RISE UP for Sustainable Urban Resilience

Multi-layered Vulnerability Profile for Debre Birhan City

Climate, Urban, and Biodiversity Dimensions

UN-HABITAT

Amhara National Regional State President Office

aecid

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Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

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Foreword from Head of UN-Habitat Ethiopia Office

Ethiopia stands at the crossroads of rapid urbanization rate and escalating climate challenges. Secondary cities are at the forefront facing the challenges and opportunities posed by climate change and rapid urbanization, and Debre Berhan city is no exception. In fact, its proximity to the capital Addis Ababa and its favourable climate have been instrumental for the rapid urban expansion through investment and labour migration. The importance of understanding the depth of vulnerability and the interplay between urbanization and climate change in Debre Berhan city has never been more urgent. It is with great enthusiasm that I applaud this timely and essential work on Resilient Settlements for the Urban Poor (RISEUP) project which sheds light on the understanding of vulnerability in the context of secondary cities in Ethiopia, and how this understanding can guide investment and build urban adaptation and climate resilience where it matters most.

In this insightful publication, the city's multi-layered vulnerability assessment (MVA) report explores how rapid urbanization has transformed Debre Berhan into a vibrant hub of investment and economic activity while also posing significant challenges to the urban poor. The synergy of urban growth and climate change is a dual force that requires our immediate attention, and we have witnessed this in three vulnerability hot- spots in Debre Berhan. This MVA report navigates through the city's context analysis and its exposure to climate change through a comprehensive understanding and mapping of vulnerabilities by considering the complex interplay of various factors such as climate change, urbanization, biodiversity loss, and land degradation – and how these factors intersect and create hotspots of vulnerability.

Through thorough analysis, and case studies, the report invites us to rethink our urban planning strategies and engagements, promoting resilience and sustainability in the face of inevitable climate impacts. Moreover, this work emphasizes the importance of community engagement and inclusive decision-making towards tackling vulnerability in urban settings. As cities evolve, it is crucial that they become arenas not only for economic growth but also for social equity and environmental stewardship. This MVA report advocates for innovative approaches that integrate climate action into urban developmental shift that is essential if we are to build future cities that thrive amidst the complexities of a changing climate.
I encourage readers to immerse themselves in this vital text, to consider the challenges presented, and to embrace the opportunities for transformative change in the context of secondary cities. As we reflect on the insights contained within these pages, let us unite in our efforts to shape Ethiopian urban spaces that not only mitigate climate change effects but also enhance the quality of life for all urban dwellers.
Congratulations to our team for crafting a work that illuminates the urban resilience in the face of climate change and rapid urbanization, and to you, the reader, for engaging in this important discourse.

Sincerely,
Haregewoin Bekele

Haregewoin Bekele
Country Program Manager
UN-Habitat Ethiopia office

Abbreviations

AI	Aerosol Index
AECID	Agency for International Development Cooperation
ANRS	Amhara National Regional State
AHP	Analytical Hierarchy Process
CC	City Council
CR	Consistency Ratio
CHIRPS	Climate Hazards Group Infra-Red Precipitation with Station
CRGE	Climate Resilient Green Economy
DB	Debre Birhan
DBRP	Debre Birhan Regio-Politan
DEM	Digital Elevation Model
ECSPGs	Ethiopian Cities Sustainable Prosperity Goals
ECT	Ethiopia Country Team
EIA	Environmental Impact Assessment
FDRE	Federal Democratic Republic of Ethiopia
GLI	Green Legacy Initiative
GIS	Geographic Information System
GCMs	General Circulation Models
GTP	Growth and Transformation Plan
ha	Hectare
IDPs	Internally displace people
IPCC	Intergovernmental panel on climate change
IS	Informal settlement
LULC	Land use land cover
MVA	Multilayered Vulnerability Assessment
NAPA	National Adaptation Plan of Action
NDVI	Normalized Difference Vegetation Index
NGOs	Non-Governmental Organizations
NUPI	National Urban Planning Institute
PD	Population Density
RISE UP	Resilient Settlements for the Urban Poor
RUSLE	Revised Universal Soil Loss Equation
RI	Random consistency Index
SIDA	Swedish International Development Cooperation Agency
SDGs	Sustainable Development Goals
SP	Structural Plan
SPI	Standardized Precipitation Index
SSA	Sub-Saharan Africa
NUDSP	National Urban Development Plan
UN	United Nations
UNFCCC	United Nations framework convention for Climate change

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Executive summary

This document presents the results of a comprehensive multi-laThis report is part of the "Accelerating the Implementation of the Paris Agreement by Building the Climate Resilience of the Urban Poor" RISE UP project. It presents a comprehensive analysis of the multi-layered vulnerability profile of Debre Birhan city in Ethiopia. The RISE UP project, implemented in collaboration with the Spanish Agency for International Development Cooperation (AECID), seeks to confront the multifaceted and interrelated challenges posed by climate change, urbanization, and biodiversity loss, which are particularly acute in urban areas of the Global South.

As cities grapple with the escalating impacts of climate change — such as rising temperatures, increased flooding, and more frequent extreme weather events — it is crucial to assess the vulnerabilities faced by their inhabitants. Urban areas often exhibit complex socio-economic dynamics and infrastructure limitations that heighten these vulnerabilities, especially for the urban poor in informal settlements. This report focuses on selected secondary and tertiary cities within the five countries (Bolivia, Colombia, Ethiopia, Jordan, and Tunisia) to highlight local contexts of multilayered vulnerability and identify critical intervention areas for enhancing climate resilience.

