pollution in wastewater. Additionally, the amount of TSS present serves as a good indicator of water turbidity [78]. The mean value of TSS in this study ranged from 13.50 to 170.50 mg/L (Figure 4). The lowest and highest mean values of TSS were at the Site 3/Site 4 and Site 6 sampling stations, respectively. Higher amounts of TSS might be due to suspended solids in the wastewater from the industrial parks' waste generation [79]. The mean values of TSS in this study were within the WHO (2006) wastewater discharge limit of 60 mg/L, except for the one at the sampling station of Site 6 (170.50 mg/L). High concentrations of suspended solids can affect the normal functions of aquatic ecosystems and the photosynthetic activity of aquatic plants by decreasing light penetration and increasing water temperature [80]. Excessive concentrations of TSS in irrigation water samples can cause negative effects; e.g., soil crust formation inhibits waterlogging and affects soil aeration, and suspended particles can coat plant leaves and reduce plant photosynthetic activity [81]. Similarly, the average concentrations of suspended solids exceeded the Australia and New Zealand (2000) guideline limits (TSS ¼ < 0.03 mg/L) of water quality for aquaculture. Statistically, there was no significant difference (p = 0.24) in TSS among the sampling stations. There was no significant difference (p = 0.24) in TSS between sampling sites.

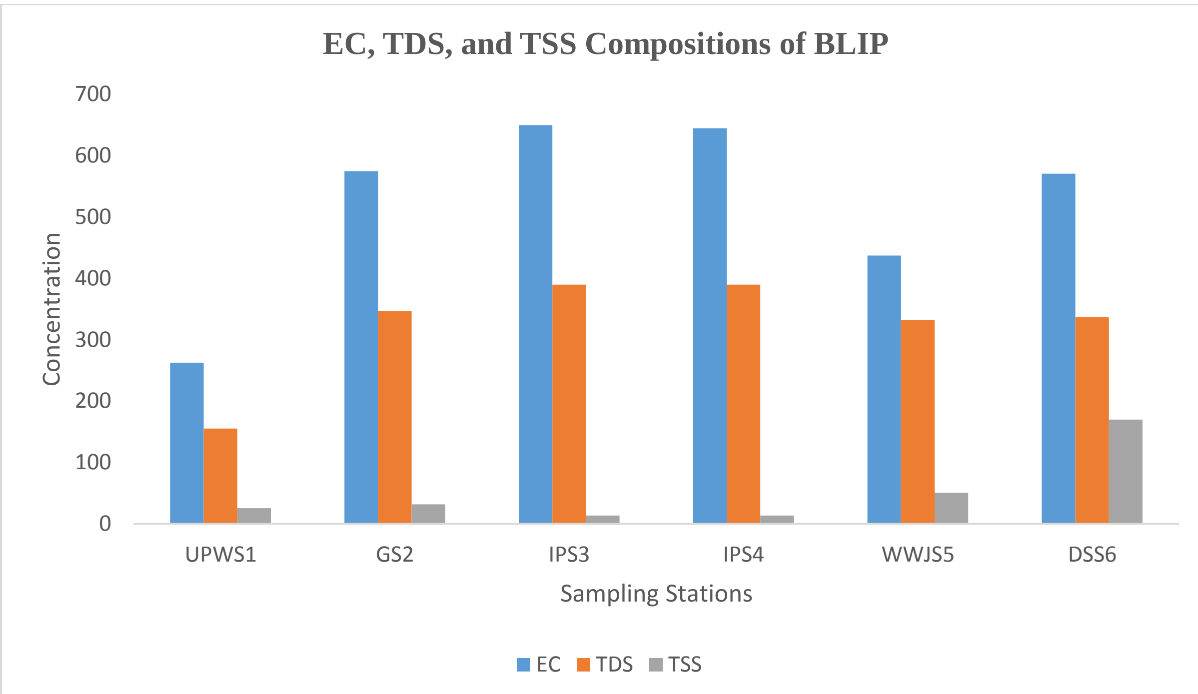

Figure 2.4: EC (μS/cm), TDS (mg/L), and TSS (mg/L) compositions at six different sampling stations.

***Total dissolved solids (TDS)**:* The level of TDS in a body of water is directly related to its level of conductivity [50]. High rates of TDS influence the taste, hardness, and corrosion properties of water and makes it unsuitable for drinking [82]. According to a study performed by [74], the spatial and temporal monitoring of electrical conductivity and TDS is a good indicator of water quality. Sources of TDS include point source water pollution from industrial and domestic waste, agricultural runoff, and the leaching of soil contamination (DENR-EMB 2005). TDS affect the ability of water to dissolve various inorganic minerals and some organic minerals or salts. TDS, salinity, and TSS can affect surface water quality. The concentration of TDS can affect the water balance in the cells of aquatic organisms, and its excess concentration affects the taste of water [77]. The mean values of TDS recorded in this study ranged from 155.3 to 389.67 mg/L (Figure

4). The lowest and highest mean values were recorded at the Site 1 and Site 3 sampling stations, respectively. The highest concentrations of TDS may be a result of dissolved solids in the river system due to human activities, i.e., generating wastewater from industrial parks. According to) [59], high rates of TDS in river water may originate from salt and organic matter, which indicates that sewage has been released into the river system. The confirmed TDS values were significantly different (p = 0.0009) among the sampling stations. The mean TDS values recorded in this study followed the drinking water authorization standards of USEPA (2009), EU (1998), CES (2013), and WHO and the irrigation standards of FAO (2013). According to the World Health Organization, a TDS level below 300 mg/L is excellent, 300—600 mg/L is good, 600–900 is fair, 900–1200 is poor, and above 1200 mg/L is not acceptable. The average concentrations of TDS in the sampling sites (from 155.30 to 389.5 mg/L) does not exceed the WHO limit for drinking water (500 mg/L) (WHO, 2011) or the maximum concentration level (500 mg/L) (USEPA, 2009). The presence of high rates of TDS in water affects the taste and flavor of the water [77].

Biological oxygen demand (BOD): Biochemical oxygen demand is the measurement of total dissolved oxygen consumed by microorganisms for the biodegradation of organic matter, such as food particles or sewage [83]. Like chemical oxygen demand (COD) and dissolved oxygen (DO), BOD is an indicator of water quality. It refers to the amount of DO that microorganisms use to degrade and mineralize organic matter in water under aerobic conditions [56]. Relative to the levels of dissolved oxygen, the higher the BOD, the more rapidly oxygen is depleted in water, reducing the amount of oxygen available to aquatic organisms [71]. High BOD levels result in a higher intake of oxygen to break down organic materials. The process of breaking down organic materials can decrease the dissolved oxygen concentration in water, which can cause an anoxic state [84].

The mean values of BOD recorded in this study ranged from 7.5 to 28.3 mg/L (Figure 5).

Higher BOD loading implies the presence of organic pollutants from untreated industrial wastewater [85,86]. The tolerance limit of BOD in surface water is 5 mg/L for aquatic life, and it reflects the amount of unstable organic matter in waterbodies [87,88]. The lowest and highest mean values of BOD were recorded at the Site 4 and Site 3 sampling stations, respectively. The differences in BOD values were not significantly different (p = 0.80). However, the recorded values complied with the WHO (2006) standards (60 mg/L) for BOD levels. Like those of COD, low concentrations of BOD at the sampling sites also indicate a low organic load to the river under study. This might indicate that the number of organic pollutants at the sampling sites is too low to affect the river's water quality, change its color to black, or produce bad odor as a result of the absence of domestic waste, sewage lines, and septic tank connections, unlike other rivers in the country. Levels >12.0 ppm can generally kill fishes due to suffocation [89].

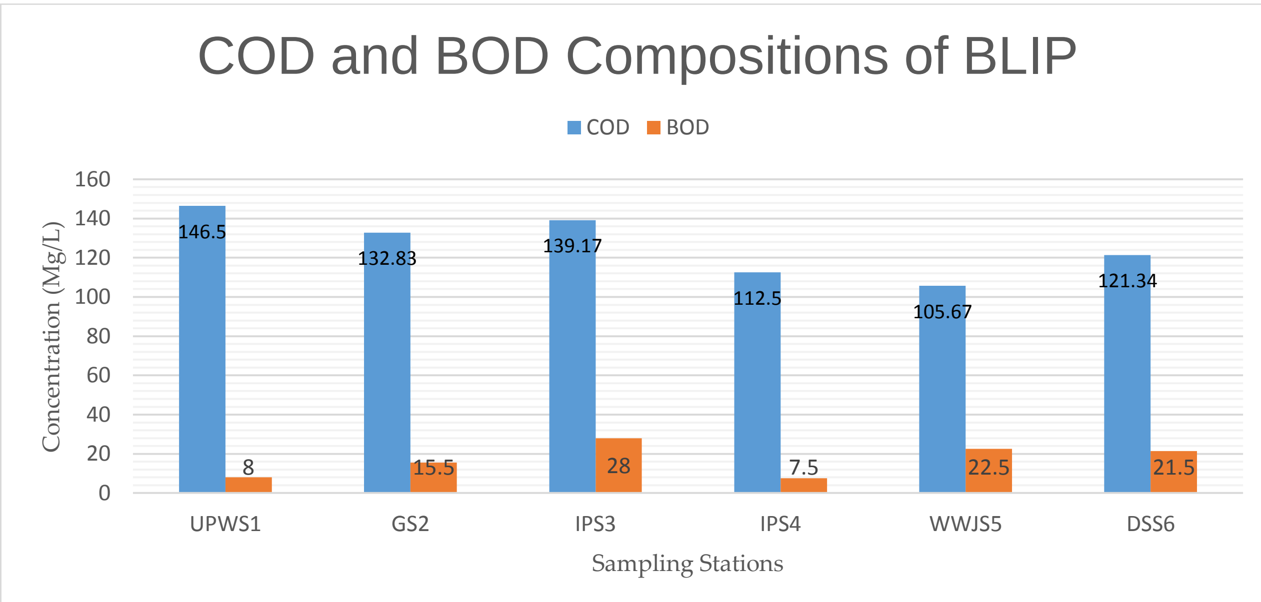

Figure 2.5: BOD and COD compositions at the six sampling sites

Chemical oxygen demand (COD): COD is an important indicator of water quality. It measures the amount of oxygen needed to oxidize soluble and particulate organic matter in water [88]. The COD values recorded in this study ranged from 105.67 to 146.50 mg/L at the Site 5 and Site 1 sampling stations, respectively (Figure 5). The levels of COD were also found to be higher than those of BOD. This is because more organic compounds can be chemically oxidized than biologically oxidized [90]. A higher COD value is an indication of discharged effluents from industrial processes [91].

The differences in COD values among the sampling stations were not statistically significant (p = 0.26). The COD value mentioned (Table 5) was also not significantly different (p = 0.26) among the sampling stations. COD is a measure of the oxygen equivalent of the organic content in a sample, which can be oxidized using a strong chemical oxidizing agent. It is an assessment used to measure the degree of pollution from organic substances in water [78]. The levels recorded at all sampling stations were within the limit recommended by *the Guideline Ambient Environment Standards for Ethiopia*, EPA/UNIDO (2003), which is 150 mg/L. For the Challawa River in the state of Kano, high COD values with mean concentrations between 170 and 260 mg/L were observed [92]. Osibanjo et al. (2011) [93]also reported high COD values in water samples from the Ona and Alaro Rivers in Nigeria and attributed the situation to leaching from landfills and agricultural and urban runoff. The lowest concentrations of COD at the sampling sites indicate a low organic load on the river. Both BOD and COD often provide an indication of the level of organic pollutants in water and wastewater [94]. Wastewater with BOD and COD values above 0.6 is biodegradable and can be treated biologically [95].

Total nitrogen (TN): TN is a measure of nitrogen (organic and inorganic) and is the sum of all forms of nitrogen: Kjeldahl nitrogen (organic and reduced nitrogen), ammonia, and nitrate–nitrite. The excessive accumulation of nutrients such as nitrate, ammonia, and phosphate can affect surface water quality in several ways. For example, when the concentration of ammonia in water exceeds the permissible level, it causes eutrophication and eventually decreases DO levels and increases water temperature, becoming toxic to aquatic biota [54,56].

The TN values recorded in this study ranged from 15.03 to 31.33 mg/L at the Site 4 and Site 1 sampling stations, respectively (Figure 6). The difference in the detected values was statistically significant ($p = 0.03$). The mean TN values found at all of the sampling stations were outside the international UNU-EHS/UNEP (2013) guideline for the ecosystem, which is <0.7 mg/L, but they were within the standard authorized by FAO (2013) for irrigation, which is between 5 and 30 mg/L. According to [96], high nitrogen values present in substances stimulate plant growth. Nitrogen pollution studies in the United States and the Netherlands indicate that 60–80% of nitrogen comes from dispersed agricultural resources ([97]. Alvarez Cobelas et al. (2008) [98] also reported that NT exports from the watershed quadrupled those of forest basins as a result of crops. The mean TN values recorded were higher than the mean TN concentrations in the surface waters of the Tai Lake area (6.4 mg/L) [99]. The highest concentrations of nitrogen may be attributed to point sources from the industrial park and chemical fertilizer runoff from farmlands around the areas. Such a high concentration in water may cause various health impacts on organisms, e.g., making fish susceptible to diseases [100]. High levels of nitrogen in the form of nitrates and ammonia may be related to point sources in the industrial park and the chemical fertilizers used by local farmers. Such a high content in the water can cause various health problems and make the fish susceptible to other diseases.

The total nitrogen concentration at the Site 4 and Site 2 sampling stations (15.03 and 21.48 mg/L, respectively) was higher than the maximum permissible limit for drinking water for rural people set by the Ethiopian Ministry of Water Resources (1.5 mg/L) (MoWR, 2001). However, compared to the TN concentration reported by [101], the values of 0.5 to 43 mg/L, recorded at all sampling sites, were found to be acceptable concentrations.

Total phosphorus (TP): Phosphorus is a common element in agricultural fertilizers and organic waste from sewage and industrial wastewater. Phosphate is an important nutrient found in aquatic plants, such as algae and plankton, and used as food for fish. However, too much phosphate in a body of water can cause an overgrowth of aquatic plants that quickly consume and reduce the amount of DO in the water and kill other aquatic life [57]. The major sources of phosphorus in the form of phosphate are, namely, waste from garment factories, laundry, domestic wastewater, and agrochemicals used in large-scale irrigated vegetable production.

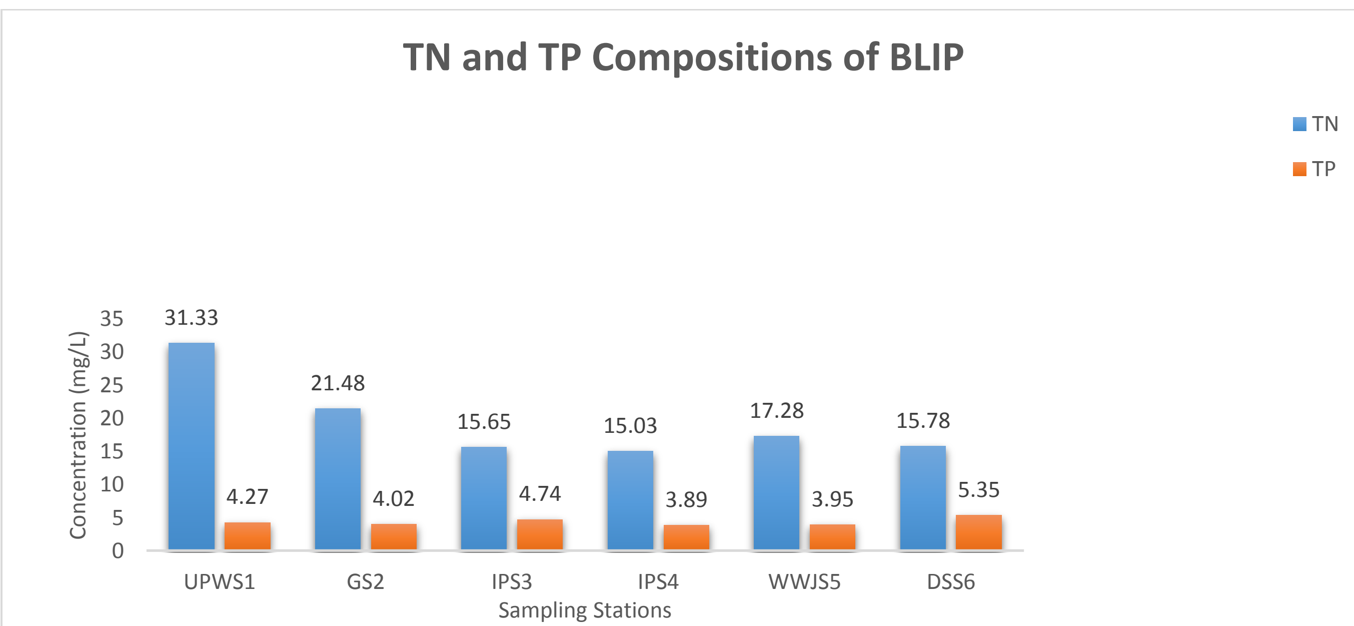

Figure 2.6: TN and TP compositions at different six sampling stations

Too much phosphorus in lakes, rivers, and streams can cause algae to grow. Water covered with algae is less attractive for fishing and swimming. Agricultural activities consume large quantities of inputs such as pesticides and fertilizers, which are the main sources of nitrogen and phosphorus. This trend is exacerbated by the increase in agricultural land. Irrigation has played a role in improving rural productivity and living standards, yet it is the source of runoff from agrochemical pollutants into water bodies. Soil particles may have been removed from the soil profile. In animal husbandry, there are often collection sites on both sides of the streams so that animal manure such as urine can enter these streams directly. Manure is usually collected as organic fertilizer, and its excessive use can cause widespread water pollution [102]

In this study, the mean TP values at the sampling stations ranged from 3.89 to 5.35 mg/L (Figure 6). These are higher than the limit of the WHO guidelines for drinking water (0.5 mg/L). Such concentrations can cause eutrophication in river water [103]. This can reduce the diversity of aquatic species and, ultimately, increase aquatic life mortality [40]. Excessive nutrient loading in the river may affect the rural population’s ability to use this river water for various purposes.

The results of this study found that the TP content ranged from 0.03 to 0.56 mg/L, which is higher than the Shending River average content of 0.43 mg/L [96]. The mean values of TP are <0.02 µg/L for the aquatic ecosystem, which are in line with the approved international guidelines of UNU-EHS/UNEP (2013).

Estimation of the WQI of the river water

According to Brown et al. (1972) [51], WQIs indicate the quality and desirability of water samples. It is estimated by using a single value derived from the set of water quality parameters. This study estimated the WQI by using water samples collected from six different sampling points along the Bole Lemi River. The Lemi River provides significant benefits for the life of the community around it. Determining its WQI helps conservation experts and decision makers to understand the river’s ecological condition.

The WQI value of the river was estimated using the nine water quality parameters. Based on this value, the desirability/suitability of the river water at the different sampling sites was examined. In general, according to Brown et al. (1972) [51], a WQI value between 0 and 25 can be considered excellent. Similarly, good values are 26–50, poor are 51–75, very poor are 75–100, and unsuitable for consumption are >100.

The results of the WQI for the water samples collected from the six sites along the river are summarized and presented as shown in Figure 7. It shows that all of the water samples analyzed during the study were found to be unsuitable for consumption and that the Lemi River's water is not suitable for human use without treatment, but it might be acceptable for other purposes.

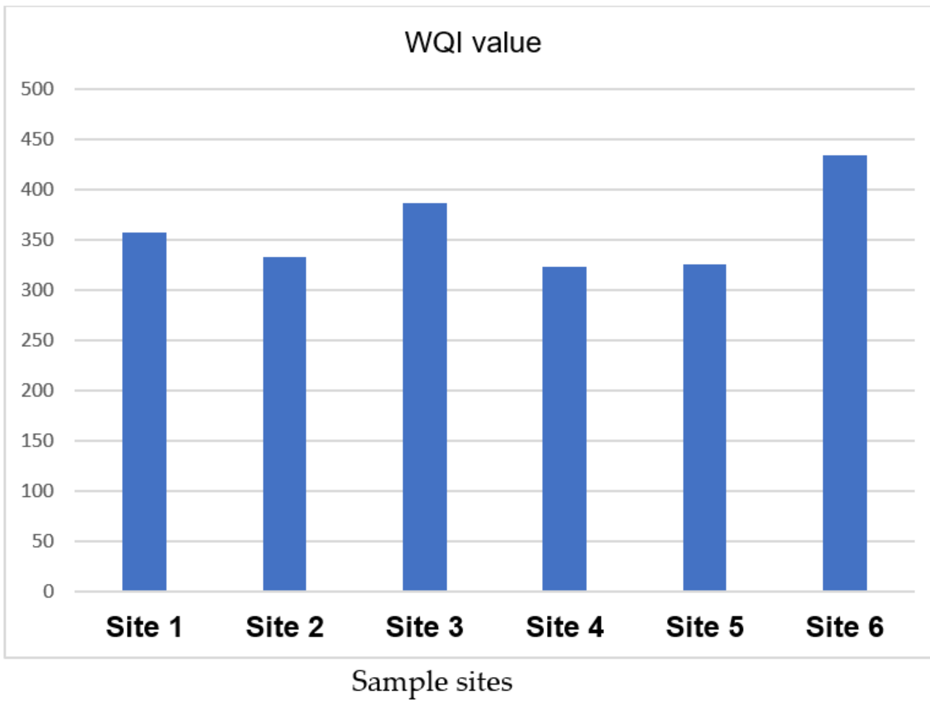

Figure 2.7: WQI values for the six water sampling stations.

4. Conclusions

Water quality assessment is an important aspect of water resource management that can provide empirical evidence for investigating the level of water quality deterioration and implementing appropriate measures to reduce the effects of pollution. This study applied water quality analyses to assess the impact of industrial parks on the water quality of the Bole Lemi River in Addis Ababa, Ethiopia. This study was conducted on a section of the river by analyzing nine water quality parameters and estimating the WQI of the sample sites to investigate the impact of the

BLIP on the current water quality in the river. The results of the water quality parameters were compared against the USEPA and WHO standards to determine the condition of the river.

This study shows that there are lower values of water quality parameters in the samples collected from the upstream sampling stations as compared to the samples from the downstream sampling stations. Physicochemical parameters of the river, such as pH at the Site 3 and Site 4 sampling stations, were above the allowable parameters set by USEPA, EU, WHO, and CES for drinking water. The TSS value at Site 6 was not within the WHO criteria, and the TN and TP values were above the acceptable UNU-EHS/UNEP international guidelines for ecosystems (2013). This shows that the discharge of industrial effluents from the BLIP has contributed to the deterioration of the water quality in the river. According to the WQI assessment, the river is at a critical level in terms of water quality.

Water quality control should be the priority of Addis Ababa's administration to protect and maintain the city's river resources. In this sense, the results of this study will be useful for the city administration to design appropriate strategies for protecting and maintaining rivers in the city in a sustainable manner. Broadly speaking, this study provides a scientific basis for the Addis Ababa Environmental Protection Authority and the city's River Protection and Development Office to prevent further water pollution and protect rivers around industrial parks. The city administration should be aware of the condition of the river and should raise awareness on how to protect water quality. Continuous discharge of untreated industrial waste into the Bole Lemi River will cause the water quality in the river to deteriorate. It is**,** therefore**,** important to properly treat industrial wastewater entering the river and prevent other waste sources from degrading the water quality. This study recommends that industrial parks in Ethiopia should be controlled because of their operational activities that pollute water resources. This study may provide useful references for the protection of other rivers in vulnerable areas in Ethiopia.**Author Contributions:** "Conceptualization, F.L., B.S. and A.S.; methodology, F.L., B.S., and A.S.; software, F.L.; validation, F.L., B.S. and A.S.; formal analysis, F.L; investigation, F.L; resources, F.L.; data curation , F.L.; writing-original draft preparation, F.L.; writing-review and editing, F.L., B.S., A.S., and G.G.; visualization, F.L. B.S. and A.S.; supervision, F.L., B.S., A.S., and G.G.; project administration, F.L.; funding acquisition, F.L. All authors have read and agreed to the published version of the manuscript."

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Chapter III: Analysis of the concentration of heavy metals in soil, vegetables and water around the bole lemi industry park, ethiopia

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Abstract

Irrigation water contaminated with industrial waste could pollute the soil and vegetables with heavy metals. The objective of this study was to analyze the concentration of heavy metals in soil and vegetables after irrigation practices with wastewater emanating from industrial parks. 24 samples were collected from 8 sampling stations for vegetable, soil and water samples separately, following APHA procedures. Samples were collected using a composite sampling method in May and June 2021. Water samples were collected using clean polyethylene plastic bottles while soil and vegetables were sampled using clean plastic bags. Analysis was done for heavy metal concentration such as Pb, Cr, Cd, and Zn for each sample using descriptive statistics of changes in concentrations, one-way analysis of variance (ANOVA), Principal Component Analysis and Pearson Correlation Coefficient. The mean concentration of heavy metals in soil, vegetables, and water samples were analyzed. Unlike the rest of the heavy metal concentrations, the result showed the highest levels for Zn, i.e., 7.82mg/kg and 5.12mg/kg for vegetables and soil samples, respectively. The maximum value of the bioconcentration factor (BCF), the highest value of Estimated Daily Intake (EDI) and the maximum Target Cancer Risk (TCR) value recorded were 19.39, 0.001 and 8.09×10^{-5} *for Cd, Zn and Cr, respectively. But, Hazard Index (HI) indicated no potential health effects. On the other hand, the concentration of heavy metals in the soil sample showed that Cr and Cd were strongly positively correlated with the concentration of Pb in vegetables during May. Cd concentration in the water sample was also strongly positively correlated with the concentration of Pb during May. Application of proper management for reduction of contaminants, and suitable irrigation methods with treated wastewater is essential. The study can provide a basis for the City Administration of Addis Ababa to properly protect the water quality of rivers and provide a reference for river management in around the industry parks across the country.*

Keywords: *Pollution, Wastewater, Bioconectration factor, Health hazard, Health index, , Health risk,*

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1. Introduction

Rapid industrialization and urbanization have polluted the environment with heavy metals, and their rate of migration and transport in the environment has increased dramatically since the 1940s (Khan *et al*., 2004). Pollution due to heavy metals poses an environmental threat and is currently a major concern (Ali *et al*., 2013; Hashem *et al*., 2017). Rapid industrial development has resulted a serious concern for the natural resources such as soil and water in many countries (Abbasnia et al., 2018). Industries are one of the anthropogenic activities that have contributed to increased concentrations of many heavy metals in the environment (Mohammadi et al., 2019).

Heavy metals are among the most important contaminants threatening human well-being (Dehghani et al. 2016; Qasemi et al. 2018). They are not biodegradable and remain in the environment. They contaminate the food chain and cause various health problems in animals and humans due to their toxicity (Davydova, 2005; Javed and Usmani, 2012; Wieczorek Dabrowska *et al*., 2013; Javed, Usmani, 2015). About one fourth of the human diseases are due to the exposures of environmental pollutants (Basma and Alhogbi, 2017). Heavy metals such as cadmium (Cd), lead (Pb), arsenic (As) and mercury (Hg) constitute one of the main environmental pollutants that can cause critical problem for all organisms, such as soil microbial populations, plants as well as humans (Lenart and Wolny-Koładka, 2013; Mohammadi et al., 2018) and harm human health (Jafarzadeh et al., 2021). For example, exposure to high Pb concentrations brings about health problems such as the skeletal, circulatory, nervous, enzymatic, endocrine, and immune systems in human body (Zhou and Guo, 2015; Esmaeilzadeh et al., 2019; Vasseghian et al., 2020), exposure to Cd can cause cancer (Vasseghian et al., 2020).

Industrialization in many countries has led to serious environment pollution (Sadeghi et al, 2020). The rapid growth of industries and increased disposal of hazardous waste have deteriorated the quality of water resources (Shams et al., 2020; Fiore et al., 2019). Industrial discharges are one of the major sources of heavy metals responsible for ecological pollution (Rajaram and Das, 2008). Human activities undoubtedly create many environmental issues, which considerably affect the surrounding soil and water resources (Miri et al., 2017). According to Karimi et al,(2020), using treated and untreated wastewater for irrigation may result in the accumulation of heavy metals in soils and consequently in plants and foodstuffs. Soil pollution occurs due to various human activities such as industrial activities and chemical application

(Esmaeilzadeh et al, 2019). Soil is generally regarded as the ultimate sink for heavy metals released into the environment (Qingjie et al., 2008). Soil pollution by industries is one of the greatest environmental issues, posing major issues to the environment, organisms, and humans (Mohammadi et al., 2019). Therefore, human health risk as a result of exposing soil to heavy metals should not be ignored (Mohammadi et al., 2019). Untreated industrial waste discharge has a severee effect on the environment and human health (Fekede et al., 2020)

The behaviors of heavy metals such as Cd, Cr, Pb, Co, etc. have become growing concern in ecological researches because of their capability of ecotoxicity, persistence, bioaccumulation and biomagnification properties, making them a threat to the water and soil resources' health (Kamani et al., 2018; Jafarzadeh et al., 2021). Heavy metals due to their non-biodegradability and long resistance properties are among the critical contaminants in the environment (Mohammadi et al., 2019). They vary in their chemical properties and biological functions, and have deleterious impacts on human health and ecosystems (Karimi et al., 2020). They have thus become a major concern due to their toxic, bio-accumulative and persistence nature (Yang et al., 2018). Their elevated concentrations in soil can damage fertility and productivity of the farmlands (Sadeghi et al, 2020), and are potentially toxic to most living organisms at a high level of exposure (Rezaei et al., 2019).

Several studies have been conducted on heavy metals. For example, the assessment of the human health risk of heavy metals in agricultural soils irrigated by effluents of stabilization ponds by Karimi et al. (2020), the levels of heavy metal contamination of surface water, groundwater and soils by Sadeghi et al. (2020) , the concentrations of heavy metals in surface sediment samples and pollution status by Seifi et al. (2019), the pollution status of heavy metals in soils by Mohammadi et al. (2019) and the human health risk indices of arsenic (As), chromium (Cr), lead (Pb) and zinc (Zn) due to drinking water consumption using chronic daily intake, hazard quotient, hazard index and cancer risk by Sajjadi et al. (2022). Consuming polluted water with heavy metals can increase the risk of human health (Jafarzadeh et al., 2021).

Heavy metals exist in water, air, soil and consequently also in foods, eventually can cause adverse health effects such as carcinogenic and non-carcinogenic human health risks (Shams et al., 2020), and the health risk due to exposure to underground water resources (Jafarzadeh et al., 2021), Many recent studies have shown the association between heavy metals and some forms of human health. For example, association between heavy metals in soil and human health risks (Adimalla , 2020), between food contamination of heavy metals and the incidence and spatial distribution of stomach cancer (Fei et al., 2018), and the involvement of heavy metals in the development of colorectal cancer (Sohrabi et al., 2018). Long-term exposure to even low concentrations of as for example can increase the risk of skin and lung cancer (Shams et al., 2020). Cd is the 'lethal' metal due to its severe health effects, causing a bone fracture, cancer, kidney dysfunction and hypertension, human respiratory cancers, also causing infertility in humans and developmental disorders in children at higher concentrations (Shams et al., 2020). Moghaddam et al. (2022) also studied the concentrations of heavy metals such as Pb, Cu, Fe, Ni, and Zn in water, soil, and vegetables in Iran and assessed the investigation of the extent of contamination health risk in consumers.

In developing countries, agricultural land is contaminated by heavy metals, which is a serious environmental problem due to heavy metal toxicity (Agca & Ozdel, 2014). Irrigation water contaminated by industrial effluents has led to severe heavy metal contamination in soil and plants. Due to the use of wastewater for soil irrigation, the concentration of heavy metals in the edible parts of growing plants is increasing (Arora *et al*., 2008).

The major sources of heavy metal contamination in the environment is human activities such as industrial waste generations, eventually resulting in the serious contamination of the surrounding water resources in local, regional, and global scales and causing significant health problems in humans and animals (Radfard et al., 2019; Kamani et al., 2018). One of the greatest water quality issues is heavy metals contamination (Shams et al., 2020). Fresh water is under pressure due to industrial activities (Almasi et al. 2014; Yousefi et al. 2018). Thus, determining the chemical contents of water resources before any human use is necessary (Mgbenu and Egbueri, 2019). The effluent generated by industries, as outlined in essence, often consists of an over-awareness of heavy metals such as cadmium (Cd), arsenic (As), mercury (Hg), copper (Cu), and lead (Pb) which are environmental issues (Bigdeli and Seilsepour, 2008; Odai *et al*., 2008; Yusuff & Oluwole, 2009; Ahmad & Goni, 2010; Alghobar & Suresha, 2017).

Likewise Ethiopia nowadays is among the very fast urbanized and industrialized nations having shared dilemmas with industrial wastewater and toxic effluent planning and management. The country, as far as recently practicing a multi-dimensional development alternative to attract investments, has given preceding attention to industrial sector development in general and Industry Park Development (IPD) as a strategic preference in particular. With this fundamental need and prolonged strategy, the country has been involved in implementing almost about fourteen Industry Parks at different localities of the country. Primarily, Bole Lemi Industry Park which is found in Addis Ababa is the first and the model for this new development sector while practicing and promoting the eco-industrial parks development at the national level.

Furthermore, the Government of Ethiopia has set and launched the IPD as the excellence center for comparative and competitive economic advantages and strategic development program to prompt Foreign Capital investment, new technology transfer, and excellence for vast job opportunity creation for the youth as well as the center for sustainable eco-industry development practice (Arkebe, 2017). This has been aimed to interface the socio-economic factors with environmental attributes to excite environmental friendly.

Fekede et al., (2020) have supposed the impacts of wastes from non-clustered and scattered industries on community welfare and the environment. And few studies had conducted on the assessment of some aspects of Industrial Parks development (IPs) in Ethiopia, and the environmental sustainability issues regarding clustered industrial park development have not yet been addressed. An assessment of socioeconomic performance particularity, the foreign direct investments and job opportunities (Fesseha et al., 2019); eliciting comments and stimulating debates on Ethiopian IPD policy (Zhang et al., 2018) and why business groups, specifically foreign investors preference to Ethiopia´s IPD (Mihretu and Liobet, 2017) had been reviewed.

To our knowledge, this is the first study in Bole Lemi Industrial Park in Ethiopia. There is no published literature on heavy metal pollution around Bole Lemi Industrial Park. Therefore, this study aimed to determine the concentrations of heavy metals around Bole Lemi Industrial Park to evaluate their status and their impacts on water, soil, and vegetables produced using industrial wastewater effluents from the clustered, Bole Lemi Industrial Park in Addis Ababa, Ethiopia.

2. Materials and methods

2.1. Description of study area

Addis Ababa, the capital of the Federal Democratic Republic of Ethiopia, is known also as *Finfinne* which was the inherent name that means "*natural spring*"**.** Addis Ababa is located in the horn of Africa at geographic coordinate's 9° 2′ 0″ N and 38° 42′ 0″ E covering a total area of 540 km^2. And it is also a chartered city and the capital of Oromia National Regional state. Addis Ababa is the largest city in Ethiopia with melodramatic urban growth (urbanization and industrialization) (AACSPO, 2017). The Population size has also increased in an uncontrollable manner. This growth shows a hundred percent incremental in two decades. According to the 2007 census, the population was estimated as 2,739,551 inhabitants, whereas the city structure Plan office had declared that the size has booming and estimated about 4,408, 656 inhabitants. It occupies a total area of 540km^2 land surrounded by a mountainous landscape (AACSPO, 2017)

The city is located in the central highland with an Afro-Alpine temperate and warm climate with an average elevation of 2,400m above sea level whereas the highest altitude of 3200m has been registered at the peak of the Entoto Mountain, and coordinates: 9°2'48" N latitude and 38°45'E longitude (Wubneh, 2013). The temperature ranges from 10^o to 23^o and the annual rainfall is 1165mm in the study areas (Census, 2007). Accordingly, Bole Lemi Industrial Park which is found at Addis Ababa City, specifically in Bole sub-city has been situated with GPS coordinates at 8 °58 '17.2200"N and 38 °51 '24.5088" E on a 156ha area of land (Fig. 1)**.** The Park has 20 sheds, and hosts companies that engaged in export business in the areas of garments, Apparel and Textiles, and Leather and leather products (Gebremariam and Feyisa, 2019).).

Hence, the city as a whole and the study site as a prime model industry park has to be predictable clean, evergreen, beautiful and attractive environment, free of industrial waste refuges and environmental friendly.

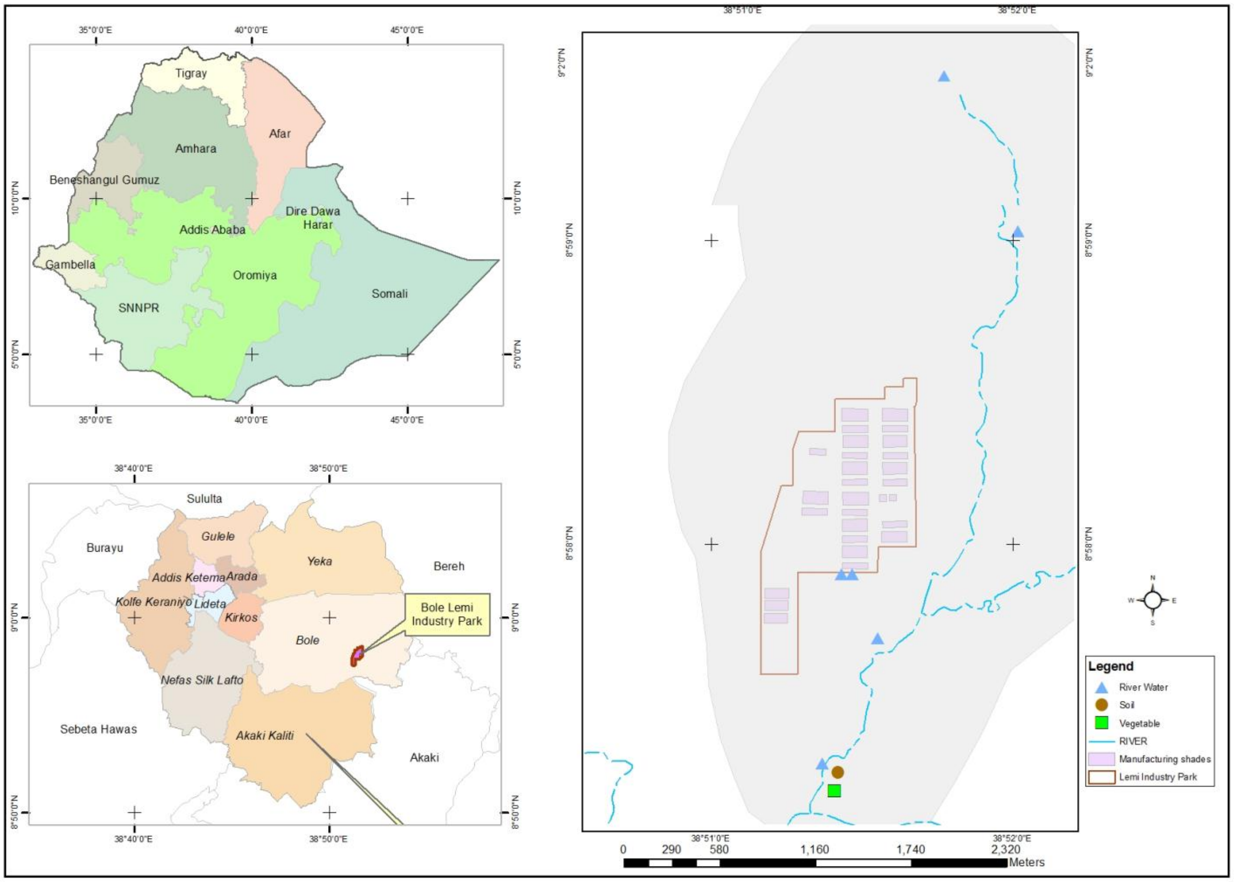

Figure 3.1: Map of the study area

2.2. Description of sampling sites

To understand the impact of industrial wastewater from various industries on pollution by heavy metals such as water, soil, and vegetables, as part of the cooperative development of Bole Lemi Industrial Park, six sampling stations (Table 1) were selected from a random sample of all sampling study stations by taking into account the stressors from sampling station of the upper stream to the downstream the river. Similarly, three sampling stations were considered where irrigation of vegetables with wastewater exists (Table 2).

Table 3.1: Description of Sampling Sites for Water Sampling points

Study Station	Stations Code	X-Coordinate	Y-Coordinate	Altitude	Brief description
BOLIP	$UPWS_1$	0481164	1001030	2660	Station 1- upper stream (Wendraide station)
	GS_2	0485375	0992975	2261	Station 2- at Garbiel Church where the river is polluted with domestic wastes (Ayat condo. Runoff)
	IPS_3	0484305	0990893	2244	Station 3 - the station at which effluents are deposited to be released from Bole Lemi industry park inside the Compound of the Treatment Plant
	IPS4	0484369	0990895	2242	Station 4- the station at which effluents are released from the Bole Lemi industry park at outside of the Treatment Plant
	WWJS5	0484525	0990508	2218	Station 5- the station at which effluent from Bole Lemi IP and Lemi river mixed
	DSS6	0484187	0989757	2202	Station 6- downstream station, where the local communities have used the Bole Lemi's river wastewater for irrigation purposes

Table 3.2: Description of Sampling Stations for Soil and Vegetable Samples

Study Station	Station Code	X-Coordinate	Y-Coordinate	Altitude	Brief description
BOLIP	GS_2	0485377	0993006	2260	Station 2, at Garbiel Church where vegetables cultivated with river water polluted with domestic wastes, runoff, etc
	Dir. S7	0484281	0989689	2211	Station 7, downstream of the Bole Lemi river where local communities used the wastewater
	DGar.S8	0484188	0989641	2202	Garden Station 8, the station at which vegetables cultivated with tap water/groundwater

2.3. Source of data

Primary and secondary data used in this study; primary data comes from field observations, samples for heavy metals analysis are taken from the water, soil, and vegetation at various sampling stations, and secondary data comes from literature.

2.4. Sampling design

As defined by the American Public Health Association (APHA, 1999), and Jones *et al*. (1991) and Kim (1995), applied methods and procedures for sampling water, soil, and plants from different stations in the study area. Sampling stations were assembled using Global Positioning System (GPS) from the research sampling station points (Fig. 1).

Through the months of May and June 2021, water, soil, and vegetation samples were taken, and the heavy metal content in each sample was analyzed for Pb, Cr, Cd, and Zn by collecting samples in plastic bottles for water and a plastic bag for soil and vegetables and were traced less than 8 hours to Oromiya Environmental Laboratory Center of Oromia Environmental Protection, Forestry and Climate Change Authority at Burayu town with properly labeled with complete information on the container sample (sample code, date, time, source, sample type, and collector name).

2.5. Sampling method

Vegetable samples collected from different stations in the study area for cabbage, swiss chard, lettuce, and tomato were packed in plastic bags and rinsed with nitric acid and distilled water before sampling. Soil samples were plowed with a shovel to collect soil samples. Take the topsoil 20 cm deep in the irrigated area and take 1kg of topsoil. Sampling is done once a day from 7:00 am to 11:00 am in order to analyze the content of heavy metals (Pb, Cr, Zn, and Cd) for both samples separately.

By using clean polyethylene plastic bottles and rinsing them three times with distilled water before sampling, water samples were collected from the study area of sampling stations and analyzed at the Oromiya Environmental Laboratory Center of Environmental Protection, Forestry, and Climate Change Authority at Burayu town using Atomic Absorption Spectrometer (NovAA 400P AAS) for the analysis of heavy metals in water and wastewater.

2.6. Digestion procedures for soil samples

Soil samples taken at each sampling point were crushed, sieved, and dried in an oven at 105 ° C for 24 hours, then 1000 g of dry soil was transferred to a 100 ml Erlenmeyer flask and 23 ml of water was added to the humidifiers in which 7.5 ml of concentrated hydrochloric acid and 2.5 ml of concentrated nitric acid were placed in a fume hood, then covered with a watch glass and placed under a fume hood at room temperature overnight. Then, the lower flask is carefully boiled on an electric stove at 100°C for 2h, then cooled to room temperature, washed with 30ml of water, and the extract is filtered through acid-resistant filter paper in a 100 ml volumetric flask. For clarification, continue rinsing the digester and filter paper residues. Use 2MHNO_3 (± 50 ℃) hot several times and after cooling, mark the volume with 2M nitric acids including blank. Bath (100 ° C) for two hours. Finally, an atomic absorption spectrometer (AAS) was used to analyze the concentration of heavy metals in the prepared soil solution.

2.7. Digestion procedures for vegetable samples

The collected vegetable samples were treated with nitric acid (HNO_3) to separate heavy metals (Pb, Zn, Cr and Cd). Approximately 1000 grams of dried vegetables were placed at 105 ° C in a porcelain crucible and Muffle furnace at 200. The samples are heated at 450 ° C for at least 2 hours until complete mineralization, remove the crucible, add 5 ml of 6MHNO_3 and decompose by gentle boiling until about 1 ml remains, the remaining 5 ml 3MHNO_3 was added and the extract was heated for 30 min, then the warm solution was filtered into a 100 ml volumetric flask and the transfer was fixed with a glass rod, the beaker and glass rod were washed several times with 1% HNO_3 and the residue and collected on the filter. The filtrate is cooled and diluted with water to 100 ml and close the jar with a stopper. Then, using an atomic absorption spectrometer (Analytical Jena, Germany, NOVAA 400), the concentration of heavy metals in the solution was determined.

The effectiveness of this method has been determined in accordance with the certification guidelines of the Soil and Plant Analytical Laboratory Network of the Ethiopian (SPALNE) and the National Soil Research Laboratory (NSRL). Quality control includes analysis of blank samples without analyte or zero concentration units which mean no calibration and no national standard solutions of heavy metals. Soil and vegetation samples were measured using the flame or graphite method with a detection limit of 1 unit per billion (ppb). The limit of Quantification (LOQ) and Limit of Detection is determined according to the version of the standard operating procedure for an atomic absorption spectrometer for the determination of heavy metals in the laboratory, as well as the instructions for use of the instrument developed by Oromia Environmental Protection, Forest and Climate Change Central Laboratory.

2.8. Data calculations

2.8.1. Bioconcetration factor

The bioconcentration factor is the relationship between the concentration of heavy metals in some plant samples and the concentration of heavy metals in soil samples (Rattan *et al*., 2005; Sharma *et al*., 2018). And Kachenko & Singh (2004), use the following formula to calculate the transfer of heavy metals from soil to plants:

$$\mathbf{BCF} = \frac{\mathbf{C\ plant}}{\mathbf{C\ soil}} \quad (1)$$

Among them, C_{plant} is the concentration of heavy metals in plant parts, and C_{soil} is the concentration of heavy metals in the soil. Values greater than 1 BCF indicate that the plant is a potential heavy metal reservoir under consideration for analysis.

2.8.2. Estimated daily intake of heavy metals

Calculation of the estimated daily intake (EDI) (mg/day) of heavy metals based on the weight of vegetables consumed per unit body weight and their respective average concentrations in vegetable samples. As stated by Chen *et al*. (2011), use the following formula to calculate the value of EDI of each heavy metal in each cabbage, lettuce, Swiss chard and tomato:

$$EDI = \frac{Ef \times ED \times FIR \times CM \times Cf}{BW \times TA} *0.001 \quad (2)$$

Ef is the exposure frequency (365 days/year), ED is the duration of exposure (65 years) based on the average lifespan (Woldeshadik *et al*., 2017), and FIR is the consumption of vegetables (cabbage, lettuce, Swiss chard and tomato per person 240 g/person/day), according to the World Health Report of the World Health Organization (2002), low-consumption fruits and vegetables CM is the concentration of heavy metals (mg/kg dry weight), and Cf is the concentration conversion factor (0.085) (Rattan et al., 2005; Arora et al., 2008; Harmanescu *et al*., 2011), after Woldeshadik *et al*. (2017), BW is the reference weight of an adult, 70 kg; TA is the average exposure time (65 years × 365 days) and 0.001 is the unit conversion factor.

2.8.3. Target hazard quotient (THQ)

Non-carcinogenic and carcinogenic risk assessment

The non-carcinogenic risk for an individual's heavy metals via veggies intake had been assessed through the target hazard quotient (THQ). Accordingly, the target hazard quotient values of the populace because of the intake of infected vegetables had been calculated as the following formula (Zheng *et al*., 2007; Khan *et al*., 2008; Chen *et al*., 2011; Ezemonye *et al*., 2019):

$$THQ = \frac{\mathrm{EDI}}{\mathrm{RfD}} \quad (3)$$

EDI is the estimated daily intake of heavy metals in the population, in mg/day/kg body weight, and RfD is the oral reference dose (mg/kg/day) of each heavy metal. If the value of THQ is <1, which indicates that safe for risk of non-carcinogenic effects and if it is >1 it is imaginary that there is a chance of non – carcinogenic effects with an increasing probability as the value increases (Chen *et al*., 2011; Antoine *et al*., 2017).

2.8.4. Hazard index (HI)

The human health risks from the analysis of heavy metals in selected vegetables are cumulative and expressed as a hazard index (Rattan *et al*., 2005; Zheng *et al*., 2007; Chen *et al*., 2011; Mahmad and Malik, 2014; Shahin *et al*., 2016; Antoine *et al*., 2017; Lie *et al*., 2018; Ezemonye *et al*., 2019). Then, as suggested by Antoine *et al*. (2017), the HI of the heavy metals selected in this study was calculated using the following formula:

$$HI = \sum_{n=1}^{i} \mathrm{THQn};\ \mathrm{i} = 1,2,3, \ldots, \mathrm{n} \quad (4)$$

HI is the sum of various hazards associated with heavy metals. When the HI value becomes <1 the impact of heavy metals on health has not been carefully considered and if the HI value is > 1 this indicates possible health effects. For HI value > 10, it indicates that there are serious chronic health effects (Antoine et al., 2017; Lie et al., 2018).

2.8.5. Target cancer risk (TCR)

According to Sharma *et al*. (2018), human health represents the risk of cancer caused by the intake of certain potentially carcinogenic heavy metals, calculated according to the following formula. Then as Kamunda *et al.* (2016), stated the target cancer risk (TCR) for the carcinogenic effects of heavy metals (Pb, Zn, Cr, and Cd) intake is calculated as follows:

$$\mathrm{CR} = \mathrm{EDI} \times \mathrm{CPSo} \quad (5)$$

$$\sum_{n=1}^{i} \mathrm{CR};\ \mathrm{i} = 1,2,3, \ldots, \mathrm{n} \quad (6)$$

RC is the lifetime cancer risk of body weight heavy metal intake, EDI is the estimated daily intake of heavy metals in the population, in mg/day/kg body weight, CPSo is the slope coefficient of oral cancer, in units of $(\mathrm{mg/kg/day})^{-1}$ and n is the deliberate amount of heavy metals used to calculate cancer risk. The CPSo values of Pb, Cr, and Cd (0.0085, 0.5 and 0.38 respectively) (Gebeyehu and Bayissa, 2020).

2.9. Statistical data analysis

The data of heavy metal content in water, soil and plants in the sample plots of the study area used one-way analysis of variance (ANOVA) and descriptive statistics of changes in heavy metal in the study area, Principal Component Analysis and Pearson Correlation Coefficient used the 24th edition of IBM SPSS statistical data.

3. Results

3.1. Method validation

For the heavy metals considered in this study, the Limit of Quantification (LOQ) and Limit of Detection Method (LDM) were calculated using standard formulas: LOQ = 3 × SD and MDL = 10 × SD. The LOQ and MDL values were specifically confirmed by sample and blank atomic absorption spectrometers. The precision and reliability of the heavy metals considered in this study are as follows (Table 3). The relative standard deviation (% RSD) of vegetables and the potential health risks of the collected samples were analyzed.

Table 3.3: Data Specification for AAS, MDL, LOQ and % RSD for the heavy metals considered in this study.

Parameter	Test method	Wavelength (nm)	MDL (mg/L)	LOQ (mg/L)	%RSD	Av. recovery	R^2
Cr	FAAS	357.90	0.0162	0.162	0.2-9.3	96.5-110	0.99719
Zn	FAAS	213.90	0.0063	0.063	0.2-10.2	89-120	0.99821
Cd	FAAS	228.00	0.0069	0.069	1.7-9.4	93.2-103	0.99501
Pb	FAAS	283.30	0.0036	0.036	0.6-8.7	89.1-112	0.99953

3.2. The concentration of heavy metal in soil and vegetable

Spatially different mean concentrations of heavy metals were observed in vegetables at different study stations available in Table 4. Zn concentration in Garden Swiss chard vegetable (8.72 mg/kg) at the station of GS2 site followed by Zn concentration in Garden cabbage vegetable (8.56 mg/ kg) was statistically significant ($P = 0.0014$). Temporarily also Zn concentration in Garden Swiss chard vegetable (8.72 mg/kg) during May month was recorded which was statistically not significant ($P = 0.88$).

Table 3.4: Mean Value of heavy metals in vegetable samples

Study Site	Vegetable	Sample Code	During May Month, 2021			
			Parameter			
			Pb (µg/Kg)	**Cr (mg/Kg)**	**Cd(mg/Kg)**	**Zn (mg/Kg)**
BOLIP	Cabbage	CGS2	0.169±0.0004	0.2382±0.0021	0.477±0.0016	4.96±0.0001
	Swiss Chard	SGS2	0.087±0.0003	0.31±0.00003	0.0399±0.0003	8.72±0.0005
	Lettuce	LGS2	0.200 ±0.003	0.2429±0.0004	0.0415±0.0006	4.60±0.0002
	Tomato	TGS2	0.061±0.0002	0.324±0.00012	0.0422±0.001	4.12±0.0002
	Garden Cabbage	CDGar.S8	0.079±0.0004	0.4045±0.0002	0.0366±0.001	8.56±0.0005
	Garden Swiss Chard	SDGar.S8	0.741±0.0008	1.141±0.00027	0.0472±0.001	3.74±0.0001
	Cabbage	CDIr.S7	0.228±0.0004	0.398±0.0001	0.045±0.001	4.12±0.0008
	Lettuce	LDIr.S7	0.741±0.0008	1.14±0.00027	0.047±0.0016	ND
	Tomato	TDIr.S7	ND*	0.327±0.00013	0.028±0.0017	ND

Study Site	Vegetable	Sample Code	During June Month,2021			
			Parameter			
			Pb (µg/Kg)	**Cr (mg/Kg)**	**Cd(mg/Kg)**	**Zn (mg/Kg)**
BOLIP	Cabbage	CGS2	0.309±0.003	0.263±0.0002	0.066±0.002	4.51±0.015
	Swiss Chard	SGS2	ND	0.555±0.0008	0.037±0.0006	0.012 ± 0.003
	Lettuce	LGS2	ND	0.138±0.0002	0.044±0.0009	0.032 ± 0.007
	Tomato	TGS2	ND	0.136±0.0002	0.03±0.001	3.82±0.021
	Garden Cabbage	CDGar.S8	ND	0.178±0.0001	0.037±0.0003	3.24±0.0288
	Garden Swiss Chard	SDGar.S8	ND	0.378±0.0001	0.034±0.001	8.35±0.005
	Cabbage	CDIr.S7	ND	0.154±0.00008	0.046±0.001	4.77±0.0135
	Lettuce	LDIr.S7	ND	0.211±0.0006	0.03±0.002	ND
	Tomato	TDIr.S7	ND	0.226±0.0005	0.05±0.0001	ND
* is to mean not detected						

3.3. The concentration of heavy metal in soil

As shown in Table 5, the results for heavy metal concentrations in soil samples from various irrigated land use systems showed spatially and temporary, the highest Zn levels (5.12 mg/kg) at GS2 which was significantly different (P = 4.9E-07) during May month which was no significant difference (P = 0.94) followed by concentration of Zn (4.31 mg/kg) at irrigation land of DSS6 station study site during June month.

Table 3.5: Mean Value of heavy metals in soil and vegetable samples

	Soil	**Sample Code**	**In May, 2021**			
			Parameter			
			Pb (mg/Kg)	**Cr (mg/Kg)**	**Cd(mg/Kg)**	**Zn (mg/Kg)**
	Irrigated land	GS2	ND*	0.6755 ± 0.0007	0.0246± 0.0001	5.12± 0.0015
BOLIP		DIr.S7	1.10 ± 0.0006	1.981± 0.00143	0.0783± 0.00112	4.36± 0.0023
		In June, 2021				
	Soil	**Sample Code**	**Parameter**			
			Pb (mg/Kg)	**Cr (mg/Kg)**	**Cd(mg/Kg)**	**Zn (mg/Kg)**
	Irrigated land	GS2	0.09± 0.00013	0.52± 0.0004	0.028± 0.0002	3.489± 0.0012
		DIr.S7	0.15± 0.0006	0.33± 0.0005	0.035± 0.0002	4.31± 0.0013

* is to mean not detected

3.4. The concentration of heavy metal in water

The mean concentrations of heavy metals analyzed in water samples at different sampling stations during the May and June months are shown in Table 6. Spatially and temporary concentration of Cr (0.82mg/L) was observed at the sampling station of UPWS1 during June month which was statistically significant (P = 0.45), followed by Zn (0.62 mg / L) at the sampling station of WWJS5 during June month which was statistically significant (P = 0.024). And the lowest concentration recorded were concentrations of Cr and Zn at the sampling station of UPWS1 during May and also for the concentration of Zn during June month.

Table 3.6:The concentration of heavy metals in water samples collected from different study sites (Mean ± SD)

Study Area	Sample Code	In May 2021			
		Heavy Metal			
		Cr (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)
	UPWS1	ND	ND	0.05 ± 0.0002	ND
	GS2	0.40 ± 0.0004	0.057 ± 0.0003	0.053 ± 0.006	0.028 ± 0.003
	IPS3	0.38 ± 0.0009	0.078 ± 0.0004	0.06 ± 0.006	0.62 ± 0.0015
	IPS4	0.41 ± 0.0005	0.26 ± 0.0001	0.12 ± 0.0009	0.04 ± 0.001
	WWJS5	0.16 ± 0.0001	0.061 ± 0.0007	0.058 ± 0.0004	0.56 ± 0.004
	DSS6	0.53 ± 0.0001	0.201 ± 0.0002	0.04 ± 0.0007	0.21 ± 0.0001
BOLIP		**In June 2021**			
	UPWS1	0.82 ± 0.0005	0.513 ± 0.0005	0.016 ± 0.0006	ND
	GS2	0.39 ± 0.0002	0.026 ± 0.0001	0.017 ± 0.0007	0.048 ± 0.0003
	IPS3	0.31 ± 0.001	0.071 ± 0.0002	0.029 ± 0.001	0.25 ± 0.0013
	IPS4	0.29 ± 0.0006	0.62 ± 0.0005	0.019 ± 0.0005	0.72 ± 0.0002
	WWJS5	0.31± 0.0003	0.097 ± 0.0005	0.024 ± 0.001	0.061 ± 0.0001
	DSS6	0.30 ± 0.0001	0.252 ± 0.0006	0.027± 0.0005	0.048 ± 0.0009

3.5. Pearson correlation coefficient for soil, vegetable and water

Pearson's correlation is necessary to determine the spatial and temporary relationship between the concentrations of heavy metals in the soil during different months and at different sampling stations. Thus, the concentrations of heavy metals were differentially correlated with the concentrations of individual heavy metals (Table 7). During May month most heavy metals are strongly positively correlated with each other’s while a few metals had seen strongly negatively correlated. On the other hand, the concentrations of heavy metals such as Cr and Cd with the concentration of Pb were strongly positively correlated in vegetables during May month. The rest concentrations of heavy metals were weakly positive and negatively correlated with each other’s (Table 7).

Pearson's correlation is necessary to determine the relationship between the concentrations of heavy metals in water spatially at different sampling stations and during different months. Consequently, the concentrations of heavy metals, as shown in Table 5, Cd concentration have a strong positive correlation with Pb concentration during May month and Zn concentration also has a strong positive correlation with Cr during May month. The concentration of Cr has a week positive correlation with Pb concentration during May month but have a week negative correlation during June month.

Table 3.7: Pearson Correlation Coefficient (r) for Soil, Vegetables

Soil

Soil	Pb (May)	Pb (June)	Cr (May)	Cr (June)	Cd (May)	Cd (June)	Zn (May)	Zn (June)
Pb (May)	1							
Pb (June)	1.000**	1						
Cr (May)	1.000**	1.000**	1					
Cr (June)	-1.000**	-1.000**	-1.000**	1				
Cd (May)	1.000**	1.000**	1.000**	-1.000**	1			
Cd (June)	1.000**	1.000**	1.000**	-1.000**	1.000**	1		
Zn (May)	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	-1.000**	1	
Zn (June)	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	-1.000**	1

Vegetable

Vegetable	Pb (May)	Pb (June)	Cr (May)	Cr (June)	Cd (May)	Cd (June)	Zn (May)	Zn (June)
Pb (May)	1							
Pb (June)	-.115	1						
Cr (May)	.949**	-.271	1					
Cr (June)	.130	.039	.162	1				
Cd (May)	-.085	.999**	-.248	.040	1			
Cd (June)	-.382	.796*	-.529	-.067	.781*	1		
Zn (May)	-.400	.079	-.424	.370	.079	-.013	1	
Zn (June)	.327	.223	.303	.010	.241	.035	.142	1

Water

Water	Pb (May)	Pb (June)	Cr (May)	Cr (June)	Cd (May)	Cd (June)	Zn (May)	Zn (June)
Pb (May)	1							
Pb (June)	-.116	1						
Cr (May)	.027	.342	1					
Cr (June)	-.472	-.408	-.777	1				
Cd (May)	-.206	.964**	.154	-.291	1			
Cd (June)	.822*	-.039	.453	-.612	-.243	1		
Zn (May)	-.166	.730	.719	-.623	.619	.226	1	
Zn (June)	-.594	.546	-.223	.393	.593	-.460	.420	1

3.6. Bioconcetration factor

The results of the analysis of the factor of bioconcentration for various heavy metals in different sampling stations of the study are shown in Table 9, determined according to equation 1. The maximum value of the bioconcentration factor recorded was 19.39 for Cd during May month at the sampling station of GS2 irrigation land in cabbage. And the lowest values recorded were 0.00 for Pb during May at all sampling stations of GS2 in all vegetables considered in this study and tomato vegetables during May month at the sampling station of DIr.S7, similarly during June month in all vegetables measured and at all sampling stations except cabbage vegetable at sampling station of GS2 (Table 8)

Table 3.8: Bioconcentration Factor (ND is to mean not detected)

	In May Period, 2021						During June Period, 2021					
		Bioconcentration of heavy Metals						Bioconcentration of Metal				
Site	Vegetable	Sample code	Pb	Cr	Cd	Zn	Vegetable	Sample code	Pb	Cr	Cd	Zn
BOLIP	Cabbage	CGS2	ND*	1.3382	19.3902	0.9688	Cabbage	CGS2	3.4333	0.5058	2.3571	1.2926
	Swiss Chard	SGS2	ND	0.4589	1.0784	1.7031	Swiss Chard	SGS2	0.0000	1.0673	1.3214	0.0034
	Lettuce	LGS2	ND	0.3596	1.6870	0.8984	Lettuce	LGS2	0.0000	0.2654	1.5714	0.0092
	Tomato	TGS2	ND	0.4796	1.7154	0.8047	Tomato	TGS2	0.0000	0.2615	1.0714	1.0949
	Garden Cabbage	CDGar.S8	0.0718	0.2042	0.4674	1.9633	Garden Cabbage	CDGar.S8	0.0000	0.5394	1.0571	0.7517
	Garden Swiss Chard	SDGar.S8	0.6736	0.5760	0.6028	0.8578	Garden Swiss Chard	SDGar.S8	0.0000	1.1455	0.9714	1.9374
	Cabbage	CDIr.S7	0.2073	0.2009	0.5747	0.9450	Cabbage	CDIr.S7	0.0000	0.4667	1.3143	1.1067
	Lettuce	LDIr.S7	0.6736	0.5755	0.6003	0.0000	Lettuce	LDIr.S7	0.0000	0.6394	0.8571	0.0000
	Tomato	TDIr.S7	0.0000	0.1651	0.3576	0.000	Tomato	TDIr.S7	0.0000	0.6848	1.4286	0.0000

3.7. Estimated daily intake (EDI) of heavy metals

The analyzed result of EDI of heavy metals at different sampling stations within different period, Table 9, has been calculated via means of the use of equation 2. The highest value of EDI recorded has been 0.001 for Zn in tomatoes at the sampling station of GS2 during June month. While the lowest value of EDI was 0.00 during June month for Pb in all vegetables designed in this study except in cabbage at the sampling station of GS2 during June month.

Table 3.9: Estimated daily intake of heavy metals

		In May Period, 2021					In June Period, 2021				
Site	Vegetable	Sample code	EDI of Heavy Metal				Sample code	EDI of Heavy Metal			
			Pb	Cr	Cd	Zn		Pb	Cr	Cd	Zn
BOLIP	Cabbage	CGS2	0.000049	0.000069	0.000139	0.001445	CGS2	0.00009	0.000077	0.000019	0.001314
	Swiss Chard	SGS2	0.000025	0.00009	0.000012	0.002541	SGS2	ND*	0.000162	0.000011	0.000003
	Lettuce	LGS2	0.000058	0.000001	0	0.00002	LGS2	ND	0.00004	0.000013	0.000009
	Tomato	TGS2	0.000018	0.000001	0	0.000018	TGS2	ND	0.00004	0.000009	0.001113
	Garden Cabbage	CDGar.S8	0.000021	0	0	0.000009	CDGar.S8	ND	0.000052	0.000011	0.000944
	Garden Swiss Chard	SDGar.S8	0.000216	0.000001	0	0.000004	SDGar.S8	ND	0.00011	0.00001	0.002433
	Cabbage	CDIr.S7	0.000066	0	0	0	CDIr.S7	ND	0.000045	0.000013	0.00139
	Lettuce	LDIr.S7	0.000216	0	0	0	LDIr.S7	ND	0.000061	0.000009	0
	Tomato	TDIr.S7	0	0	0	0	TDIr.S7	ND	0.000066	0.000015	0

* is to mean Not Detected

3.8. Target hazard quotient (THQ)

The target hazard quotient was calculated based on equation 3. Thereafter, the results of the target non-cancer hazard quotient (THQ) analysis showed that person who ate lettuce had a high health risk with a Pb accumulation of 0.062 at the sampling station of DSS6 during May which was followed by THQ of Cr in Swiss chard at sampling station of GS2 during June month (Table 10). Additionally, the highest value of HI recorded was at the sampling station of GS2 in cabbage (0.056) during June month followed by HI in Swiss chard (0.054) at the sampling station of GS2 during June month.

Table 3.10: Target hazard quotient for heavy metals

In May Period, 2021								In June Period, 2021					
Site	Vegetable	Sample code	THQ of Heavy Metals					Sample code	THQ of Heavy Metals				
			Pb	Cr	Cd	Zn	**HI**		Pb	Cr	Cd	Zn	**HI**
BOLIP	Cabbage	CGS2	0.014072	0.023139	0.000366	0.004818	0.042395	CGS2	0.025729	0.025549	5.06E-05	0.004381	0.055709
	Swiss Chard	SGS2	0.007244	0.030114	3.06E-05	0.008471	0.04586	SGS2	ND*	0.053914	2.84E-05	1.17E-05	0.053954
	Lettuce	LGS2	0.016653	0.000359	4.84E-07	6.80E-05	0.01708	LGS2	ND	0.013406	3.37E-05	3.11E-05	0.013471
	Tomato	TGS2	0.005079	0.000479	4.92E-07	6.09E-05	0.005619	TGS2	ND	0.013211	2.30E-05	0.003711	0.016945
	Garden Cabbage	CDGar.S8	0.00598	0.000144	1.03E-07	3.05E-05	0.006155	CDGar.S8	ND	0.017291	2.84E-05	0.003147	0.020467
	Garden Swiss Chard	SDGar.S8	0.0617	0.000406	1.33E-07	1.33E-05	0.062119	SDGar.S8	ND	0.03672	2.61E-05	0.008111	0.044858
	Cabbage	CDIr.S7	0.018984	1.57E-05	1.40E-08	1.63E-06	0.019002	CDIr.S7	ND	0.01496	3.53E-05	0.004634	0.019629
	Lettuce	LDIr.S7	0.0617	4.51E-05	1.47E-08	0	0	LDIr.S7	ND	0.020497	2.30E-05	0	0.02052
	Tomato	TDIr.S7	0	2.20E-06	1.49E-09	0	0	TDIr.S7	ND	0.021954	3.83E-05	0	0.021993

* is to mean not detected

3.9. Target cancer risk (TCR)

The TCR was calculated based on Equation 5. The TCR analysis results are then shown in (Table 11), for Pb, Cr, and Cd in cabbage, Swiss chard, lettuce, and tomato through different study station sites, accordingly the maximum TCR value determined was 8.09×10^{-5} for Cr in the garden Swiss chard at sampling station of SGS2 during June month followed by 5.51×10^{-5} for Cr in Swiss chard at sampling station, SDGar.S8 during June month.

Table 3. 11:Target cancer risk for heavy metals

		During May Period, 2021				In June Period, 2021			
Site	Vegetable	Sample code	CR of Heavy Metals			Sample code	CR of Heavy Metals		
			Pb	Cr	Cd		Pb	Cr	Cd
BOLIP	Cabbage	CGS2	4.19E-07	3.47E-05	5.28E-05	CGS2	7.65E-07	3.83E-05	7.31E-06
	Swiss Chard	SGS2	2.16E-07	4.52E-05	4.42E-06	SGS2	ND*	8.09E-05	4.10E-06
	Lettuce	LGS2	4.95E-07	5.38E-07	6.99E-08	LGS2	ND	2.01E-05	4.87E-06
	Tomato	TGS2	1.51E-07	7.18E-07	7.11E-08	TGS2	ND	1.98E-07	3.32E-06
	Garden Cabbage	CDGar.S8	1.78E-07	2.16E-07	1.49E-08	CDGar.S8	ND	2.59E-05	4.10E-06
	Garden Swiss Chard	SDGar.S8	1.84E-06	6.10E-07	1.92E-08	SDGar.S8	ND	5.508E-05	3.77E-06
	Cabbage	CDIr.S7	5.65E-07	2.36E-08	2.03E-09	CDIr.S7	ND	2.244E-05	5.09E-06
	Lettuce	LDIr.S7	1.84E-06	6.76E-08	2.12E-09	LDIr.S7	ND	3.07E-05	3.32E-06
	Tomato	TDIr.S7	0	3.30E-09	2.15E-10	TDIr.S7	ND	3.29E-05	5.54E-06

* is to mean not detected

3.10. Principal component analysis of soil, vegetables and water samples

Soil analysis results for principal components showed through May and June strongly positive correlation at the sampling stations of the study (Table 12). The results of the analysis of the principal components of vegetables considered in this study at sampling stations CGS2, SGS2, LGS2, TGS2, CDGar.S8, SDGar.S8, and CDIr.S7 indicated a strongly positive correlation by the first component through May and June and also strongly positive correlation at the sampling stations of SGS2, LGS2, LDIr.S7 and TDIr.S7 during June, while having slightly negative correlation at sampling stations of LDIr.S7 and TDIr.S7 by the first component (Table 12).

The analysis of principal components analyzed in water samples collected from different study stations through the months of May and June showed in (Table 11). Accordingly, by component 1 at sampling stations of UPWS1, GS2, IPS4, WWJS5, and DSS6 they indicated a strongly positive correlation during May and June. Similarly, at sampling stations of the study of IPS3 and WWJS5 indicated that strongly positive correlation through May by component 2, while components 1 and 2 at the sampling station of UPWS1 during May slightly showed a slightly negative correlation (Table 12).

Table 3.12: Principal component analysis for soil, vegetable, and water samples

Component Matrix								
Soil	Component	**Vegetable**	Component		**Water**	Component		
	1		1	2		1	2	3
GS2 (May)	.997	CGS2 (May)	.986	.154	UPWS1 (May)	-.627	-.585	.515
GS2 (June)	.998	CGS2 (June)	.983	.180	UPWS1 (June)	.920	-.296	-.256
DIr.S7 (May)	.965	SGS2 (May)	.981	.193	GS2 (May)	.928	-.190	.319
DIr.S7 (June)	.992	SGS2 (June)	-.495	.869	GS2 (June)	.938	-.051	.343
		LGS2 (May)	.981	.190	IPS3 (May)	.270	.919	.286
		LGS2 (June)	-.397	.887	IPS3 (June)	.734	.611	.295
		TGS2 (May)	.973	.230	IPS4 (May)	.882	-.451	-.135
		TGS2 (June)	.980	.197	IPS4 (June)	.066	.762	-.644
		CDGar.S8 (May)	.979	.205	WWJS5 (May)	-.088	.979	.182
		CDGar.S8 (June)	.977	.214	WWJS5 (June)	.990	-.069	.125
		SDGar.S8 (May)	.913	.363	DSS6(May)	.985	.152	.077
		SDGar.S8 (June)	.978	.208	DSS6 (June)	.865	-.248	-.435
		CDIr.S7 (May)	.973	.226				
		CDIr.S7 (June)	.981	.193				
		LDIr.S7 (May)	-.668	.492				
		LDIr.S7 (June)	-.544	.838				
		TDIr.S7 (May)	-.521	.854				
		TDIr.S7 (June)	-.573	.810				

4. Discussion

The rapid development of industries and use of industrial wastewater in agriculture have resulted in increased concerns about the accumulation of heavy metals in agricultural soils (Esmaeilzadeh et al., 2018). According to Seifi et al. (2019), the spatial distribution of heavy metals is much higher in the industrial areas as comparison to urban areas. Contamination of water and soils with a variety of heavy metals is one of the increasing environmental issues all over the world (Kanu and Achi, 2011). The issue has been aggravating in developing countries due to the rapid and unplanned growth of population, poor management, and excessive consumption in agricultural and industrial activities (Saleh et al., 2018). In this study, the analysis of soil, vegetables and water was carried out to assess the content of heavy metals Pb, Cr, Cd, and Zn. The results were compared with the WHO/FAO and USEPA standards and guidelines.

Average concentrations of Pb in cabbage and lettuce at the study sampling stations of GS2 and garden Swiss chard, cabbage, and lettuce of sampling station of DIr.S7 irrigated with the wastewater in May. Similarly, the mean value of Pb in cabbage at sampling station of GS2 during June was above the permissible limit in accordance with the WHO/FAO set for Pb (0.1 μg/g). Existence of metals in soil is natural, but values exceeding the standard permissible limit are considered environmental contaminant sources (Esmaeilzadeh et al., 2018). Comparison of metals with the standard values of the quality of agricultural soils in Iran indicated that lead had a larger value than standard levels and can cause problems due to entrance into agricultural crops and food chain (Esmaeilzadeh et al., 2018), causing toxicity and carcinogenic effects for humans (Saleh et al., 2018). Likewise, the mean values of Cr and Cd concentrations in vegetables considered in this study at all sampling stations were above the permissible limit in accordance with the WHO/FAO set for Cr (0.1 - 0.2 μg/g) and Cd (0.02μg/g) in both May and June. Cr, an element which is found in food resources and drinking water, is very harmful to human health, seriously damaging lungs and kidneys (Saleh et al., 2018). And also the average values of Zn concentrations in vegetables considered at these study site at most sampling stations are above the permissible limit in accordance with the WHO/FAO standards and guidelines except during both months at sampling station Dir.S7 Lettuce and Tomato are within the standard and guidelines.

The use of industrial wastewater for irrigation can be considered one of the reasons of existence of metal contamination in vegetables and water in the study area. Such heavy metal contamination in agricultural soils may cause disorder in the soil structure, and interference in the plant growth (Esmaeilzadeh et al., 2018). Besides, issues related to environmental pollution have been increasing negative impacts on human health through entering the food chain (Almasi et al. 2014). High concentrations of heavy metals, especially Pb, will lead to a risk of cancer if the daily intake exceeds the recommended values (Chaang *et al*., 2014; Sa *et al*., Lin *et al*., 2016). Heavy metals in the environment may also affect aquatic life and alter plant diversity (Atafar et al., 2010; Islam et al., 2013). According to Woldetshadik *et al*. (2017), exceeding the permissible Pb concentration in leafy vegetables in Akaki, Addis Ababa, has supposed. The accumulation of high heavy metals measured in this study in leafy vegetables in the present study may be related to the impact of sewage irrigation which was influenced by different industries. Eating vegetables contaminated with Pb has public health implications as lead and other heavy metals tend to bioaccumulate in the tissues of the human body, causing toxic effects (Antonio & Leret, 2000; Antonio *et al*., 2003; Assi & Chemi, 2016). Pb causes detrimental problems in blood, central nervous system, kidneys, and reproductive and immune systems in all animals and negatively affects children's intelligence (Jamal et al. 2018). Cd accumulates produce serious problems in kidney and liver organs (Chen et al. 2014).

Average heavy metal concentrations for Pb, Cr and Cd in water samples taken from various sampling stations within the months of May and June exceeded the acceptable limit in accordance with US Environmental Protection Agency guidelines (USEPA, 2004). However, the average heavy metal concentrations for the Cr at sampling station UPWS1, with May, Pb at some sampling stations, and Zn heavy metals in this study were below the limits set by the US EPA guidelines through May and June. This suggests that the continued use of wastewater and wastewater on agricultural land may increase the number of heavy metals in the soil (Seema, 2016).

Bioconcentration factors (BCFs), which represent the relationship between metal concentrations in plants and metal concentrations in soil, are used to represent the absorption of heavy metals by soil and plants and indicate the transfer of heavy metals from soil to vegetables. Accordingly, the Bioconcentration factor for Pb in cabbage at the sampling station of GS2 in June (3.43), similarly

BCF for Cr in cabbage and Swiss chard during the month of May and in garden Swiss chard at the sampling station of DIr.S7 during June, for Cd in cabbage, Swiss chard, lettuce and tomato at sampling stations of GS2 during May and June as well as for Zn in Swiss chard and garden cabbage at sampling stations of GS2 and DIr.S7 during May, in cabbage and tomato at sampling station of GS2 likewise at sampling station of DIr.S7 in garden Swiss chard and cabbage during June is greater than 1. Comparing the results obtained from this research, it was observed that the total concentration obtained for zinc was larger than that obtained in the research conducted in Eshghabad region in the northeast of Iran by Esmaeilzadeh et al. (2018). According to these authors, Zn at high concentrations can lead to toxicity and cause immunologic and digestive diseases.

According to Gupta *et al*. (2010), the transport factor of lead is very low compared to Cd and Cr. In general, the transfer of metals from soil to plants can depend on the nature of the soil, the composition of the starting metal material, the plant species, and the solubility of metals (Intawongse, Dean, 2006; Kabala *et al*., 2009).

People are encouraged to eat more vegetables because they are a source of vitamins, minerals, and fiber and are good for human health, but an increasingly important aspect of food quality is controlling the concentration of heavy metals in food to protect people from the harmful effects of heavy metals (WHO / FAO, 2003). The EDI values for Pb, Cr, Cd, and Zn at different sampling stations through the months of May and June were within the FAO / WHO Maximum Permissible Daily Intake (PMTDI) range.

The non-carcinogenic risk to human health from eating vegetables contaminated with heavy metals is estimated by calculating the target hazard quotient (THQ) expressed in the methods section using the “3” equation, so the THQ value of heavy metals analyzed in this study in vegetables which were considered in this study through the study months at all sampling stations showed less than 1. So with the exception of heavy metals determined for THQ in this study, it is generally considered safe and cancer-free.

The hazard index (HI) was also calculated, reflecting the increasing effects of the consumption of various potentially hazardous heavy metals as a result of the consumption of various vegetables, as well as data of HI on cabbage, Swiss chard, lettuce, and tomato for heavy metals

Pb, Cr, Cd and Zn at different sampling stations through May and June indicated that less than 1. As a result, this indicated that no potential health effects due to the consumption of these vegetables at these study station.

As Sharma *et al*. (2018), state that the human health risk of cancer from the ingestion of carcinogenic heavy metals is calculated using Equation 6. Then Target Cancer Risk (TCR) derived from the heavy metals in this study for Pb, Cr, and Cd, there may be beneficial carcinogenic effects depending on the dose of expression, hence the calculated TCR value for Pb and Cr in cabbage, Swiss chard, lettuce, and tomato vegetables via the sampling stations of the study during May and June were within the TCR value of Pb and Cr (1×10^{-4} - 1×10^{-6}) as commented by the Ministry of Health (Health Canada, 2010) while the value of TCR for Cd in Swiss chard at sampling station of GS2 during May was not within (1×10^{-4} - 1×10^{-6}) as stated by the Ministry of Health (Health Canada, 2010) as well as in all vegetables considered in this study for Cd heavy metal the TCR value at all sampling stations during June was not within (1×10^{-4} - 1×10^{-6}) as noted by the Ministry of Health (Health Canada, 2010). So, there is currently a cancer risk for Cd due to the consumption of these heavy metal-contaminated vegetables covered in this study. Mohammadi et al. (2019b) evaluated the health risks of exposure to heavy metals along with the water distribution network of Khorramabad city in Iran and concluded that the degree of toxicity of heavy metals to human health is directly related to their daily intake, and long-term exposure to low amounts of toxic metals could result in many types of cancers. This calls for human health risk assessment to determine the nature and magnitude of adverse health effects in local communities around the study area who may be exposed to toxic substances in a contaminated environment. Agricultural soils influence public health directly and indirectly through food production, and therefore, protecting soil resource and ensuring its stability are important (Esmaeilzadeh et al., 2018).

5. Conclusion

Results for heavy metal concentrations in soil samples from various irrigated land use fields have shown both spatially and temporarily, accordingly the difference is not significant in irrigated soil at the Dir.S7 study site for a few heavy metals. Similarly, Zn concentration was also recorded in the garden cabbage during May was not statistically significant. Heavy metals like

Cr and Cd concentrations with Pb concentrations had a strong positive correlation in vegetables during May.

In the study area of the sampling stations of vegetables irrigated with wastewater at GS2 for Pb in cabbage and lettuce, and in garden Swiss chard, cabbage and lettuce of sampling station of Dir.S7 through the month of May as well as the mean value of Pb in cabbage at sampling station of GS2 during the month of June has exceeded the permissible level. Generally**,** Heavy metals concentrations were observed at most study's sampling stations in irrigation water (Table 6).

Vegetables irrigated with contaminated industrial wastewater were observed with heavy metal concentrations exceeding the permissible level on certain vegetables at some irrigated sampling stations of the study site. Therefore, there was a high bio-concentration factor in vegetables in the sampling stations. Hence, industrial wastes or residues must be and permanently checked and regulated. Heavy metals are not to remain in water sources and agricultural lands without significant treatment, tests and approval. Moreover, it is indispensable to monitor constantly the quality of water and soil to avoid the penetration of heavy metals into vegetables through water and soil effluence in order to prevent potential health hazards for human beings and other biotas. Application of optimal management for reduction of contaminants, and suitable irrigation methods with treated wastewater is essential. This study can provide a basis for the City Administration of Addis Ababa to properly protect the water quality of rivers and provide a reference for river management around the industry parks across the country.

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Authors' contributions

FL was responsible for all activities of the research process such as the research method selection, sample collections, data compilation, entry, data analysis, and interpretation of the results as well as writing up of the manuscript. BS and AS were also involved in improving the quality of the manuscript by providing constructive guidance, critical comments and suggestions on the data analysis, and interpretation. GGS was also involved in improving the quality of the manuscript by providing critical comments and editing the manuscript. All authors read and approved the final manuscript.

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Declarations

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This article does not contain any studies with participants performed by any of the authors.

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The authors declare that they have no competing interests.

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Chapter IV: Development-induced impacts on the livelihoods of local communities in Ethiopia: the case of bole lemi industry park in addis ababa

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Abstract

Livelihood encompasses the resources and capabilities that individuals and households utilize to ensure their survival and enhance their well-being. This study examined the impact of Bole Lemi Industry Park on livelihood systems in Addis Ababa, Ethiopia. It focused on how the establishment of the industrial park affected the livelihoods of displaced communities. A survey was conducted among 379 household heads that were displaced by the industrial park, ensuring representation across various factors such as gender, marital status, education level, ethnic group, and religion. Descriptive statistics, including frequency counts, mean values, standard deviations, and percentages, were used to analyze the data. Multiple linear regression models were employed to investigate how socioeconomic variables predicted household heads' annual income before and after the establishment of the park. The findings revealed that the displaced household heads faced challenges in terms of income and employment opportunities, resulting in deteriorating living conditions and increased poverty due to significant changes in their livelihoods. The study identified the balance gap between industrial development and the interests of local farming communities, thereby failing to ensure sustainable livelihoods. It recommended that development projects in Addis Ababa prioritize the affected communities by offering compensation, support for resettlement, and opportunities for livelihood diversification. Taking a comprehensive and participatory approach to industrial park development is crucial for achieving sustainable and equitable economic growth while safeguarding the well-being of local communities.

Keywords: Livelihood, Bole Lemi Industry Park, Displaced communities, Sustainable livelihoods, Addis Ababa

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1. Introduction

Livelihoods refer to the ways individuals and families adapt to meet their basic needs (Krantz, 2001). The term "livelihood" commonly refers to the capacity and resources individuals and households utilize to develop strategies for their survival and well-being (Ablo et al., 2020). It is a comprehensive concept that encompasses both the actions people take and the outcomes they achieve in order to sustain themselves, such as earning a living or supporting their families. This perspective assumes that humans actively design and implement strategies for survival (Nath, 2009; UNDP, 2010).

According to Moran et al. (2007), a livelihood asset refers to something owned that has the potential to yield future benefits for sustaining livelihoods. The concept of livelihood asset is fundamental to the sustainable livelihoods approach, which focuses on the assets impoverished individuals need to maintain a sufficient income (Arhin et al., 2022). Livelihood strategies encompass the actions and choices individuals make to achieve their livelihood objectives (Peng et al., 2022). Economic, social, and environmental factors can drive households to diversify their livelihoods (Dai et al., 2020). Livelihood diversification plays a crucial role in managing risks as it enables families to mitigate the impacts of economic instability or fluctuations (Ellis, 2000; Kien, 2011), achieve higher and more stable income levels (De Janvry et al., 2005; Akaakohol and Aye, 2014; Gautam and Andersen, 2016), engage in a process where rural households develop a range of activities and social support mechanisms to enhance their survival and improve their quality of life (Peng et al., 2022), gain prominence in long-term poverty reduction strategies (Martin and Lorenzen, 2016), and typically involve a shift away from relying solely on farming income (Ellis and Allison, 2004).

A sustainable livelihood refers to the ability of a system to maintain or expand its resources and capabilities over time, without depleting the natural resource base (UNDP, 2017). It entails finding a balance between human needs for natural resources and the environment's capacity to continuously provide those resources (UNDP, 2010). Farrington et al. (2002) explore the application of sustainable livelihood approaches (SLAs) in urban areas, emphasizing the assets required by impoverished individuals to sustain an adequate income (Arhin et al., 2020). This concept has been widely used in international development to assess household sustainability (Paul et al., 2020; Wang et al., 2016). The importance of a holistic approach is emphasized by

Farrington et al. (2002), considering social, economic, political, and environmental factors as components of urban livelihoods. The Sustainable Livelihoods Framework (SLF), developed by the UK Department for International Development (DFID), serves as an analytical tool to understand how people establish and maintain their livelihoods, incorporating property, means of living, livelihood context, and vulnerability to shocks and pressures (Levine, 2014). The SLF is based on five types of assets: social (e.g., groups), human (e.g., individual skills), natural (e.g., land), financial (e.g., income), and physical resources (e.g., infrastructure) (Moran et al., 2007). These assets, as per the livelihood model, help individuals cope with displacement shocks (Speranza et al., 2014; Khan et al., 2021), complementing each other (Reddy et al., 2004). The SLF identifies the key factors influencing livelihoods, along with the relationships between them (Natarajan et al., 2022), and acknowledges the influence of vulnerability settings, policies, and institutions on people's assets (Speranza et al., 2014).

Industrialization, despite creating opportunities, can also adversely affect people's livelihoods (Speranza et al., 2014; Rana and Ilina, 2021). Displacement can disrupt household income and necessitate the liquidation of significant assets (Arhin, 2022). There is a common belief that this transformation will steer households away from land-based livelihoods toward market-oriented activities (Scoones 2009; Peng et al., 2019). Land, being the most crucial natural resource for humanity (Gessese, 2018; Tezera et al., 2016), directly and indirectly supports livelihoods. It serves as a tangible natural asset employed in production (UNDP, 2010). Access to arable land holds immense importance in the lives of millions of people in Sub-Saharan Africa. However, access to this critical resource has been diminishing in many countries, particularly among marginalized rural populations (Scoones et al., 2019).

Large-scale development projects often involve relocating residents, resulting in physical displacement (Vanclay, 2017), which can have either temporary or permanent effects on their livelihoods or income-generating activities, known as economic displacement (IFC 2002). Land holds immense significance for many individuals, with 'land is life' being a common sentiment (Wickeri, 2011), and people worldwide have varying degrees of attachment to their places (Vanclay, 2008). Consequently, land acquisition for projects and the subsequent displacement and disruption can cause substantial harm (Smyth & Vanclay, 2017). Relocated individuals experience various impacts due to their unique capacities and interests (Oliver-Smith, 2010; Vanclay, 2012).

Urbanization often accompanies industrialization, leading to unavoidable expansions at the outskirts of cities (Bekele, 2010). In Ethiopia, industrialization, urbanization, and economic advancements have occurred in the past two decades, causing a shift in livelihoods from farming to non-farm sectors across the country. However, the establishment of industrial parks has resulted in the displacement of local communities from their original areas. This development poses potential impacts such as household relocations and changes in livelihoods, including the loss of farmland and subsequent income reduction, potentially affecting food security. This study examines the consequences of industrialization on farmers who have experienced the loss of agricultural lands, making them victims of the industrialization process. Such outcomes have social and environmental implications (Vanclay, 2017).

This study explores the changes in farming livelihoods in the Bole Lemi area caused by the development of the Bole Lemi Industry Park on the outskirts of Addis Ababa. The study aims to assess the impacts of the establishment of the Bole Lemi Industry Park on the livelihoods of displaced communities in Addis Ababa, Ethiopia.

2. Materials and methods

2.1. Description of the study area/study site

Addis Ababa, the capital city of Ethiopia, is situated in the horn of Africa and spans an area of 540 km2. The city is located in the elevated plateaus of central Ethiopia, surrounded by the North-South oriented mountain systems adjacent to the Great Rift Valley. Addis Ababa is positioned at latitude 8° 2′ 48″ and longitude 38° 45′ 0″ (Wubneh, 2013). As the largest city in Ethiopia, Addis Ababa has experienced significant urban growth characterized by rapid urbanization and industrialization (AACSPO, 2017).

Addis Ababa, the diplomatic capital of Africa, hosts over 90 embassies and consulates. It serves as the headquarters for the United Nations Economic Commission for Africa (UNECA) since 1958 and the former Organization of African Unity, now known as the African Union, since 1963. The city is a melting pot of various ethnic groups and is home to Orthodox Christians, Muslims, Protestants, and Catholics. In terms of the economy, Addis Ababa's residents are involved in diverse economic activities, including trade, manufacturing, civil administration, transportation, communication, hospitality, and agriculture (farming, horticulture, and animal husbandry).

Addis Ababa is located at an altitude ranging from 1800 meters at Akaki plains to 3200 meters above sea level at Mt. Entoto. The city's topography is characterized by rugged terrain with typical volcanic features. The central part of the city has gentle and rolling landscapes with scattered hills, while the southern and southeastern areas are predominantly flat. The average annual temperatures in Addis Ababa range from 9°C to 24°C (CSA, 2022). The study area has a tropical climate with bimodal rainfall. The average annual rainfall is 1178 mm, with the highest precipitation occurring from June to mid-September and a relatively smaller amount from mid-February to mid-April. The annual rainfall ranges between 1000-1880mm, and the annual temperature ranges from 20 to 25.6 ºC. The population of Addis Ababa has experienced rapid and uncontrolled growth, with a 100% increase over the past two decades. The 2007 census estimated the population at 2.8 million inhabitants, but the City Structure Plan Office has projected a current population of approximately 4.5 million (AACSPO, 2017).

The Bole Lemi Industry Park (BLIP) is situated in the southeastern outskirts of Addis Ababa, approximately 15-20 kilometers away from the city center. It is specifically located in Lemi Kura sub-city at coordinates 8°58'17.2200" latitude and 38°51'24.5088" longitude (Fig. 1). Surrounding the park are expansive agricultural lands to the south and southeast, residential areas (condominiums) to the north and northwest, and the Akaki River and its small tributaries to the east. BLIP is the first industrial park in Ethiopia developed in collaboration with the World Bank Group. Functioning as a large Export Zone and modern Industrial Park, BLIP commenced operations in 2014 with an initial area of 156 hectares, which has now expanded to over 342 hectares. The surrounding land use predominantly consists of cultivated agricultural lands and scattered settlements. The park serves as a hub for companies involved in export-oriented businesses, particularly in garments, apparel, textiles, leather, and leather products (Gebremariam and Feyisa, 2019). Numerous foreign countries have established their presence in the park for apparel exports and various commercial activities.

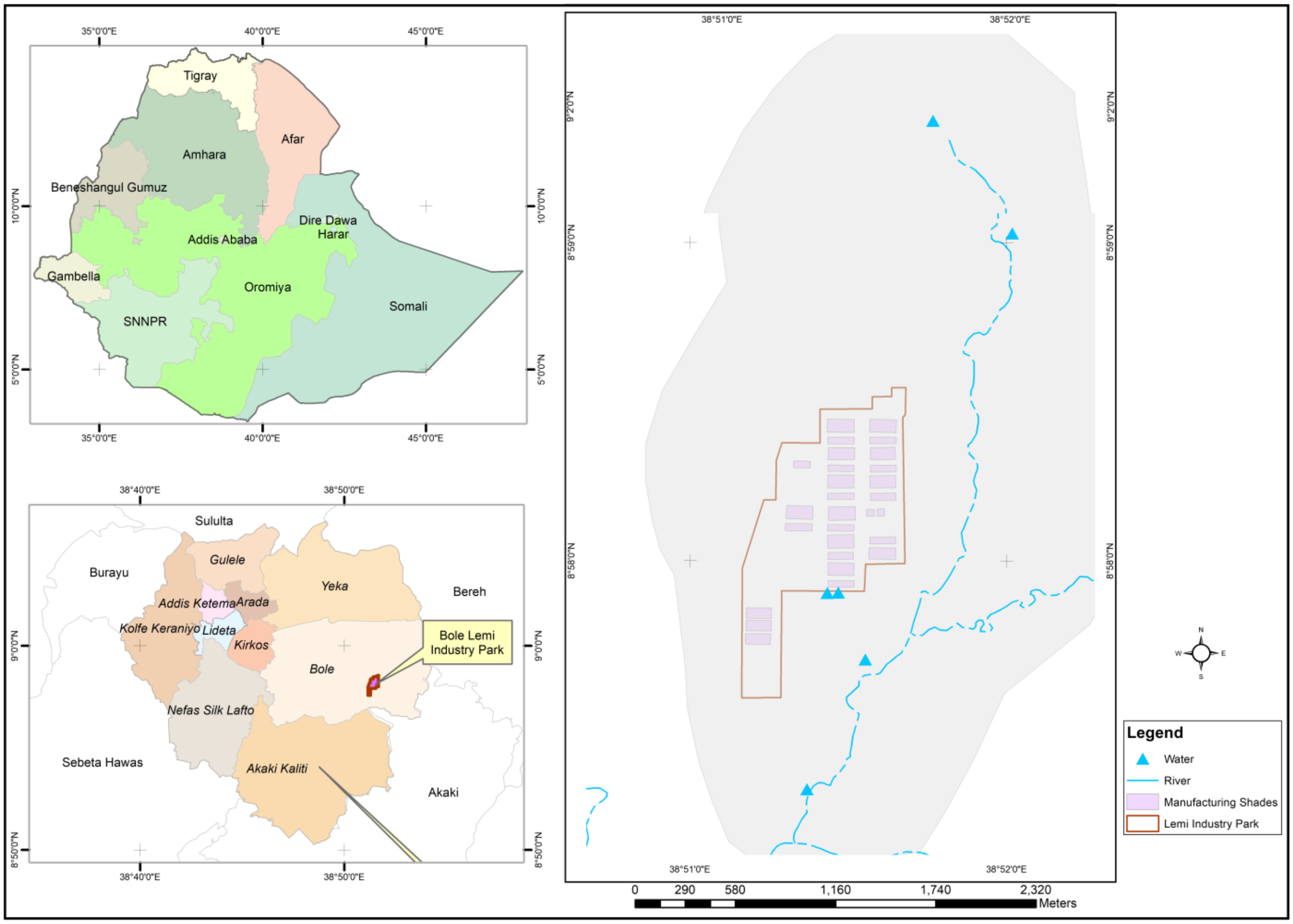

Figure 4.1: Map representing the Bole Lemi Industry Park in Addis Ababa, Ethiopia

2.2. Sampling design

A semi-structured questionnaire was created and administered to assess the income decline and changes in income sources among local farmers' households. The survey focused on the periods before (2012) and after (2020) the establishment of BLIP in its current location. The participants' perceptions and observations regarding livelihood changes resulting from BLIP's establishment were also investigated.

For data collection, the survey targeted farmers' heads of households residing in the outskirts of Lemi-Kura sub-city, Addis Ababa. All households selected for the survey belonged to the displaced group, having been relocated due to BLIP's development in their previous locations.

The selection of household representatives was randomized and independent of gender, marital status, education level, ethnicity, and religion. Both male and female household heads were interviewed, and in cases where the head was unavailable or declined participation, another randomly selected household was approached as a replacement.

The sampling units consisted of heads of households displaced due to BLIP. As defined by FAO (2007), a household refers to a group of individuals cohabiting and sharing common arrangements for food and other essential needs. Before conducting the survey, a pre-test of the questionnaires was performed on 20 households in September 2020 to identify and rectify any errors, ambiguities, and enhance the survey tools' validity (Babbie and Mouton, 2014).

2.3. Data collection methods

Semi-structured questionnaires were administered to collect data on livelihood changes caused by the establishment of BLIP. Local community members who were fluent in Oromifa and Amharic languages were selected as research assistants to conduct the survey. The questionnaires were initially prepared in English but were orally translated into local languages by the research assistants during interviews to ensure clarity. The research assistants received training on survey objectives and procedures, and they explained the survey's purpose and scientific terms to each participating household.

The questionnaire consisted of two parts. The first part collected demographic information about household respondents, including gender, marital status, educational level, ethnicity, and religion, which are important factors influencing livelihood changes. The second part assessed income level, land-holding size in 2012 and 2020, and other relevant factors affected by the establishment of BLIP. On average, the questionnaire took approximately 40 minutes to complete.

Random sampling was used to select respondents from the total displaced population in the new resettlement area. A total of 379 family heads, who had lost their land due to the industrial park development, were randomly sampled and interviewed. The survey was conducted in December 2020, and complete anonymity was ensured for all participating households.

2.4. Data analysis

Descriptive and inferential statistical analyses were conducted. Descriptive statistics, including mean, standard deviation, minimum, median, maximum, frequency counts, and percentages, were used to summarize numerical variables. Regression models were employed to examine the associations between independent variables and time periods. The data entry and analysis were performed using IBM SPSS software version 25. Frequency and regression tables were generated to present the percentage of household responses and the analysis results for the variables under investigation. Regression analysis is suitable for assessing the impact of explanatory variables on dichotomous dependent variables with two categories (Nancy et al., 2015). In this study, two explanatory variables were considered: the time periods of 2012 before the establishment of BLIP and 2020 after the park was established. Statistical methods, specifically logistic regression models, are commonly used to explore relationships between variables (Noszczyk, 2019). These approaches offer the advantage of quantifying the influence of independent variables and providing confidence levels for their contributions (Dang & Kawasaki, 2016).

Multiple linear regression model (Equation (1)) was used to determine how the socioeconomic variables predicted the annual income of the heads of households.

$$Y = \alpha + \beta 1x1 + \beta_2 x_2 + \ldots .. + \beta 6x6 + \varepsilon \ldots\ldots\ldots\ldots\ldots \text{ Equ. 1}$$

Where Y indicates the respondent's income; x_1, x_2, and x_3 represents gender, age, marital status, education level, ethnicity and religion, etc. Furthermore, α denotes the constant, β_1, $\beta_{2,}$ …..,β_6 indicate the respective coefficients the independent variables, whereas ε is the error term in the model

The regression model focused on the income earned by the displaced communities in 2012 and 2020, representing the period before and after the establishment of the Bole Lemi Industry Park. Regression analysis was used to examine the relationship between these variables. The data were analyzed with a confidence level of 95% and 99% to ensure statistical significance.

3. Results and discussion

3.1. Demographic characteristics of heads of households

This study reveals that the displacement caused by development projects has resulted in substantial land and income loss for affected households. It specifically examines the effects of industry-induced changes in livelihoods on impoverished farmers residing in the peri-urban region of northeastern Addis Ababa.

The cooperation of local communities is crucial for the success and sustainability of development projects (Lubell, 2004). Consequently, the perspectives of communities displaced by the development of the Bole Lemi Industry Park in the outskirts of Addis Ababa were collected and analyzed. Household heads in the Bole Lemi area were interviewed to gather their opinions and insights regarding the establishment of the industry park. A summary of the demographic characteristics of the household heads, including their gender, marital status, educational level, ethnicity, and religion, is presented in Table 1. The majority of the participants (approximately 70.5%) were males. This could be attributed to the presence of more men engaged in various activities in their localities during the survey period. However, it is important to note that development-induced displacement has adverse effects on the livelihoods of impoverished female-headed households in Ethiopia (Megento, T. 2013). Additionally, a study by Shaw and Saharan (2019) highlights the challenges faced by women, who often bear the brunt of displacement, in Kolkata, India.

The majority of the participants, approximately 81%, were married. However, as indicated in Table 1, among the selected household heads who participated in the survey, a significant majority (over 60%) had no literacy skills. Regarding the ethnic and religious backgrounds of the respondents, the highest percentage was represented by individuals from the Oromo ethnic group and those who identified as Orthodox Christians, each accounting for approximately 91% of the total respondents. This means that more than 9 out of 10 respondents belonged to these respective groups, surpassing the representation of any other groups.

Table 4.1: Demographic characteristics of interviewed heads of households

Sex of respondents (HH head)	Freq.	Percent	Cum.
Male	267	70.45	70.5
Female	112	29.55	100
Marital status of respondents			
Single	13	3.45	3.45
Married	305	80.9	84.4
Separated	15	3.98	88.3
Widowed	18	4.77	93.1
Divorced	26	6.9	100
Educational level of respondents			
Cannot read and write	227	60.37	60.4
Basic reading and writing	41	10.9	71.3
Primary school	52	13.83	85.1
Junio secondary school	17	4.52	89.6
Secondary school	27	7.18	96.8
College and above	12	3.19	100
Ethnic background of respondents			
Oromo	346	91.29	91.3
Amhara	8	2.11	93.4
Gurage	23	6.07	99.5
Silte	2	0.53	100
Religion background of respondents			
Orthodox	343	90.5	90.5
Protestant	8	2.11	92.6
Muslim	28	7.39	100

3.2. Status of livelihoods and livelihood transformation

The process of transforming agricultural livelihoods is intricate (Ross, 2003). The heads of households acknowledge that farming serves as the primary means of sustenance for communities residing in the outskirts of the city. The survey results indicate a decline in total income since the establishment of the industry park in 2012, which can be attributed to their displacement from their original location. Despite not being widely recognized by the majority of respondents, the new development has had adverse effects on their livelihoods. A significant portion of the land previously utilized for farming by local communities has been allocated for industrial park purposes.

In response to questions aimed at evaluating the state of livelihood among the displaced individuals following the establishment of BLIP in their communities, approximately 84% of the household heads expressed that their livelihoods have been adversely affected (Table 2). When queried about the involvement of local communities in the implementation of new developments within their areas, the vast majority of household heads (around 82%) reported a lack of participation. Regarding the perspectives of household heads on the introduction of new developments, a significant majority of the study participants (approximately 80%) expressed resistance towards the new initiatives.

When inquired about their economic status before the establishment of the industry park, 18% of household heads reported being poor, 29% identified as rich, and the majority of respondents (52.4%) described themselves as moderate. Further exploration revealed that a significant proportion of respondents experienced changes in their livelihood means due to the development of the industry park. The majority (69%) reported becoming jobless, while 16% transitioned from rural to urban lifestyles. Additionally, a smaller percentage shifted their livelihood means from agrarian to semi-agrarian (7.3%) or engaged in trade and services (5.6%) (Table 2). It is noteworthy that farming communities have historically relied on their land for sustenance. However, a significant portion of the land previously used for agriculture in the Bole Lemi area has now been allocated for the industry park.

As per the current Master Plan of Addis Ababa, the land owned by households in the peri-urban areas was primarily designated for agricultural purposes. The survey conducted in this study demonstrates that a majority of the displaced communities heavily relied on farming for their livelihoods. The findings indicate that the establishment of the industry park has brought about changes within the local communities (Table 2). These changes can be analyzed through the lens of livelihood dynamics (Kapfudzaruwa et al., 2018).

Consequently, this study explores the impact of industrialization on local communities' access to agricultural land and the subsequent implications for poverty. The research reveals that many individuals residing in the project area relied entirely on farming for their livelihoods, with crop farming being the predominant activity.

The overwhelming majority of household heads participating in this study emphasized the significant impact of the new development on the livelihoods of local displaced communities. The African continent has experienced a surge in urbanization and industrialization, making it a focal point for such transformations (Kapfudzaruwa et al., 2018). As a result, peri-urban areas are experiencing complex repercussions (Ablo & Yekple, 2018), including the rapid expansion of cities into surrounding rural regions (Gyasi et al., 2014; Fuseini et al., 2017). These changes in land use, induced by development, can have both positive and negative implications for livelihoods. It is crucial to examine any shifts in livelihood patterns that occur when people's means of subsistence are impacted by changing land use and the erosion of assets (Ablo et al., 2020).

Table 4.2: Views of the heads of displaced heads of households

Livelihood of the displaced people	Freq.	Percent	Cum.
Highly decreasing	161	49.09	49.09
Decreasing	113	34.45	83.54
Remain the same	12	3.66	87.2
Increasing	40	12.2	99.39
Highly increasing	2	0.61	100
Respondents' response of community participation on introduction of new development			
Yes	65	18.11	18.11
No	294	81.89	100
Respondents' response of their and other community observation on the new introduction			
Highly recognized	14	4.33	4.33
Recognized	51	15.79	20.12
Defendant	198	61.3	81.42
Highly defendant	60	18.58	100
Respondents' response on dejected household before the development BLIP			
Poor	16	9.76	9.76
Very poor	14	8.54	18.29
Moderate	86	52.44	70.73
Rich	48	29.27	100
Respondents' response on rate of transformation			
Agrarian to semi-Agrarian	13	7.26	7.26
To trade and service	10	5.59	12.85
To joblessness	124	69.27	82.12
Rural to urban lifestyle	29	16.2	98.32
Other	3	1.68	100

The issue of displacement and resettlement caused by development projects is a global phenomenon (Vanclay, 2017). According to Table 2, the primary livelihoods of displaced households undergo a dramatic transformation, shifting towards semi-agrarian work, petty trade, and service occupations. Some individuals from the affected groups may engage in trade activities after receiving monetary compensation from the city administration of Addis Ababa. However, a majority (approximately 69.3%) of household heads become unemployed after being displaced from their original land due to the development of an industrial park. This suggests that adequate planning for resettlement and compensation mechanisms were not considered to safeguard the livelihoods of displaced households. Development projects bring about significant changes in the lives of displaced households, leading to asset loss, limited employment opportunities, and heightened vulnerability (Ejigu & Abraha, 2018). Households that fail to secure employment may face challenges of livelihood and food insecurity (Bren et al., 2017).

Unemployed peri-urban farmers who have been displaced face a heightened risk of food insecurity (Crush et al., 2012). Muromo et al. (Undated) emphasizes the importance of effective community engagement to maximize the benefits of development projects for local communities, particularly in terms of generating employment opportunities. However, a portion of the displaced farmers (approximately 16%) have transitioned from a peri-urban to an urban lifestyle (Table 2). This finding aligns with the views expressed by Ellis (2000). It is crucial for developing countries to consider various strategies for diversifying livelihoods, such as crop diversification, non-farm employment, migration, and self-employment, and their implications for household income, food security, and overall well-being.

The expansion of urban areas caused by industrialization can result in land loss, which adversely affects the livelihoods of peri-urban farmers (Belay, 2022). Shaw & Saharan (2019) conducted a study on the effects of displacement caused by development on the well-being of displaced individuals in Kolkata, India. The research revealed that development-induced displacement brings about substantial alterations in the living circumstances of affected households. These changes include diminished access to essential services, disruption of social networks, and the experience of economic and psychological stress.

The expansion of urban areas negatively affects the economic, social, and environmental aspects of the lives of those living in the periphery, causing agricultural land loss, displacement of farmers, loss of income, and unemployment (Enyew, 2019). Specifically, the expansion of urban areas due to industrialization has a detrimental impact on individuals whose livelihoods primarily rely on economic activities (Enyew, 2019). Additionally, the outward expansion of urban centers due to industrialization can lead to the loss of valuable agricultural land and natural landscapes (Melese, 2004). This study supports the findings of Muluwork (2014), who investigated the impact of urban expansion on the livelihoods and food security of farmers displaced due to urbanization in Ethiopia. Urban expansion has resulted in the displacement of numerous farmers from their lands, causing the loss of agricultural land, changes in livelihoods, food insecurity, and poverty, which further exacerbate their marginalization and impoverishment (Yntiso, 2008).

The assessment of livelihood impact focuses on income levels (Adato and Meinzen-Dick, 2007). Table 3 presents the income and land-holding sizes of households before (2012) and after (2020) the establishment of BLIP. Prior to the development of BLIP in 2012, households were earning an average of approximately 84,000 birr per year. However, following their displacement due to industrial development, their income has decreased significantly, with a minimum of 15,000 birr and a maximum of 1,400,000 birr per year. By 2020, the average income level after displacement had further declined to 21,428 birr per year, with a minimum of 4,000 birr and a maximum of 546,000 birr. Similarly, the average land size per household before the intervention in 2012 was around 2.6 hectares, with a maximum of 18 hectares. However, after the intervention in 2020, the average land size had reduced to approximately 0.4 hectares, with a maximum of 8 hectares. This aligns with the findings of Debela et al. (2020), which indicate that industrialization in Ethiopia leads to changes in land use and the livelihoods of smallholder farmers.

According to Table 3, the majority of household heads had an average annual income of 80,000 birr before being displaced from their farmland. However, after displacement, their average annual income decreased to approximately 21,500 birr, resulting in a mean difference of around 62,000 birr due to the introduction of the new industry park development. Furthermore, the highest proportion of household heads possessed an average of 3 hectares of land in 2012. However, this figure has significantly dropped to an average of only 0.4 hectares of land, indicating a loss of approximately 2.2 hectares of land per household following their displacement from the land due to the development of the industry park.

The findings indicate that the majority of household heads experienced a loss of annual income following their displacement from agricultural land, resulting in a significant decrease of approximately 75% in their average annual income due to the new development in their former areas. This substantial decline in income has a detrimental impact on their livelihoods. The challenges posed by changes in livelihoods that local communities face, and their potential inability to cope with them, can potentially plunge them into poverty (Adato & Meinzen-Dick, 2007). This strongly suggests that prior to being displaced from their agricultural lands, the household heads were earning the highest annual income from agricultural livelihoods, providing them with a better means to sustain their livelihoods compared to the period after the establishment of the industry park in their localities.

The loss of agricultural income does not lead to the creation of additional employment opportunities in the developed industry park (Adato & Meinzen-Dick, 2007). Moreover, the conversion of land for industrialization poses numerous challenges to the natural environment, such as the loss of productive farmland, changes in energy demand, alterations to the local climate, modifications to hydrological and biogeochemical cycles, habitat fragmentation, soil, air, and water pollution, as well as biodiversity loss (Woldegebriel & Girma, 2023). These factors also increase the vulnerability of communities to various risks (Yntiso, 2008). This situation directly impacts the livelihoods of impoverished individuals by depleting natural resources (Abebe, 2020), particularly endangering agricultural activities that serve as the primary source of income for peri-urban residents (Abebe, 2020). Therefore, it is crucial to adopt a comprehensive and participatory approach to displacement by providing appropriate compensation, resettlement packages, basic services, and support for livelihood restoration and income generation (Teddla, 2009; Ambaye & Abeliene, 2015). The adverse consequences of development-induced land loss on farmers, including reduced income, food security, and living standards, are significant (Dires et al., 2021). Consequently, there is a pressing need for adequate compensation and resettlement policies that address the loss of livelihoods and the long-term well-being of affected communities (Rousseau & Espagne, 2021).

Table 4.3: Income level and size of land-holding (hectare) before (2012) and after (2020) the establishment of BLIP.

	Mean	Std. Dev.	Min	Median	Max
Income in 2012**	83,782.322	13,2842.18	15,000	60,000	1,400,000
Income in 2020**	21,428.127	45,396.445	4,000	15,500	546,000
Difference	62,354.195	101,698.64	600	39,200	950,000
Total land early 2012	2.56	2.291	0	2.053	18
Total land late at 2020	.393	.845	0	.037	8
D/c	2.167		0	2.016	10

** the two are significantly different

Information was gathered from 349 households for the purpose of constructing a regression model, both prior to and following the establishment of BLIP, specifically in 2012 and 2020 respectively. The annual income derived from agricultural pursuits by household heads serves as a significant indicator of poverty levels within the research site. Additionally, various factors have been considered as variables in relation to the annual income of households, and these are presented in Tables 4 and 5.

To examine the impact of respondents' background characteristics and their views (including Gender, Age, Marital status, Educational level, Ethnicity, Religion, Family size, Respondents' perception of livelihood changes among displaced individuals, and their involvement in the introduction of the new development, i.e., Bole Lemi Industry Park), multiple linear regression analysis was conducted. The objective was to determine whether these factors significantly predicted the income levels of respondents in both 2012 (Table 4) and 2020 (Table 5). The perception of residents towards industrial park development is influenced by factors such as education level, occupation, and location (Le et al., 2020). Independent variables, including gender, age, occupation (such as agriculture), the educational level of the household head, and family size, play a significant role in determining the income level of families in farming communities (Herfkens, 2002). Consequently, the conversion of farmland to other land uses, such as industrial purposes, has a direct impact on the livelihood assets of local communities, leading to a decrease in household income, food security, and changes in the social structure, as well as the loss of traditional knowledge and practices (Tufa & Megento, 2022). This highlights the correlation between land use conversion due to industrialization and the loss of income and displacement of peri-urban livelihoods (Simon, 2008).

The educational level of farming communities can serve as an advantage in effectively managing land to maximize its benefits (Coulibaly and Li, 2020). In relation to household income in 2012 (Table 4), prior to the establishment of the industry park, the study revealed significant predictors such as Basic reading skills ($\beta = 25230.76$, $p < .01$), Primary school education ($\beta = 23854.22$, $p < .01$), and belonging to the Amhara ethnic group ($\beta = -72724.95$, $p < .01$). The findings indicate that household heads who possessed literacy skills and those belonging to the Amhara ethnic group had significantly higher income in 2012 (p-value < 0.01) compared to those who were unable to read and write and those belonging to other ethnic groups. Paudel et al. (2017) propose that factors such as household assets and educational level play significant roles in influencing households' choice of livelihood strategies.

Furthermore, the study revealed that individuals with a college education or higher ($\beta = 31284.98$, $p < .05$), belonging to the Gurage ethnic group ($\beta = -55442.82$, $p < .05$), and following the Muslim religion ($\beta = 43964.523$, $p < .05$) significantly predicted household income in 2012 (Table 4). This implies that household heads with a college education or higher, belonging to the Gurage ethnic group, and practicing the Muslim religion had significantly higher income ($p < .05$) before their displacement in 2012, compared to those with an education level below college and those belonging to non-Muslim and non-Gurage ethnic groups. However, in 2020 (Table 5), it was found that only belonging to the Gurage ethnic group ($\beta = -14183.38$, $p < .05$) and being a Muslim follower ($\beta = 14645$, $p < .05$) significantly predicted household income. After their displacement in 2020, household heads who were Gurage and Muslim had significantly higher income ($p < .05$) compared to those who were non-Muslim and from other ethnic groups.

The factors influencing livelihood diversification differ based on the type of household, with ethnic minority households and those with lower levels of education more inclined to engage in diversified livelihood strategies (Dai et al., 2020). Interestingly, family size, representing the number of individuals residing in the same household and working together on the same land, was not found to have an impact on the income of the household head. This finding contradicts the findings of Omideyi (1998).

Table 4.4: Multiple regression analysis results for variables predicting income in 2012 (N = 349).

Income 2012	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Sex of respondent (Male)	0	.	.	.	.	.	
Female	6063.12	7051.68	0.86	.391	-7822.804	19949.045	
Age	-30.25	272.237	-0.11	.912	-566.326	505.832	
Marital status (Single)	0	.	.	.	.	.	
Married	3698.822	18909.527	0.20	.845	-33537.168	40934.811	
Separated	-4924.792	22760.761	-0.22	.829	-49744.499	39894.914	
Widowed	-7451.841	22817.69	-0.33	.744	-52383.651	37479.969	
Divorced	9297.789	21351.968	0.44	.664	-32747.771	51343.349	
Educational level (Unable to read and write)	0	.	.	.	.	.	
Basic reading	25230.76	8844.293	2.85	.005	7814.886	42646.641	***
Primary school	23854.22	7956.653	3.00	.003	8186.254	39522.186	***
Junio secondary	13523.51	17284.658	0.78	.435	-20512.84	47559.866	
Secondary school	15600.77	10521.609	1.48	.139	-5118.016	36319.565	
College and above	31284.98	15295.362	2.05	.042	1165.884	61404.082	**
Ethnicity (Oromo)	0	.	.	.	.	.	
Amhara	-72724.95	26464.769	-2.75	.006	-124838.46	-20611.437	***
Gurage	-55442.82	21570.971	-2.57	.011	-97919.63	-12966.005	**
Silte	-29531.122	36296.014	-0.81	.417	-101003.98	41941.739	
Religion (Orthodox)	0	.	.	.	.	.	
Protestant	-3970.572	18880.261	-0.21	.834	-41148.933	33207.788	
Muslim	43964.523	19947.553	2.20	.028	4684.489	83244.557	**
Total family size	2338.272	1214.376	1.93	.055	-53.036	4729.579	*
Total family size <14	994.186	2340.626	0.42	.671	-3614.895	5603.267	
Total family size >64	2479.315	4222.838	0.59	.558	-5836.153	10794.783	
Respondents response	0	.	.	.	.	.	
Increasing	11026.128	32398.193	0.34	.734	-52771.277	74823.533	
More or less remain	37844.646	34958.587	1.08	.28	-30994.599	106683.89	
Decreasing	14996.958	32052.57	0.47	.64	-48119.858	78113.775	
Highly decreasing	25731.684	31698.899	0.81	.418	-36688.696	88152.063	
Respondents response	0	.	.	.	.	.	
Recognized	25036.577	16530.955	1.51	.131	-7515.61	57588.764	
Defendant	9005.915	15162.919	0.59	.553	-20852.383	38864.212	
Highly defendant	27380.864	16255.368	1.68	.093	-4628.647	59390.376	*
Constant	-622.222	39452.097	-0.02	.987	-78309.934	77065.489	
Mean dependent var		87052.098	SD dependent var			142526.950	

*** p<.01, ** p<.05, * p<.1

Table 4.5: Multiple regression analysis results for variables predicting income in 2020 (N = 349).

Income in 2020	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Sex of respondents	0	.	.	.	.	.	
Female	117.241	2168.443	0.05	.957	-4152.782	4387.265	
Age	7.022	83.715	0.08	.933	-157.826	171.87	
Marital status	0	.	.	.	.	.	
Married	-114.232	5814.818	-0.02	.984	-11564.572	11336.108	
Separated	-2145.58	6999.101	-0.31	.759	-15927.968	11636.808	
Widowed	9120.108	7016.607	1.30	.195	-4696.753	22936.969	
Divorced	1657.492	6565.887	0.25	.801	-11271.826	14586.81	
Educational level	0	.	.	.	.	.	
Basic reading	2896.36	2719.685	1.06	.288	-2459.146	8251.874	
Primary school	2622.70	2446.729	1.07	.285	-2195.319	7440.71	
Junio secondary	4493.34	5315.159	0.85	.399	-5973.091	14959.765	
Secondary school	3445.02	3235.472	1.06	.288	-2926.164	9816.196	
College and above	1478.12	4703.436	0.31	.754	-7783.725	10739.963	
Ethnic background	0	.	.	.	.	.	
Amhara	-6032.038	8138.111	-0.74	.459	-22057.325	9993.249	
Gurage	-14183.38	6633.232	-2.14	.033	-27245.317	-1121.454	**
Silte	4933.103	11161.29	0.44	.659	-17045.325	26911.532	
Religion	0	.	.	.	.	.	
Protestant	-10117.68	5805.819	-1.74	.083	-21550.299	1314.938	*
Muslim	14645.329	6134.019	2.39	.018	2566.431	26724.227	**
Total family size	-86.708	373.43	-0.23	.817	-822.053	648.636	
Total family size <14	-725.016	719.76	-1.01	.315	-2142.342	692.31	
Total family size >14	-1176.095	1298.554	-0.91	.366	-3733.163	1380.972	
Responses	0	.	.	.	.	.	
Increasing	2885.204	9962.682	0.29	.772	-16732.966	22503.374	
Remain the same	8904.639	10750.022	0.83	.408	-12263.933	30073.212	
Decreasing	3981.003	9856.4	0.40	.687	-15427.881	23389.887	
Highly decreasing	7267.147	9747.644	0.75	.457	-11927.577	26461.872	
Responses	0	.	.	.	.	.	
Recognized	3787.774	5083.39	0.75	.457	-6222.262	13797.81	
Defendant	5230.784	4662.709	1.12	.263	-3950.862	14412.429	
Highly defendant	8269.592	4998.645	1.65	.099	-1573.567	18112.752	*
Constant	3050.972	12131.809	0.25	.802	-20838.569	26940.512	
Mean dependent var		23111.399	SD dependent var			51414.106	
**** p<.01, ** p<.05, * p<.1*							

The implementation of past development projects in Addis Ababa resulted in the forced displacement of farmers residing in peri-urban areas. Unfortunately, these farmers were not adequately compensated or provided with alternative means of sustaining their livelihoods. Consequently, they lost their land, houses, and livestock, which had served as their primary sources of income. As a consequence, their living standards deteriorated, pushing them into poverty (Wayessa, 2020). To address this issue, it is important to consider the findings of Xu et al. (2021), who conducted a study on China's new rural revitalization strategy. This strategy aims to enhance rural livelihoods, promote sustainable development in rural regions, and tackle challenges associated with equitable urban-rural development, environmental degradation, and poverty reduction.

The development of industrial parks brings about a range of impacts on individuals' lives, encompassing both positive and negative aspects. On the positive side, industrialization contributes to job creation and an increase in income for individuals (Le et al., 2020). However, it also brings about negative consequences such as environmental pollution and social issues. Smallholder farmers are particularly affected by industrialization, as it significantly alters land use and leads to the loss of farmland, resulting in reduced crop productivity and negative effects on their livelihoods (Debela et al., 2020). Moreover, this can lead to an increase in poverty among affected households (Weldearegay et al., 2021). It is worth noting that households that have experienced land loss due to development-induced activities face lower income levels and fewer employment opportunities compared to those who have not undergone such land loss (Nguyen et al., 2019).

Industrialization leads to urbanization in the outskirts of cities, resulting in various consequences. This includes the reduction of agricultural land, deforestation, and increased pollution, as well as the displacement of farming communities from their homes, ultimately affecting their means of living (Enyew, 2019). Moreover, it leads to a rise in food insecurity and poverty levels (Gebregziabher & Yiadom, 2014). While industrial development can be a catalyst for economic growth, poverty alleviation, and improved living standards, Kniivilä (2007) warns that without appropriate policies and institutions, it can also exacerbate income inequality. This highlights the importance of adopting a comprehensive approach. Rahman and Hickey (2020) suggest the use of an analytical framework to identify the main factors contributing to livelihood vulnerability in specific contexts and to guide policy and intervention strategies.

To promote livelihood diversification and address the unique needs of different households, it is crucial to implement policies and interventions that consider their specific characteristics (Dai et al., 2020). Additionally, measures should be taken to safeguard the rights and interests of displaced communities and mitigate the adverse effects of displacement on their well-being and means of living (Ambaye & Abeliene, 2015). Unfortunately, in the development of industrial parks in Ethiopia, the government did not support farmers in diversifying their livelihoods to reduce vulnerability to the loss of their agricultural lands. When planning and implementing industrial park projects, policymakers should consider various factors to minimize negative impacts on local communities (Le et al., 2020). Despite the potential benefits of Eco-Industrial Park development, such as achieving sustainable development goals, reducing environmental harm, and improving social welfare (Sertyesilisik & Sertyesilisik, 2016), the establishment of industrial parks in Ethiopia has resulted in the displacement of small-scale farmers and the loss of natural, economic, and social assets, including land, water resources, livestock, and social networks (Yesuf, 2021).

4. Conclusion

Industrialization has significant effects on the livelihoods of the surrounding population. The primary impacts include the loss of fertile agricultural lands and the displacement of farming communities from their farms. Furthermore, it negatively affects natural resources, leading to deforestation, habitat loss, and the degradation of water quality and quantity. Additionally, it has an impact on socio-economic activities, resulting in changes to livelihoods.

This study was conducted in the Bole Lemi area on the outskirts of Addis Ababa, using survey data to explore the perceptions and attitudes of farming communities who were displaced by the development of Bole Lemi industrial parks in their local vicinity. The study examines various factors that influence the perception of these displaced farming communities towards the development of industrial parks, including gender, education level, family size, marital status, ethnic group, and more. The findings of the study indicate that the displaced farmers encounter difficulties in terms of income and employment opportunities, leading to a decline in their living conditions and increased poverty as their livelihoods undergo significant changes. Furthermore, the study highlights the lack of balance between industrial development in the area and the interests of the local farming communities, thereby failing to ensure their sustainable livelihoods.

A comprehensive approach to industrial development, considering social factors and economic considerations, is crucial for displaced communities. Adopting an inclusive approach prioritizing community well-being ensures long-term sustainability. This study recommends effective policies to mitigate negative impacts of future projects on affected communities. For upcoming developments, eco-industrial processes should be considered to enhance sustainable development, promoting economic growth, reducing environmental impact, and benefiting displaced communities. Development projects in Addis Ababa must prioritize affected communities, providing compensation and support for resettlement and livelihood diversification. A comprehensive, participatory approach to industrial park development is essential for sustainable, equitable economic growth while safeguarding local communities.

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Chapter V: Exploring Compensation Procedures and Displaced communities' preference:

A case study of Bole Lemi Industry Park, Addis Ababa: Ethiopia

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Abstract

This study provides an overview of compensation for communities displaced by the development of Bole Lemi Industry Park in Addis Ababa. A survey was conducted among a diverse group of household heads who were displaced, ensuring representation across various factors such as gender, marital status, and education level. Descriptive statistics and a multinomial logistic regression model were used to analyze the data. The findings offer insights into compensation rates, leasing prices, income distribution, knowledge of compensation mechanisms, employment creation, community participation, perceptions towards development projects, and preferences for compensation types. The study also examines respondents' awareness and experience of the compensation procedures in the locality and identifies barriers encountered in development. It emphasizes the need to address gender disparities in compensation preferences and highlights the importance of transparency, accountability, and inclusive engagement for fair and sustainable development outcomes. The findings of this study provide valuable information to stakeholders and development practitioners and promote more informed and equitable compensation approaches to development.

Keywords: *Development-induced displacement, Community preference, compensation procedure, Bole Lemi Industry Park, Addis Ababa*

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1. Introduction

Development-induced displacement globally affects communities (Cernea, 1997). Large-scale infrastructure projects, urbanization, natural resource exploitation, and industrialization are the root causes of communities' displacement in pursuit of economic growth and development (Robinson, 2003; Huggins, 2010). Peri-urban areas are especially shaped by a complex interplay of factors, including development-induced economic activities (Abera et al., 2022). The process of displacement and subsequent compensation affects the economic and social well-being of communities (Dires et al., 2021). Analyzing the impacts of development-induced projects on peri-urban communities, such as the loss of land, disruption of livelihoods, and changes in social dynamics and rehabilitation mechanisms through compensation, is therefore crucial to promoting sustainable development (Adigrat, 2020).

Displacement has significant consequences, including the loss of homes, land, livelihoods, and social networks (Cernea, 1997). Compensation for displacement-affected communities has become a crucial focus in development planning and policy to address the social and economic costs of displacement (UN-Habitat, 2003). Robinson (2003) and Maldonado (2009) emphasized the importance of recognizing and addressing the multidimensional losses faced by displaced communities and advocated for a broader understanding of justice that encompasses non-economic factors such as social, cultural, and psychological challenges faced by displaced communities. Cernea (2003) and Maldonado (2009) call for a broader understanding of justice that encompasses non-economic factors and recognizes the multidimensional losses faced by displaced communities. Stanley (2004) also provides an overview of the causes and consequences of development-induced displacement, including the social, economic, and psychological impacts on affected populations.

Industrial parks are widespread worldwide, functioning as centers of economic growth that draw investment, generate employment, and stimulate local progress. However, the establishment of these parks frequently leads to the displacement of communities, resulting in significant social and economic upheavals for the affected populations (Huggins, 2010). Compensation for communities affected by development-induced displacement is thus a significant concern for policymakers and development experts. Patel et al. (2015) examined the risk of impoverishment in the context of development-induced displacement and the challenges and risks associated with forced displacement and resettlement. Over 15 million individuals are forced to relocate due to major development initiatives such as the creation of industrial parks, as reported by the United Nations (UNDP, 2018). Displacements of this nature often result in forced evictions, deprivation of access to natural resources, and disruptions to social structures, causing profound consequences for the affected communities (UN-Habitat, 2003). Madebwe et al. (2011). Examine the social, economic, and gendered impacts of displacement on the affected communities, shedding light on the challenges faced by the villagers and their struggle for sustainable livelihoods.

Governments and international organizations have implemented policies, guidelines, and frameworks to address the social and economic costs of displacement and facilitate the assessment and provision of compensation (Brechin & Westermann, 1991). These initiatives strive to guarantee that impacted communities receive sufficient compensation for their losses and opportunities to reconstruct their lives and livelihoods (UNDP, 2018). Nevertheless, achieving equitable compensation remains a challenging and disputed matter due to the participation of various stakeholders with differing interests and power dynamics (UN-Habitat, 2003). Compensation for displacement caused by development has emerged as a significant concern, with millions of individuals being forced to relocate each year due to major development endeavors like dams, highways, mining activities, and urban renewal projects (UNDP, 2018). These displacements often occur without the affected communities' voluntary, prior, and informed consent, leading to human rights infringements and exacerbating social disparities (UN-Habitat, 2003).

Compensation is regarded as a vital tool in alleviating the adverse consequences of displacement, reinstating the dignity of affected communities, and upholding their rights to adequate housing, livelihoods, and social integration (Stanley, 2004). Various dimensions of integration, such as social, economic, and cultural integration, influence the perceived discrimination experienced by displaced individuals (Cernea, 2003; Wang et al., 2020). Compensation for development-induced communities includes financial aid, alternative income sources, housing, and social support to help them recover and rebuild (Cernea, 1997). Compensating development-induced displaced communities is crucial for responsible and sustainable development (Huggins, 2017).

By emphasizing the dynamics and impacts of displacement resulting from large-scale land acquisitions, particularly driven by foreign investors, Thomson (2014) highlights the need for dedicated attention to this issue. However, determining the appropriate form and extent of compensation is an intricate and diverse undertaking that involves considering the distinct needs and situations of each community, evaluating the value of their forfeited assets and resources, and considering the potential long-term impacts of displacement on their socio-economic welfare (UNDP, 2018). Addressing the matter of compensation involves managing power dynamics, fostering meaningful engagement of affected communities, and finding a middle ground among the interests of various stakeholders, such as governments, investors, and development organizations. This requires implementing transparent and inclusive decision-making procedures that consider the viewpoints and apprehensions of the impacted communities (UN-Habitat, 2003). Van Beers et al. (2020) emphasize the importance of continuous endeavors to align industrial parks with sustainable practices and international standards, as well as the significance of persistent monitoring and evaluation to ensure their long-term success.

This study aims to analyze compensation mechanisms for communities displaced by the development of Bole Lemi Industrial Park in Addis Ababa, Ethiopia. The study provides policymakers and decision-makers with an understanding of fair compensation and recommendations for improvement to minimize adverse effects on local communities and ensure their meaningful participation.

2. Materials and methods

2.1. Description of the study area/study site

Addis Ababa, the capital city of Ethiopia, is situated in the Horn of Africa and spans an area of 540 km^2. The city is located on the elevated plateaus of central Ethiopia, surrounded by the North-South-oriented mountain systems adjacent to the Great Rift Valley. Addis Ababa is positioned at latitude 8° 2′ 48″ and longitude 38° 45′ 0″ (Wubneh, 2013). As the largest city in Ethiopia, Addis Ababa has experienced significant urban growth characterized by rapid urbanization and industrialization (AACSPO, 2017).

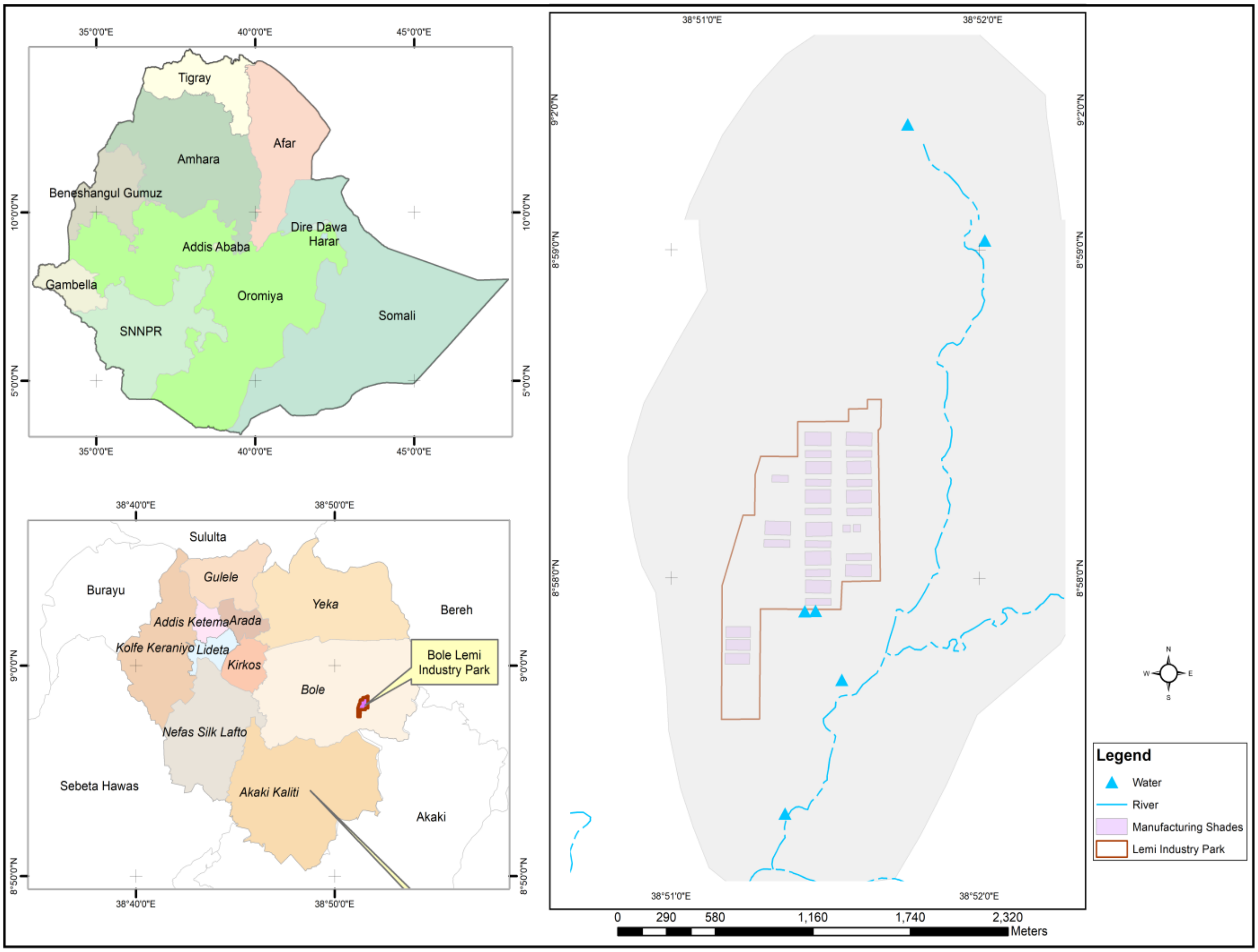
Addis Ababa, Africa's diplomatic capital, houses over 90 embassies and consulates. It has been the headquarters for the United Nations Economic Commission for Africa (UNECA) since 1958 and the African Union (formerly the Organization of African Unity) since 1963. The city boasts a diverse population, with various ethnic groups and followers of Orthodox Christianity, Islam, Protestantism, and Catholicism. In terms of the economy, Addis Ababa residents engage in a wide range of activities, including trade, manufacturing, civil administration, transportation, communication, hospitality, and agriculture (farming, horticulture, and animal husbandry).

Addis Ababa is located at an altitude ranging from 1800 meters at Akaki Plains to 3200 meters above sea level at Mt. Entoto. The city's topography is characterized by rugged terrain with typical volcanic features. The central part of the city has gentle and rolling landscapes with scattered hills, while the southern and southeastern areas are predominantly flat. The average annual temperatures in Addis Ababa range from 9°C to 24°C (CSA, 2022). The study area has a tropical climate with bimodal rainfall. The average annual rainfall is 1178 mm, with the highest precipitation occurring from June to mid-September and a relatively smaller amount from mid-February to mid-April. The annual rainfall ranges between 1000-1880mm, and the annual temperature ranges from 20 to 25.6 °C. The population of Addis Ababa has experienced rapid and uncontrolled growth, with a 100% increase over the past two decades. The 2007 census estimated the population at 2.8 million inhabitants, but the City Structure Plan Office has projected a current population of approximately 4.5 million (AACSPO, 2017).

The Bole Lemi Industry Park (BLIP) is situated on the southeastern outskirts of Addis Ababa, approximately 15–20 kilometers away from the city center. It is specifically located in Lemi Kura sub-city at coordinates 8°58'17.2200" latitude and 38°51'24.5088" longitude (Fig. 1). Surrounding the park are expansive agricultural lands to the south and southeast, residential areas (condominiums) to the north and northwest, and the Akaki River and its small tributaries to the east. BLIP is the first industrial park in Ethiopia, developed in collaboration with the World Bank Group. Functioning as a large Export Zone and modern Industrial Park, BLIP commenced operations in 2014 with an initial area of 156 hectares, which has now expanded to over 342 hectares.

The surrounding land use predominantly consists of cultivated agricultural lands and scattered settlements. The park serves as a hub for companies involved in export-oriented businesses, particularly in garments, apparel, textiles, leather, and leather products (Gebremariam and Feyisa, 2019). Numerous foreign countries have established their presence in the park for apparel exports and various commercial activities.

Figure 5.1: Map representing the Bole Lemi Industry Park in Addis Ababa, Ethiopia



2.2. Sampling design

A semi-structured questionnaire was created and administered to assess the level of compensation and changes in income sources among local farmers' households. The sampling units consisted of heads of households displaced due to BLIP. The survey focused on the period (2012) during which the BLIP was established in its current location. The participants' views regarding compensation resulting from BLIP's establishment were investigated. The survey targeted farmers' heads of households residing on the outskirts of Lemi-Kura sub-city, Addis Ababa. All households selected for the survey belonged to the displaced group, having been relocated due to BLIP's development in their previous locations. The selection of household representatives was randomized and independent of gender, marital status, and education level. Both male and female household heads were interviewed, and in cases where the head was unavailable or declined participation, another randomly selected household was approached as a replacement.

As defined by FAO (2007), a household refers to a group of individuals cohabiting and sharing common arrangements for food and other essential needs. Before conducting the survey, a pre-test of the questionnaires was performed on 20 households in September 2020 to identify and rectify any errors or ambiguities and enhance the survey tools' validity (Babbie and Mouton, 2014).

2.3. Data collection methods

Semi-structured questionnaires were administered to collect data on compensation caused by the establishment of BLIP. Local community members who were fluent in Oromifa and Amharic languages were selected as research assistants to conduct the survey. The questionnaires were initially prepared in English but were orally translated into local languages by the research assistants during interviews to ensure clarity. The research assistants received training on survey objectives and procedures, and they explained the survey's purpose and scientific terms to each participating household.

The questionnaire consisted of two parts. The first part collected demographic information about household respondents, including gender, marital status, and educational level, which are important factors influencing the level of understanding of the issue under investigation. The second part assessed the level of compensation gained, income level, and other relevant factors affected by the establishment of BLIP. On average, the questionnaire took approximately 40 minutes to complete. A total of 379 family heads, which had lost their land due to the industrial park development, were randomly sampled and interviewed. However, they did not all equally respond to each survey question. The survey was conducted in December 2020, and complete anonymity was ensured for all participating households.

2.4. Data analysis

Descriptive and inferential statistical analyses were conducted. Descriptive statistics, including mean, standard deviation, minimum, median, maximum, frequency counts, and percentages, were used to summarize numerical variables. A multinomial logistic regression model was employed to examine the associations between independent variables. The data entry and analysis were performed using IBM SPSS software version 25. Frequency and logistic regression tables were generated to present the percentage of household responses and the analysis results for the variables under investigation. Statistical methods, specifically logistic regression models, are commonly used to explore relationships between variables (Noszczyk, 2019). These approaches offer the advantage of quantifying the influence of independent variables and providing confidence levels for their contributions (Dang & Kawasaki, 2016).

3. Result and discussion

3.1. Demographic characteristics of heads of households

Data about compensation was collected and analyzed based on the perspectives of communities displaced by the development of the Bole Lemi Industry Park on the outskirts of Addis Ababa. Household heads in the Bole Lemi area were interviewed to gather their opinions and insights regarding the compensation they were given due to their displacement by the establishment of the industry park. A summary of the demographic characteristics of the household heads, including their gender, marital status, and educational level, is presented in Table 1. The majority of the participants (approximately 70.5%) were male. This could be attributed to the presence of more men engaged in various activities in their localities during the survey period. However, it is important to note that development-induced displacement has adverse effects on the livelihoods of impoverished female-headed households in Ethiopia (Megento, T. 2013). Moreover, a study by Shaw and Saharan (2019) highlights the challenges faced by women, who often bear the brunt of displacement, in Kolkata, India.

The majority of the participants, approximately 81%, were married. However, as indicated in Table 1, among the selected household heads who participated in the survey, a significant majority (over 60%) had no literacy skills.

Table 5.1: Demographic characteristics of interviewed heads of households

Sex of respondents (HH head)	Freq.	Percent	Cum.
Male	267	70.45	70.5
Female	112	29.55	100
Marital status of respondents			
Single	13	3.45	3.45
Married	305	80.9	84.4
Separated	15	3.98	88.3
Widowed	18	4.77	93.1
Divorced	26	6.9	100
Educational level of respondents			
Cannot read and write	227	60.37	60.4
Basic reading and writing	41	10.9	71.3
Primary school	52	13.83	85.1
Junio secondary school	17	4.52	89.6
Secondary school	27	7.18	96.8
College and above	12	3.19	100

3.2. Level of compensation

Compensation has significant implications for the livelihoods of the affected communities (Nguyen et al., 2019). The data on compensation prices per square meter provides valuable insights into the prevailing rates and ranges in the given context. The average payment per square meter for compensation was calculated to be 7.8 Birr. This amount represents the mean value, reflecting the average compensation received for each square meter of land. It is worth noting that the actual compensation values can vary significantly, with a minimum payment of 1 Birr per square meter and a maximum payment of about 19 Birr per square meter. This range indicates the spectrum of compensation rates observed in the area. Shifting the focus to leasing prices per square meter, the mean cost is found to be 23,780.55 Birr. Just like compensation, the leasing prices exhibit variability, with the lowest observed price being 1.25 Birr per square meter and the highest recorded price reaching up to 70,000 Birr per square meter. Together, these figures present an overview of the compensation and leasing prices per square meter. They provide essential information regarding the average values as well as the range within which compensation occurs.

Regarding the respondents' knowledge of compensation mechanisms during development, according to the survey results, 75% of the respondents answered affirmatively, indicating that they are familiar with these mechanisms. On the other hand, 25% of the respondents responded negatively, indicating a lack of familiarity. The fact that 75% of the respondents acknowledged roughly their familiarity suggests that a majority of the respondents have a good understanding of the compensation mechanisms implemented during the development process relative to the rest (25%). This implies that they are likely aware of the various ways in which compensation was addressed and managed in the context of Bole Lemi industry park development activities. This calls for further work to achieve inclusive and sustainable industrial development as a means to reduce poverty and promote shared prosperity (UNIDO, 2009). However, the 25% of respondents who answered "no" indicate that there is a significant portion of respondents who lack familiarity with compensation mechanisms. These individuals may not have a clear understanding of how compensation is handled during development or may not be aware of its importance in ensuring fair and equitable outcomes. The study by Trembecka (2023) emphasizes the importance of accurate assessment methods and the consideration of multiple factors to ensure fairness in compensation, including the purpose of expropriation and the value of the property.

The result of this study identified the level of understanding and awareness among the surveyed individuals regarding compensation mechanisms in the context of development activities. It reveals that while a majority of the respondents are familiar with these mechanisms, a notable minority still require education or clarification on the issue. These findings emphasize the need for further efforts to inform individuals about compensation mechanisms during development to ensure a well-informed and equitable approach. This demands understanding the concept of compensation and its implications in legal and moral contexts in order to explore its strengths and weaknesses, focusing on the complexities of compensation (Goodin, 1989).

The household heads were asked about their total average monthly income. The data shows a breakdown of the income distribution among the respondents. Among the participants, 2.78% indicated earning up to 800 Birr per month (Table 2). This represents the lowest-income group in the survey. The majority of respondents, comprising 47.22% each, reported earning income in the range of 801 to 1600 Birr and 1601 to 2400 Birr per month, respectively. These two figures represent the largest portion of the participant's income distribution. Moreover, 2.78% of the respondents mentioned earning above 2401 Birr per month. This represents the highest income group in the survey. Overall, the figures illustrate the income distribution among the participants, highlighting that a significant portion of them fall within the range of 801 to 2400 Birr per month. This range seems to encompass the incomes of almost half of the respondents. The data indicate that a considerable number of respondents have a moderate income level, with a smaller percentage falling into the lower and higher income categories. This income variation might be considered in the study by Trembecka (2023), which examined the concept of the benefit principle, which suggests that compensation should be proportionate to the benefits derived from the expropriated property.

Table 5.2: Responses of the heads of displaced heads of households

Total average monthly income	Freq.	Percent	Cum.
up to 800 Birr	1	2.78	2.78
801 - 1600 Birr	17	47.22	50.00
1601 -2400 Birr	17	47.22	97.22
2401 Birr and above	1	2.78	100.00
Average monthly income paid for unskilled house			
up to 800 Birr	30	18.63	18.63
801 - 1600 Birr	120	74.53	93.17
1601 -2400 Birr	6	3.73	96.89
2401 Birr and above	5	3.11	100.00
Total permanent employment created earlier IPP to ‘yet’ ‘no’			
1	7	77.78	77.78
2	1	11.11	88.89
4	1	11.11	100.00
Community participation on introduction of new development			
Yes	65	18.11	18.11
No	294	81.89	100.00
Compensation mechanism types			
Only money	16	5.41	5.41
Money and land	270	91.22	96.62
House and land	3	1.01	97.64
Establishing as development association with a financial support	2	0.68	98.31
None of fair	3	1.01	99.32
Other	2	0.68	100.00
Preferable and fairly rated compensations			
Only money	18	5.39	5.39
Money and land	200	59.88	65.27
Establishing as development association with financial support	21	6.29	71.56
None of fair	95	28.44	100.00
Experience in the locality			
Not seen yet	2	1.69	1.69
The issue is talked but hidden	43	36.44	38.14
It is as a normal business for local technicians and Managers	4	3.39	41.53
Highly sever to the displaced community	9	7.63	49.15
2 to 4 are right	60	50.85	100.00
Development barriers encounter			
No blocks still	30	8.62	8.62
Lack legal procedure (check and balance affirmative)	207	59.48	68.10
Even it makes conducive environment for sever corruption as an asylum of liability	28	8.05	76.15
2 to 3	75	21.55	97.70
Other	8	2.30	100.00

Regarding the average monthly income they pay for unskilled house labor, among the respondents, 18.6% indicated that they pay up to 800 Birr per month for unskilled house labor (Table 2). This group represents the lowest income level in terms of the wages provided. The majority of participants, comprising 74.53%, reported paying between 801 and 1600 Birr per month for unskilled house labor. This range represents the largest portion of the respondents and indicates that a significant number of individuals offer wages within this range. In addition, 3.7% of the respondents mentioned paying between 1601 and 2400 Birr per month, indicating a slightly higher income group for unskilled house labor. 3.1% of the respondents stated that they pay above 2401 Birr per month for unskilled house labor. This group represents the highest income level in the survey, indicating that a small percentage of respondents provide higher wages for this type of work. The majority of respondents fall within the 801–1600 Birr range, suggesting that this is the most common wage bracket for unskilled house labor. The data provide insights into the prevailing income levels and can be helpful in understanding the compensation practices for this type of work.

Regarding perceptions regarding the project's impact on permanent employment opportunities, 78% of the respondents answered "yes" (Table 2), indicating that they believed the industry park did create permanent employment opportunities. This majority acknowledged the positive contribution of the project in terms of generating long-term employment. Conversely, 11% of the respondents answered "no," expressing their belief that the industry park did not result in any permanent employment. This group represents a smaller percentage of respondents who held a negative view regarding the project's impact on long-term job creation. It is worth noting that a portion of the respondents maintained a neutral position on the matter. This indicates that they neither agreed nor disagreed with the statement, possibly due to a lack of information or uncertainty regarding the project's employment outcomes. They can help with evaluations, and potential improvements in future industrial park projects to better align with local communities' expectations regarding permanent employment generation, although industrial park development has challenges. Saleman and Jordan (2015) studied the significance of effective planning, infrastructure development, and government support for the successful implementation of industrial parks.

The findings in this study provide insights into community participation in the introduction of new development. Out of the respondents, only 18% reported community involvement to some extent, while 82% indicated a lack of community participation (Table 2). This significant disparity highlights differing perceptions among participants. The findings emphasize the need for increased community engagement in future initiatives, as the majority felt that community participation was lacking. According to Agegnehu and Mansberger (2020), studying the level of community participation in decision-making processes and investigating how they can utilize compensation money is an important aspect of development-induced projects to ensure sustainable and equitable resource allocation and development

Vanclay (2017) emphasizes the significance of community engagement, participation, and empowerment in ensuring successful resettlement. Enhancing community involvement fosters a sense of ownership and empowerment within the community, resulting in more effective and sustainable outcomes. Sustainable and participatory approaches are necessary to mitigate the negative impacts on affected communities (Wilmsen, 2011). According to Vandergeest (2003), more equitable and participatory approaches are necessary to address the concerns of affected communities. Saleman and Jordan (2015) and Van Beers et al. (2019) further emphasized the importance of effective stakeholder engagement and collaboration with local communities in the development and operation of industrial parks to ensure the sustainable and inclusive growth of these parks.

Concerning the various compensation mechanisms received, a small percentage (5.41%) received only monetary compensation, while the majority (91%) received a combination of money and land (Table 2). A small proportion (1.01%) received a house and land, and 0.7% mentioned support for establishing a development association. Interestingly, 1% felt they didn't receive fair compensation, and 0.7% reported other unspecified forms of compensation. Overall, the dominant form was a combination of money and land. These findings provide valuable insights into compensation practices where valuation methods, eligibility criteria, and dispute resolution mechanisms are the key issues to promote fair and just compensation processes (Studies, 2008).

Regarding the preferences and perceptions of fair compensation, a small percentage (5.4%) preferred monetary compensation only (Table 2). However, the study of Atahar (2021) challenges the notion that financial compensation alone is adequate to address the complexities of displacement. While the majority (about 60%) favored a combination of money and land. A small proportion (6.3%) expressed a preference for establishing a development association with financial support. Yet, a significant percentage (28.4%) felt that none of the predefined compensation options were fair. To mitigate the impacts of development-induced projects and support the affected households in rebuilding their livelihoods, adequate rehabilitation mechanisms are needed (Adigrat, 2020). According to Studies (2008), equitable and transparent compensation processes are necessary to safeguard the rights and interests of affected communities. The findings of Atahar (2021) advocate for the implementation of comprehensive support measures that go beyond monetary compensation to effectively address the diverse challenges faced by those affected by development-induced displacement. Robinson (2003) investigated the reasons, impacts, and difficulties associated with displacement caused by development projects. The study by Maldonado (2009) contributes to the discourse on development-induced displacement and advocates for more holistic approaches to support affected communities.

The findings of this study highlight the need to consider individual preferences and perceptions when designing fair compensation practices. Van der Ploeg & Vanclay (2018) focus on the challenges associated with fulfilling the responsibility to respect human rights in the context of project-induced displacement and resettlement. Terminski (2012) highlights the challenges faced by affected communities, including loss of livelihoods, cultural disruption, and violations of human rights. Understanding the challenges and complexities emphasizes the importance of upholding principles of substantive justice in the compensation process (Hidatilah et al., Undated). Yet, the compensation approach has always had limitations in addressing the social and cultural dimensions of displacement (Cernea, 2003).

The respondents' responses provided insights into their awareness and perceptions of a specific issue in the locality. A small percentage (about 1.7%) stated they had not seen the issue, while a significant proportion (36.4%) mentioned it was talked about but hidden (Table 2). 3.4% perceived the issue as a normal business for local technicians and managers, while 7.6%

considered it highly severe for the displaced community. About 50.9% believed that responses indicating the issue being talked about but hidden, seen as normal business, and severe to the displaced community were accurate. These findings demonstrate the diverse range of awareness and perceptions among the respondents regarding the issue. While some recognized the issue's existence but hidden nature, others viewed it as a regular occurrence or as having severe impacts on the displaced community. The data suggests complexity and ambiguity surrounding the issue, with varying perspectives and understandings among respondents.

The respondents' responses provided insights into the perceived barriers hindering development. A small percentage (8.6%) stated they had not encountered any blocks, while the majority (59.5%) identified a lack of legal procedures and the need for checks and balances as a significant barrier (Table 2). Furthermore, 8.1% expressed concerns about corruption and liability in the absence of proper procedures. 21.6% believed that the lack of legal procedures and concerns about corruption and liability were interrelated barriers. Furthermore, 2.3% mentioned other unspecified barriers. The findings emphasize the importance of establishing effective legal frameworks and oversight mechanisms to overcome barriers to development. This shows that addressing corruption and liability concerns is crucial for sustainable and equitable development.

The survey results indicate a notable gender disparity in compensation preferences (Table 2). While the majority of respondents (more than 90%) preferred both money and land as compensation, female-headed households expressed a preference for monetary compensation alone. This disagrees with the works of Atahar (2021), which argue for the importance of considering non-monetary factors in the compensation process for the broader dimensions of displacement. Abusharaf (2003) also highlighted the adverse impacts experienced by women who are displaced as a result of projects. This preference was associated with a significantly higher risk compared to male-headed households. The presence of this gender disparity highlights the need to understand the underlying factors that play a role in the displacement experiences of individuals affected by development projects (Asthana, 2012). Factors such as property ownership, household responsibilities, access to resources, and societal norms may contribute to this disparity. Recognizing and addressing these gender-related factors is crucial in designing equitable and inclusive compensation mechanisms (Terminski, 2013). Such approaches should aim at promoting local development and minimizing the adverse impacts of displacement on affected communities (Koenig, 2001). While studying the complex dynamics of development-induced displacement, Robinson (2003) emphasized the importance of safeguarding the rights of affected individuals and communities.

Table 3 provides the results of a multinomial logistic regression analysis of this study. It examines the relationship between various independent variables and different dependent variables, as shown in Table 3. When examining the "Only money" dependent variable, it is observed that the coefficient for the "Female" category of the sex variable is 3.675, indicating that being female is associated with a higher likelihood of falling into the "Only money" category. The coefficient for age is 1.028, suggesting that as age increases, the probability of being in the "Only money" category also increases. However, this coefficient is not statistically significant, as the associated p-value is 0.222 ($p > 0.05$). Addressing the issue, Abusharaf (2003) studied the challenges and vulnerabilities faced by women who are displaced due to development-induced projects, emphasizing their rightful compensation.

Table 5.3: Multinomial logistic regression

Only money	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Sex	1	.	.	.	.	.	
Female	3.675	2.204	2.17	.03	1.134	11.908	**
Age	1.028	.023	1.22	.222	.983	1.075	
Marital status	1	.	.	.	.	.	
Married	3834590.7	9.332e+09	0.01	.995	0	.	
Separated	9319630.5	2.268e+10	0.01	.995	0	.	
Widowed	.358	1144.277	-0.00	1	0	.	
Divorced	.696	1985.803	-0.00	1	0	.	
Educational level	1	.	.	.	.	.	
Basic reading	1.39	1.181	0.39	.699	.263	7.354	
Primary school	1.104	.81	0.13	.893	.262	4.65	
Junio secondary	2.251	2.657	0.69	.492	.223	22.753	
Secondary school	0	.001	-0.01	.993	0	.	
College and above	0	.002	-0.01	.995	0	.	
Total family size	.955	.118	-0.37	.71	.75	1.217	
Total income 2012	1	0	-0.40	.687	1	1	
Constant	0	0	-0.01	.994	0	.	
Establishing							
Sex	1	.	.	.	.	.	
Female	.279	.234	-1.52	.128	.054	1.443	

Age	.993	.026	-0.28	.778	.944	1.044	
Marital status	1	.	.	.	.	.	
Married	.33	.32	-1.14	.254	.049	2.214	
Separated	0	0	-0.01	.996	0	.	
Widowed	1.415	2.252	0.22	.827	.063	32.031	
Divorced	1.207	1.52	0.15	.881	.102	14.252	
Educational level	1	.	.	.	.	.	
Basic reading	.479	.523	-0.67	.5	.056	4.074	
Primary school	1.119	.833	0.15	.88	.26	4.813	
Junio secondary	1.815	2.114	0.51	.609	.185	17.804	
Secondary school	1.913	1.562	0.80	.427	.386	9.475	
College and above	3.068	2.916	1.18	.238	.476	19.764	
Total family size	.908	.123	-0.72	.473	.697	1.183	
Total income in 2012	1	0	0.31	.759	1	1	
Constant	.644	.832	-0.34	.733	.051	8.098	
None fair							
Sex	1	.	.	.	.	.	
Female	1.975	.662	2.03	.042	1.024	3.809	**
Age	1.011	.013	0.89	.371	.987	1.037	
Marital status	1	.	.	.	.	.	
Married	1.792	1.585	0.66	.51	.316	10.148	
Separated	1.041	1.159	0.04	.971	.117	9.228	
Widowed	.742	.842	-0.26	.793	.08	6.864	
Divorced	1.369	1.353	0.32	.751	.197	9.505	
Educational level	1	.	.	.	.	.	
Basic reading	1.241	.545	0.49	.623	.524	2.936	
Primary school	1.188	.462	0.44	.658	.555	2.545	
Junio secondary	1.135	.851	0.17	.866	.261	4.938	
Secondary school	1.488	.824	0.72	.473	.503	4.405	
College and above	2.355	1.757	1.15	.251	.546	10.163	
Total family size	.966	.062	-0.55	.583	.852	1.094	
Total income in 2012	1	0	-2.68	.007	1	1	***
Constant	.282	.286	-1.25	.212	.039	2.058	
Mean dependent var		2.931	SD dependent var			1.421	
Pseudo r-squared		0.080	Number of obs			318	
Chi-square		50.535	Prob > chi2			0.102	
Akaike crit. (AIC)		667.126	Bayesian crit. (BIC)			825.132	

**** p<.01, ** p<.05, * p<.1*

Marital status is also another important factor. The coefficients for different marital status categories (e.g., "Married," "Separated," "Widowed," and "Divorced") provide insights into their influence on the dependent variable. However, none of these coefficients are statistically significant (p >.05). Educational level also plays a role in the "Only money" category. The coefficients for different educational levels, ranging from "Basic reading" to "College and above," indicate their impact on the dependent variable. However, none of these coefficients are statistically significant ($p > .05$).

Two additional variables, "total family size" and" total income in 2012," are included in the analysis. The coefficient for "total family size" is 0.955, suggesting that an increase in family size is associated with a higher likelihood of being in the "Only money" category. However, this coefficient is not statistically significant. The coefficient for "total income in 2012" is 1 indicating no effect on the dependent variable. The analysis follows a similar pattern for the "Establishing" and "None fair" dependent variables. The coefficients for the independent variables are presented, and their significance is determined by the associated p-values. However, it is important to note that not all coefficients reach statistical significance. Receiving fair compensation and adequate resettlement measures is a challenge faced by displaced communities in the context of development-induced displacement, as studied in India (Maitra, 2009). Fair and equitable compensation mechanisms are important to mitigate the negative consequences of land expropriation (Dires et al., 2021).

As can be seen in Table 3, the mean of the dependent variable for all categories is 2.931, indicating the average probability of belonging to a specific category. The standard deviation of 1.421 suggests that there is variability within each category, indicating that the independent variables do not fully explain the dependent variables. The pseudo-squared value of 0.080 indicates that the model explains a modest proportion of the variation in the dependent variables. Table 3 also includes the number of observations, indicating the sample size used in the analysis. The chi-square value of 50.535 and the associated p-value of 0.102 provide information about the overall significance of the regression model. While the p-value is greater than 0.05, suggesting a lack of overall significance, it is important to consider the specific coefficients that are statistically significant. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are provided as measures of model fit and complexity. Lower values of these criteria indicate a better fit and a more parsimonious model.

The lessons learned from UNIDO provide valuable insights for countries seeking to establish and enhance industrial parks as a means of promoting sustainable development (van Beers et al., 2019). Shi & Yu (2014) highlighted the importance of strong leadership, policy incentives, and effective governance structures in the successful mainstreaming of industrial parks. Effective and robust regulatory systems (policies, measures, and practices) are important for promoting and achieving equitable and inclusive sustainable development outcomes (Cernea, 2007; Baimisheva et al., 2019) and ensuring the rights and well-being of affected communities (Maitra, 2009). A more comprehensive and holistic framework that prioritizes well-being and considers the broader socio-economic integration of displaced communities is needed to minimize the adverse impacts of displacement on affected communities (Cernea, 2003).

4. Conclusion

This provides valuable insights into various aspects related to compensation, community participation, income levels, and the perceptions of displaced communities about development. The findings reveal the prevailing rates and ranges of compensation prices per square meter, highlighting the variability in these values. The majority of respondents demonstrated a rough familiarity with compensation mechanisms, but there is a need for further education and clarification for those who lack understanding. The income distribution among respondents indicates that a significant portion falls within the moderate-income range. The wages offered for unskilled housework also vary, with the majority falling within a specific range. The majority of respondents believed that the Bole Lemi Industry Park needed to create permanent employment opportunities for the marginalized community. Community participation in the introduction of new development was perceived as lacking by the majority of respondents, emphasizing the need for increased engagement and inclusivity.

The types of compensation mechanisms varied, with the combination of money and land being the most prevalent. Preferences and perceptions of fair compensation varied among respondents, highlighting the importance of considering individual perspectives. The study also revealed diverse awareness and perceptions of specific issues in the locality, underscoring the need for open dialogue and increased awareness. Finally, the barriers to development identified by respondents included a lack of legal procedures, concerns about corruption, and the need for checks and balances. The findings of this study provide stakeholders with valuable information to inform decision-making processes and promote more informed and equitable approaches to development.

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Chapter VI: Synthesis/Conclusion & Recommendation

6.1. Synthesis

The synthesis section presents the entire work linking industrial park development's impact on environmental features, pollution on the quality of river water, the hazardous effects of heavy metals on environmental attributes like soil, vegetables, and water sources, and the implication of industrial effluents on human health and other biota. Furthermore, the study talked about the increasing need for development-induced investment in land acquisition and urban expansion and its implications for the livelihood of the displaced surrounding community. Moreover, the debates on compensation procedures and legal liability and their implication on development integrity, inclusiveness, and sustainability in the locality were detected.

Moreover, the study argued for the need for strong insight to practice the gap of Eco-industrial park development at all development zones at the country level in general and at the study region in particular. This approach is assumed to mitigate the impacts of the parks on the environment and the livelihood of the displaced grass-roots community, and it is supposed to play a significant role in guaranteeing sustainable development in the locality. This section also offers relevant policy implications and future research directions, as presented below.

6.2. Conclusion & Recommendation

1. Analysis of the concentration of heavy metals in soil, vegetables and water

An analysis of Heavy Metal Concentrations in the Soil, Vegetables, and Water near Bole Lemi Industrial Park was conducted. Heavy metals are known to pose significant risks to human health and the environment when present in excessive amounts. Soil, vegetable, and water samples were collected from various locations near the industrial park. The samples were analyzed using appropriate laboratory techniques to determine the concentrations of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and arsenic (As). The results revealed elevated levels of heavy metals in the sampled areas, indicating contamination due to industrial activities. The concentration of lead in soil exceeded the maximum permissible limit, posing a potential threat to agriculture and public health. Similarly, the levels of cadmium, chromium, and arsenic were also found to be above acceptable limits in some samples.

Furthermore, the study found that the concentration of heavy metals in vegetables was significantly higher compared to the soil and water samples. This indicates the potential for bioaccumulation, as vegetables uptake heavy metals from the soil and water they are grown in, making them a direct pathway for human exposure. The findings of this study highlight the urgent need for environmental monitoring and remediation strategies in the vicinity of the Bole Lemi Industrial Park.

The study recommends conducting regular monitoring programs to assess the impact of industrial activities on the environment and human health. Additionally, raising awareness among the local communities about the risks associated with heavy metal contamination and promoting safe agricultural practices is crucial. Efforts should be made to reduce the release of heavy metals into the environment, control industrial emissions, and implement proper waste management practices.

In conclusion, the analysis of heavy metal concentrations in soil, vegetables, and water near the Bole Lemi Industrial Park reveals contamination, indicating potential risks to both the environment and public health. Addressing this issue requires immediate action to mitigate industrial pollution, implement proper waste management, and promote sustainable practices in the region.

2. Assessment of the Impact of Industrial Wastewater on the Water Quality of Rivers

Assessment of Industrial Wastewater Impact on the Water Quality of Rivers near Bole Lemi Industrial Park was conducted around the Bole Lemi Industrial Park (BLIP). The study focuses on evaluating the impact of industrial wastewater on the water quality of rivers surrounding the Bole Lemi Industrial Park (BLIP). Industrial activities often result in the discharge of wastewater containing various pollutants, posing a significant threat to aquatic ecosystems and public health.

Water sampling from multiple locations along the rivers near BLIP was conducted. The collected samples were analyzed to assess the concentrations of pollutants, including heavy metals, organic compounds, and nutrients. Additionally, physical and chemical parameters such as pH, temperature, dissolved oxygen, and turbidity were measured. The results indicate that the water quality in the rivers near BLIP is significantly impacted by industrial wastewater discharge. High concentrations of heavy metals, such as lead (Pb), cadmium (Cd), and chromium (Cr), were detected in the water samples, surpassing the recommended standards for freshwater ecosystems. The presence of these pollutants can have detrimental effects on aquatic organisms and may enter the food chain, posing risks to human health.

Moreover, organic compounds, including oil and grease, were found in excessive amounts, indicating inadequate treatment of industrial wastewater. The high levels of nutrients, particularly nitrogen and phosphorus, suggest potential eutrophication, leading to algal blooms and oxygen depletion in the rivers.

The study emphasizes the urgent need for effective wastewater treatment and management practices within BLIP. Implementing appropriate treatment technologies, such as biological treatment and advanced filtration systems, can help remove pollutants and minimize the environmental impact. Furthermore, the establishment of stringent regulations and monitoring programs is suggested to ensure industries comply with environmental standards. Regular water quality assessments should be conducted to track changes over time and identify emerging issues promptly.

To mitigate the negative effects on public health and the environment, community awareness and involvement are crucial. Stakeholders, including industries, local communities, and government agencies, should collaborate to develop sustainable practices and promote responsible waste management. Effective wastewater treatment measures, strict regulatory enforcement, and community engagement are essential to safeguarding water resources and ensuring the sustainability of the surrounding ecosystem and public health.

3.Assessment of impacts on Livelihoods of displaced communities

The study examines the consequences of development projects on impoverished farmers in Addis Ababa's peri-urban region. It focuses on the Bole Lemi Industry Park and its impact on livelihoods. Interviews with household heads revealed significant land and income losses due to displacement. Most participants were male, married, and had low literacy skills. The Oromo ethnic group and Orthodox Christians were well represented. Since the park's establishment in 2012, respondents reported a decline in income and adverse effects on their livelihoods. About

84% of household heads expressed negative impacts, and 80% reported a lack of community involvement. Prior to the park, respondents described themselves as moderate in terms of wealth. Many became jobless or engaged in different activities after displacement. The study highlights the heavy reliance on farming and the consequences of land allocation for industrial purposes. Industrialization's impact on agricultural land access and poverty is explored, emphasizing the complexity of peri-urban changes. Understanding shifts in livelihood patterns resulting from land use changes is crucial, given the continent's urbanization and industrialization.

Displacement caused by development projects leads to significant livelihood transformations, with households engaging in different occupations such as semi-agrarian work, petty trade, and services. However, most become unemployed, indicating insufficient planning for resettlement and compensation. These result in asset loss, limited employment opportunities, and increased vulnerability. Displaced peri-urban farmers are at a higher risk of food insecurity. Effective community engagement is vital for project benefits and employment generation. Urban expansion due to industrialization causes land loss, impacting livelihoods. Displacement alters living conditions, disrupts services, and social networks, and causes economic and psychological stress. Average annual income decreased from 84,000 to 21,428 birr after displacement, accompanied by a decline in land size. These findings align with other Ethiopian studies on industrialization. The income declines push households closer to poverty. Agricultural livelihoods provided higher income before displacement, offering better sustenance.

Past development projects in Addis Ababa have forcibly displaced farmers in peri-urban areas, leading to their impoverishment due to inadequate compensation and a lack of alternative livelihood options. Farmers are disproportionately affected, facing reduced crop productivity and increased poverty. Displaced households experience lower incomes and limited job opportunities. Industrialization drives urbanization, resulting in agricultural land loss and farmer displacement, leading to food insecurity and poverty. Tailored policies considering household characteristics promote livelihood diversification. Measures should protect the rights of displaced communities and mitigate their negative effects. Policymakers must consider various factors to minimize negative impacts on local communities when planning industrial parks. Despite potential benefits, industrial park establishment in Ethiopia has displaced small-scale farmers, causing the loss of natural, economic, and social assets.

4.Assessment of Compensation procedures relative to displaced communities preference

The study on compensation and leasing prices per square meter provided valuable insights into prevailing rates and ranges. The average compensation payment was 7.84 Birr per square meter, with a range of 1 to 18.6 Birr. For leasing prices, the mean cost was 23,780.55 Birr per square meter, with a range of 1.25 to 70,000 Birr. Regarding knowledge of compensation mechanisms, 75% of respondents were familiar, while 25% lacked familiarity. Majority awareness implies understanding, but the minority highlights the need for education. Participants' monthly income shows that 47.22% earn between 801 and 1600 Birr, and 47.22% earn between 1601 and 2400 Birr. 2.78% earn above 2401 Birr. Analysis of unskilled house labor income reveals 74.53% pay between 801 and 1600 Birr, 3.73% pay between 1601 and 2400 Birr, and 3.11% pay above 2401 Birr. These statistics offer insights into income distribution and compensation practices.

Regarding the permanent employment created by an earlier IPP project, 78% of respondents believed it created permanent jobs, while 11% disagreed. Some respondents remained neutral. These findings highlight positive perceptions but also indicate a minority with contrasting views, emphasizing the need for further investigation. The data provides insights into community participation in new developments. Only 18% reported involvement, while 82% felt participation was lacking. The contrasting responses indicate a disparity and emphasize the importance of increased community engagement for inclusive and transparent development. Regarding compensation mechanisms, 5.41% received monetary compensation, 91.22% received money and land, and 1.01% received a house and land. 0.68% received support for a development association, 1.01% felt the compensation was unfair, and 0.68% received unspecified compensation. The majority received a combination of money and land. These findings shed light on the diversity of compensation mechanisms and can inform discussions on fair and equitable compensation practices. The responses reveal preferences for compensation: 5.39% preferred monetary compensation, 59.88% preferred a combination of money and land, 6.29% preferred a development association with financial support, and 28.44% found none of the options fair. These viewpoints emphasize the need to consider individual preferences to ensure equitable compensation practices.

Regarding the respondents’ awareness and perception of the compensation experience in the locality, among the participants, 1.69% were unaware of the issue, 36.44% believed it was talked about but hidden, 3.39% saw it as normal business, and 7.63% viewed it as severe for the displaced community. Interestingly, 50.85% recognized the complexity of the issue by acknowledging multiple perspectives. The responses highlight diverse understandings and the need for open dialogue and awareness-raising to address the issue effectively. The participants' responses discussed barriers to development. Among the participants, 8.62% reported having encountered no barriers, while 59.48% identified a lack of legal procedures and checks and balances as significant obstacles. Additionally, 8.05% expressed concerns about corruption, and 21.55% saw a connection between the lack of legal procedures and corruption. Unspecified barriers were mentioned by 2.30% of the participants. The responses underline the importance of proper legal frameworks, transparency, and accountability to overcome barriers and promote sustainable development. The study reveals a gender disparity in compensation preferences. While over 90% preferred money and land, female-headed households showed a preference for monetary compensation alone, with a higher associated risk compared to male-headed households. This gender disparity highlights the need to consider gender-specific needs and factors when designing compensation mechanisms. Understanding and addressing these factors can ensure equitable and inclusive compensation practices that promote social justice and sustainable development outcomes.

Further, suggested study area

- Investigate the establishment objectives of industry parks, the extent of employment opportunities created (for daily laborers, technicians, and Professionals), and the Challenges in salary standard and scale at the Local, regional, and National levels (in Ethiopia).
- The linkage of industrial parks with local SMEs and Universities involves practically exchanging technology and sharing development infrastructure.
- Synergy and integration of Ethiopian industry park development relative to micro- and macro-economic benefits.
- Policy, rules, and regulation gaps, suffering the livelihood of displaced communities, and the limits of the eco-industry park.

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Appendix 1: Household survey questionnaire

Impacts of industrial park development on the environment and livelihoods of the surrounding community in Ethiopia: the case of bole lemi Industry Park

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Survey questionnaire for sampled informants`

General direction

The survey questionnaire is to collect data pertaining to Environmental attributes; the socio-economy of a household living near and around **Bole Lemi Industry Park**. The objective of the survey is entirely meant for the **Research** consumption and all the information collected will be kept confidential on behalf of the researcher. You can write your given name on the questionnaire paper; or use pseudo names instead if it is required.

To this effect, I kindly request your honest and true answers to each question to the best of your knowledge.

I thank you for your time and cooperation in advance.

Part I : General INFORMATION

I. Location identification

1. **S**ub City/ K.Ketema 2. *Worde*/town -----------------
3. Name of *Kebele*/village ---------------
4. Full name of respondent (He/She must be head of the household):

____

II. Questionnaire and enumerators identification

1. Questionnaire Number: ________________________________
2. Date of interview: ____
3. Enumerator's Name: ____

Part II

I. Household demographic characteristics

1. Sex of household head: 1. Male ------------ 2. Female ---------

2. Age: --------------------(in years)

3 Marital status: 1. single 2. Married 3. Separated 4 .widowe 5. Divorce

4. Educational level: 1. cannot read and write 2. Can read and write 3. P/School 4. J/Se.School 5. S/School 6. Collage & above

5. Ethnicity: 1. Oromo 2. Amhara 3. Tigre 4. Gurge 5.Silte 6.Wolayita 7. Other, specify, ---------

6. Religion: 1. orthodox 2. Protestant 3. Catholic 4. Muslim 5. Wake feta

   6. other, specify, ---

7. Are you borne here please? 1. Yes 2 .No

8. *If your answer for **QN7is "NO"** for how many years you have been here? ----- in years?

9. Would you brief your Family size (in number): Male: ------------; Female------- Total----------------

10. Indicate your family size relative to age category in table below please ?

Table -1- House hold family size relative to productivity

Ser. No.	Age categories	Male	Female	Total
1	**<15**			
2	**15-64**			
3	**>64**			

Part III: Questionnaire per Specific Objectives

Section I Livelihood options (assets of the household)

A. Land tenure and Property right / Asset & welfare / Natural capital

1. Do you own any pieces of land? 1. Yes 2. No
2. If your answer for **Q N 1** is **"Yes** "please, list below, the area of land types you have owning

(Multiple answer is possible where required)

Table -2- Area of land owned before and after IP plantation in hector (1h=10000m2)

S. No	Land use type	Area in hector		Remark
		Before 2004 EC (DIDR)	After 2004 EC, to yet now (DIDR)	
1	Residential			
2	Mixed Use			
3	Cottage industry plot			
4	Farming land			
4	Horticulture filed			
5	Commercial tree/ timber plot			
6	Grazing private			
7	Grazing Communal			
8	Trade & Service			
9	Other Service (if)			
Total				

NB. If area of land defined is **below 1/4th** of hector please indicate the area in M2, 1 **M2 =0.0001hac.**

B. Livestock

Table 3: List of livestock early2012 & late of 2020

S NO	List of livestock	Number owned (2012)	Number owned (2020&)	Estimated Price in Birr	
				Unit Price	Total Price
1	Oxen				
2	Cows				
3	Heifers				
4	Young bulls				
5	Calves				
6	Sheep (adult)				
7	Goats (adult)				
8	Donkeys (adult)				
9	Horses (adult)				
10	Mules (adult)				
11	Poultry (adult)				
12	Beehives				

C . Source of income /financial capital

3. If your answer for **QN1** is "Yes" Please rate the average income you earn annually from each land use type, and from other **income sources** either in Cash or in-kind, in the table below?

Table -4 -Description of Average income earned from different sources in 8 years

S.NO	**Income Sources**	**Amount of income earned from each Land Use type and other sources in Birr annually**		**Remark**
		Early 2012 GC	**Late of 2020 GC**	
1	Farming land			
2	Horticulture filed			
3	Commercial tree/ timber sells			
4	Land renting			
5	House renting			
6	Cottage industry			
7	Trade & Service			
8	Wage & salary			
9	Animal and animal products including Poultry& Bee keeping			
Total/ Average				

4. How you rate the growth and trends of yours and your family average annual income since 2004 EC to 2013 EC?

1. Highly increasing 2. Increasing 3. Decreasing 4. Highly decreasing 5. **3 &4**

5. If your answer for **QN4** is "**5"** what is your assumption for the cause? (**>1** answer is possible) 1. HHs are displaced with unfair compensation 2. Even if, HHs are fairly compensated, they are not technically & administratively supported to restore their life. 3. Expropriated community has not given job Opportunity/options during displacement for restoration. 4. Displaced community lacks appropriate government guidance 5. All are answer

6. *Do you think that there is a clear rehabilitation strategy during development induced displacement of the indigenous community of the locality (DIDS)? 1. NO 2. Yes

7. *If your answer is for **QN 6** is **"yes",** what is your recommendation to improve the livelihood of the displaced community? 1. Full consideration of the community participation in development program 2. Rehabilitation strategy setting in line with development plans and programs 3. Attempting to post development planning & programing 4. Providing attention to Stakeholders earlier development planning stage.

8. Do you mind while new development introduced in the locality the community has attentive?

1. Yes 2.no

9. If your answer is for **QN8** is **"No",** what is yours & others community observation on the new introduced development? 1. Highly recognized 2. Recognized 3. Accused 4. Highly accused

10. If your answer for **QN9** is **"3&4",** what is your experience on such projects/investments?

1. It may face challenges from the grass root community 2. It may also dismantled 3. All

11. If your answer for **Q10** is **"1",** did you experienced such Challenges regarding Bole Lemi Industry Park? 1. No 2. Yes

12. If your answer for **Q11** is **"Yes"** how do you evidenced the situation and the consequences?

1. The community has accusing the project 2. The community has seen while highly accusing the project 3. Parts of the community observed while trying to damage & destroy the project. 4. All

13. *Would you mind please; the average income growth trend you earned annually after the introduction of Bole Lemi Industry Park at the locality vs. your annual income illustrated in table two above? 1. Increased b. 2. Decreasing 3. Integral 4. Other, specify, (----------)

14. If your answer for **QN 13** is "Decreasing" what are the leading causes? 1. The major source of my assets was land & it was appropriated 2. Equivalent & appropriate job opportunity has not given 3. Rehabilitation strategy and resettlement process has not supported administratively & technically

15. Would you remark please before BoLIP plantation, for what period of time your aggregate annual income can consume and cover your family compressive expenses? 1. >one year 2. One year 3. 1/2 year 4. Three to six months 5. **<3** months

16. How do you grade; the average annual income you earn from different sources after BLIP plantation relative to its appearance? 1. Highly increasing 2. It seems similar 3. Decreasing 4. Highly decreasing 5. Other Specify-------------------------------

17. From the introduction of BoLIP how do you rate yours & your family cumulative life standard?

1. Highly improved 2. Improved 3. Declines 4. Very declining 5. Drives to the deep poorest

18. *How you rate yours and your family average **annual expenditure** for aggregate consumption? Late 2004 EC to 2013 EC? (8 years) --------------------------in birr

19. How do you rank, your & your family average annual expenditure you mentioned in QN18**?**

1. Normal as it was 2.Increasing 3.Higly increasing 4. Beyond capacity & severing life

D. Employment /social capital

1. Please indicate your household socio economic situation pre and post industry park plantation in table below(More than one answer is possible)

Table -3- Household Livelihood /Employment/ Options (Before and after Industry Park Plantation)

S. No	Family Members	Sex Code- A	Age Code-B	Education Code -C	Religion Code - D	Livelihood/ Employment options (Code- E)		If IP employed Later 2004 to 2012 EC		
						Before IPP 2004 EC	After IPP 2004 EC	Enrolment Type Code - F	Work/enrolment Level Code - G	Average monthly Salary in Birr Code - H
	Household Head									
	Spouse									
	1st Child									
	2nd Child									
	3rd Child									
	4th Child									
	5th Child									
	6th Child									
	7th Child									
	8th Other									
	9th Other									
	10th "									
	11th "									
	12th "									

Code A, 1 = Male 2 = Female

Code B, 1= ≤ 7 2 = 7-14 3 = 15 - 35, 4 = 36- 60 5 = ≥ 61

Code C, 1= Illiterate, 2 = Read & write 3 = Primary (1-6), 4 = Junior Secondary (7-8), 5 = Senior Secondary (11-12), 5 = >12 Specify (TVT, Diploma, 1st Degree or 2nd Deg.)---------

Code D⇒1= Orthodox, 2 = protestant; 3 Catholic, 4 = Muslim, 5 =Wakefeta, 6=Other, Specify

Code E, 1= IP employed 2 = Agriculture 3 = Semi Agriculture 4 = Trade & Service 5 = Micro & SMES 6=Unemployed

Code F, 1 = Permanent 2 Temporary

Code G, 1 Daily Laborer 2 = Skilled labor 3 =Professional Worker 4 = Lowest employed (Security guard, Kitchen Made & sanitation worker) 5 Other (Specify)

Code H, 1 =Daily Laborer--------------Birr 2= Technician/Skilled --------------Birr 3 = Professional --------------Birr 4 = No standard for all

2. Do you think that is there any change on job opportunity creation where you rate the pre and post industry park plantation in the locality? 1. Yes 2. No

3. If your answer for **QN 2** is yes, can you indicate its trend and magnitude please?

   1. Employment is Increasing 2. Decreasing 3. Stagnant 4. Unknown

4. If your answer for **QN 2** is “Decreasing”, what expectation you reason out?

   1. The displaced communities are not well rehabilitated 2. The number of job opportunity created by IP is too low than the number of displaced families per house hold 3. Limited/absence of rehabilitation options 4. Other (specify)

5. Is there anyone of your family member who have engaged in any of the nearby industry park activities? 1. Yes 2. No

6. Would you state below your family members that recruited in the **industry park,** relative to enrollment type**,** please? During The Park history is possible

Table-6- Employment opportunity created for household members in aggregate since IP Plantation

NO	Engagement Type	Employment opportunity created earlier IPP to yet now (2004 EC- 2013 EC)		Average Monthly Salary	Remark
		Temporary	Permanent Total		
1	Daily laborer				
2	Skilled labor/Technician				
3	Professional worker				
4	Low level tasks (Security Guard, kitchen mud and sanitation worker)				
Total					

NB: Help to Compare the Salary with UN (ILO) & National indexes (if there)

7. How much is the average monthly income for unskilled household member employed in industry? -----------------------(in birr)

8. Do you have agreed for the monthly salary paid for the laborer in the industry?

   1. Yes 2. No

9. If your answer for QN 8 is "No", how you worth the Salary? 1. Very low 2. Low 3. Fair .
   4. Non Standard for Ethiopia (Non-index)

10. Do you think that since IPD introduction, the livelihood stile of your family have associated with new job modality? 1. Yes 2. No

11. If your answer for **QN 10** is **“yes”,** how do you rate the transformation?

1. Agrarian to Semi Agrarian 2. To trade & Service 3. To entrepreneurs 4. To joblessness 5. Rural to urban life style 6. Others (Street dwelling, Beggary, creasy, robbery & criminalist), specify

12. *****Do you have experienced for saving from your average monthly earned income from the IP relative to the community in the locality? 1. yes 2. No

13. If your answer for **QN 12** “**yes”** how many birr you save monthly**?** --------------------in -Birr

14. What are the major problems related to the indigenous local community to not be directly employed in the industry park as a pleasure to that they are affected?

1. Attention is not given to the indigenous 2. Lack of skill 3. Lack of Professional knowledge 4. Availability of excess labor from other places 5. Employers are selective: prefer people from other region even abroad else 6. Other, (specify)

15. What implication (positive-negative) do you think employment in the industries has on own livelihood activities in your locality? Please, put in order of their importance

1. Diversify sources of household income 2. Divert/reduce farm labor

3. Affect agricultural production 4. Accelerate rural-urban migration 5. Other,

Specify ----------------

Part IV- Household perception towards compensation mechanisms

1. Are you familiar with any compensation mechanisms during development induced displacement /DIDR/? 1. Yes 2. No

2. If your answer for **QN1** is "**yes**", which mechanism you are aware of?

1. Only Money 2. Money & Land 3. House & Land

4. Establishing as development association with financial support

5. None compensated

6= other compensation mechanisms (specify)----------------------

3. *Among the compensation types presented in **Q2** above, which one is preferable and fairly rated?

1. Only Money 2. Money & Land 3. House & Land

4. Establishing as development association with financial support

5=All are faire 6= None of fair 7 =Other (specify)

4. Which one of the following mechanism have you received?

1. Only Money 2. Money & Land 3. House & Land

4. Establishing as development association with financial support

5. None compensated

6= other compensation mechanisms (specify)----------------------

5. ***If** your answer for **QN3** is **"None of fair**", would you mention the reasons please? (**multiple** answers are possible)

1. The aggregate value of compensation is very lower than the value of my aggregate assets & welfare (House, land and land related properties)

2. Lower than the value of my aggregate asset & welfare

3. It was equivalent only to existing rate, lacking of future & long term rehabilitation expenses

4. Compensation strategy and parameter is debatable by itself

5. Unclear

6. *If your answer for **QN1** is **“No”** how you are reasoning it?

1. Lack of community participation in setting compensation mechanisms

2. Less community participation

3. Clarity of compensation procedure, even if participate

4. Personal ignorance to involve

5= Other (specify), --------------------

7. *If your answer for **QN5** is “**1”** what is your argument to address the gap in the future please?

1. No matter, if it continued as usual

2. Better to involve the community

3. Must pledge community participation

4. Other (specify), --------------------

8. *Do you aware of the way compensation mechanism is formulated, implemented & regulated?

1. Yes 2. No

9. If your answer for **QN8** is “**Yes**” would you indicate it please?

1. Government alone. 2. Government–community partnership

3. Development stakeholders with Government 4. Unknown

10. If your answer for **QN8** is “**1**”, what you suggest to correct the procedure in the future please?

1. Be continuing as existing yet 2. Must legalized, not to the government intervene alone

3. Compensation process & procedures must be formulated with the knowledge of the major stakeholders including the local community

11. Do you think that DIDR compensation formulation and implementation is manipulated with a single government institution, as such AAC administration? 1. Yes 2. No 3. Don’t know

12. If your answer for **QN10** is ‘Yes’ which sector office you think of it?

1. AAC Mayor office 2. AAC Land management Office

3. City Land development & Urban Renewal Agency

4. All 5= Other (specify), --------------------

13. **If the whole compensation procedures and phases (Engineering cost estimation, implementation & Regulation) are operated with a particular sector, what development barriers you feel to encounter?

1. No blocks still 2. Lack legal procedure (check & balance affirmative)

3. Even it makes conducive environment for severe corruption as an asylum of liability 4. “**2 to 3**” 5= Other (specify), --------------------

14. If your answer for **QN13** is **“4”** would you mind such experience in the locality please? (**>1** answer is possible)

1. Not seen yet

2. The issue is talked but hidden

3. It is as a normal business for local technicians & Managers

4. Highly sever to the displaced community

5. “**2 to 4** “are right

6= Other (specify), --------------------

15. If you answer for **QN14** is “**5**” what is your intention to alleviate/tackle the problem?

1. Let it be, it was common for long

2. Regulatory & implementing body must be separated soon

3. Council office must be established from relevant stallholders for counseling & guidance

4= Other (specify), --------------------

16. **Would you mind that the change in life standard for those compensated & displaced households please?

1. Stagnant 2. Some are improved

3. Many are improved 4. Some are declined

5. A lot are depressed 6.” **2 & 3**”

7. “**4&5**” 8= Other (specify), --------------------

17 If your answer for **QN15** “**16**” is “**6**” What is your observation in this regard?

1. The HHs were efficiently uses their compensation money

2. They were well trend on the rehabilitation strategy & implemented effectively

3. They involving Saving Practice

4. All

5= Other (specify), --------------------

18. *If your answer for **QN16** is "**7**" What is your observation in this regard?

1. Even if they were paid well, they couldn't manage it 2. They lack technical & administrative support from LG 3. Eventhogh they were supported by LG; they were not willing to restore themselves 4. They spend their money recklessly in moving to the city center (to be yarada Lij)

19. **Do you know, an exemplary /sample households dramatically change their life standard & stile as the result of compensation fee they received? 1. Yes 2.No

20. If your answer for **QN19** is "**Yes**" can you list a maximum number of 10 sample HHs in the table below please? (<10 is Possible)

Table -8- Grown, Sample HHs due to DIDR & compensation charge

S.N	List of Grown Sample HHS (Coding is possible)	Life Status Pre & Post IP Planation(indicate Poor =1, very poor=2, Middle =3 , Rich =4)		Remark
		Before IPD	Since IPD	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total				

21. For the Sample HHs you list under **QN20,** what promoting indicators could be explained?

1. Some are economically standing but changed to urban life style
2. Some are become investors /entrepreneurs
3. Some have proceeded in mechanized urban agriculture development 4.All

22. If your answer for **Q19** is "**No**" can you list a maximum number of the most **10 depressed** HHs in the table below please? (<10 is Possible)

Table-9- Depressed, Sample HHs due to DIDR & compensation issue

S.N	**List of Depressed Sample Households** **(Coding is possible)**	**Life Status Pre & Post IP Planation(indicate Poor =1, very poor=2, Middle =3 , Rich =4)**		**Remark**
		Before IPD	Since IPD	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total				

23. *For the Sample of the most **depressed** HHs you list in **QN22** what destructive indicators could you expound?

1. Lack of restoration guidance from the government

2. Unfair rate /lack of compensation charge

3. Their own failure/carelessness

4. All are answer

5= Other (specify), --------------------

24. If your answer for **QN23** is "**4**" What you recommend in the future as **HH preferences**?

1. No matter if continued as usual

2. Need to institutionalize compensation issue for free

3. An elected community representatives must be a membership in cost estimating project committee

4. Sustainable Pre and post project performance evaluation & readjustment program

5. Need complete support for displaced residents due to DIDR.

6= Other (specify), --------------------

25. **Which gender of the displaced HH is the most undesirably Compensated/overlooked during DIDR in your locality? 1. Male HH 2. Female HH

26 .If your answer for **QN25** is "**Female HH**" what root event you agreed with, please?

1. It is familiar to undermine Females
2. Females are not devoted for their right
3. Females are satisfied with limited resource than Males
4. Not notified

27. If your answer for **QN 2**6is “**No 1**”, how does it observed laterally with the gender strata?

1. Not well noticed 2 Bottom level.
3. Middle Level 4. Equal status
5. “**1&2**” 6= Other (specify), --------------------

28. If your answer for **QN27** is “**No 5**” what adjustment to be taken from your perspectives?

1. Let it be as it was 2. Females have to work strongly for their right
3. Special support to females by Government
4. Need to keep silent if the females are accept their cultural status
5= Other (specify), --------------------

29. **If you displaced due to DIDR, how many birr you have paid for your land compensation in M2 -----------------in Birr? And what amount, for your total Land & Property right ------------ Birr?

Table 10 List of Compensation Paid for displaced households due to DIDR from 2003 t0 2012

S.NO	Year in EC	Area of total Land in **ha.**	Price in Birr in per M2		Remark
			Unit price	Total Price	
1st round					
2nd round					
3rd round					
4th round					
Total					

30. *Do you aware of the average land leasing price in M2 for the land that booked from you and your locality HHs, when the government transfers to the investors? If you know State in in Birr-------------

Appendix II: Industrial effluents identified parameters and tested in the laboratory

Spatial & temporal, parameters Tested (2021)

NB: - X is representing what to be done (Water, Soil & Vegetation)

S.N	Parameters	Parameters to be done per categories (X)				Remarks
		Biological	Water	Soil	Vegetable	
	Physicochemical					
1	**PH**		X			
2	**Temperature**		X			
3	**BOD5**		X			
4	**COD**		X			
5	**EC**					
6	Total Suspended solids **(TSS)**		X			
7	Total dissolved solids **(TDS)**		X			
8	Total nitrogen **(as N)**		X			
9	Total phosphorus **(as P)**		X			
	Heavy Metals					
10	Cadmium**(cd)**		X	X	X	
11	Lead **(Pb)**					
12	Zinc **(Zn)**		X	X	X	
13	Chromium **(Cr)**		X	X	X	

Appendix III : Public organizations and other stalk holders take parts & addressed as a potential resource

No	Hierarchical & Structural List of Organizations of three Level			
	Federal	**Regional**	**City**	**Park Level**
1	Ministry of Industry	Bureau of Industry	Bureau of Industry	-
2	EIPDC	IAIP	‘ ’	Industry Park
3	Ethiopian Investment Commission	Regional office	City office	-
4	Ethiopian SMES Agency	Regional Agency	City level Agency	-
5	MS&M Enterprises	Office	office	Park desk
6	Financial institutions (National Bank)	Regional/ Micro Financing Agencies	City level Micro Financing Agency	
7	Ministry of Urban Development & Housing	Regional Bureau	-	
8	Federal Urban Planning Institute	Regional Institute	City Plan Commission/Institute	
9	Ministry of Land Administration	Bureau of Land Administration	Bureau of Land Administration	
10	Ministry of Construction	Regional Bureau	City level Bureau	
11	Ministry of Works & Employees affairs	Regional Bureau	City level Bureau	
12	Federal Plan Commission,	Regional Commission	City level Comission	

13	Ministry of Agriculture	Regional Bureau		
14	Ministry of Finance	Regional Bureau		
15	Ministry of Revenue & Custom	Regional Bureau		Park desk
16	Ministry of Trade	Regional Bureau		Park desk
17	Ministry of Youth	Regional Bureau	City level Bureau	-
18	Federal Environmental & Forestry Agency	Regional Agency	City level Agency	Park desk
19	Research institutions	Regional Centers (if)	-	-
20	Universities	-	-	-
21	Ministry of Science & Technology	-	-	-
22	Police Commission	Regional Office	-	Park desk