The selected cities were chosen due to their significant exposure to climate-related risks and the urgent need for enhanced adaptive capacity, particularly among the urban poor residing in informal settlements. By addressing the unique challenges faced by these communities, this analysis serves as a foundation for developing targeted strategies that foster systemic resilience, mobilize and allocate resources, and meaningfully engage stakeholders in coordinated actions.

By highlighting the current vulnerability landscape, the report aims to equip local and subnational governments, community organizations, and international partners with the data, insights and understanding needed to implement targeted and effective interventions that safeguard urban populations, infrastructure, and ecosystems, and promote sustainable urban development. The findings are anticipated to inform broader climate adaptation policies and practices, ultimately contributing to the long-term sustainability and resilience of urban environments.

Debre Birhan Regio-Politan (DBRP) city is highly vulnerable to current climate change due to its geographical location and its rugged topography, exposing the city to various climate extremes namely, flood, drought, soil erosion, changes in rainfall pattern, and temperature rise. In recent years, the city has experienced frequent and severe flood and drought, more intense soil erosion, heavy rainfall, and extreme temperature that strains our communities and damages infrastructures and natural resources. At the same time, other changes related to unplanned urban expansion, land use land cover change, and industrialization are ongoing challenges to the city that overall compromise the city's biodiversity and better way of life. These global/local changes are threatening biodiversity, water resources, agriculture and settlements. Such climate extremes are projected to become increasingly severe, and frequent in the coming decades. Besides, the improper land use planning and governance, environmental protection, and macro-economic development has rendered the adaptive capacity of the city to climate change quite low, while it remains highly exposed and sensitive to climate change. Hence, the need for taking multilayered as well as integrated vulnerability assessment, and long-term adaptation actions become even more pertinent when considering these other emerging challenges in the DBRP city, which will exacerbate the impacts of climate change.

This study aims to assess multilayered vulnerability of the city by considering the three dimensions of urban development; urbanization, biodiversity and climate change to improve the ability of urban poor people to be more resilient to current and future climate change and other urban developmental activities. The approach utilizes several raster spatial dataset or vulnerability indicator datasets like three biodiversity indicators (land use land cover (LULC), Normalized Difference vegetation Index (NDVI), and climate-topographic based biodiversity connectivity); five climate change indicators (flood, soil erosion, maximum temperature, minimum temperature, and drought); and seven urban indicators (population density, LULC, access to services, socioeconomic vulnerability, informal settlements, slum areas and historical sites). These vulnerability indicator datasets were standardized, and weighted overlay was used to generate vulnerability maps in the city. . There were also overlap analysis of urban and climate change, climate change and biodiversity and so on. Finally, the MVA map was generated based on all the 15 vulnerability indicator datasets.

The urban vulnerability map identified informal settlements, slums, and neighborhoods next to industrial areas, and densely populated areas along with historical sites, as very highly/highly vulnerable hotspot areas. Urban poor is always the most affected community by climate change and other developmental activities due to their low adaptive capacity and usually they are located in the peripheries/marginalized areas. Urban poor are mostly located in areas that are not well developed and with little to no infrastructure, exposing them to most of the developmental or global changes in the city. Analysis of the climate change vulnerability map indicated that the compounding of high susceptibility to floods, high increases in maximum and minimum temperatures, severe soil erosion and drought areas create hotspots of high vulnerability to climate change. Concerning biodiversity, degraded/barren land, urban areas, and low NDVI values translate to highly and very highly vulnerable areas. On the other hand, grasslands and forest/sparse vegetation were rated as having very low and low vulnerability to biodiversity challenges. The final, multilayered vulnerability assessment considering all dimensions indicated that densely populated, informal settlement, slum and degraded areas are highly and very highly vulnerable to climate change. The city is particularly vulnerable to climate change because of its unplanned expansion, fast population increase, high rate of rural-to-urban migration, sizable informal settlements, and slum regions with little access to vital infrastructure and development resources. In addition to the old main town, historically flood risk areas around Chacha town and rivers exhibited high and very high vulnerability. The city is vulnerable to climate hazards (rainfall anomaly, temperature rise, water stress, drought, and flash/river floods) because of the city's geographical location. Due to high levels of poverty and population could be said to be highly vulnerable to future climate change. The purpose of this vulnerability mapping is to highlight hotspots of particularly high relative vulnerability within the city due to climate exposure, high sensitivity, and low adaptive capacity. So that adaptation option that can minimize vulnerability and increase the resilience of the city in the long run, an integrated approach is needed. While implementing adaptation options, the increase in adaptive capacity of all sectors is vital.

In conclusion, the MVA analysis output indicated that some part of the city is very highly and highly vulnerable when considering climate change, biodiversity and urban dimensions. This indicates that the impact of climate change and urbanization on biodiversity have been so alarming that immediate response is crucial. It is vital to enhance education and research, training, and access to finance for investment to increase the community's adaptive capacity. The impact of climate change on urban poor was also high that informal and slum areas with high population density have been experiencing high susceptibility. Thus, implementing various infrastructures that can save water, minimize flooding and soil erosion, as well as capacitating the community is vital to enhance city's resilience to climate change.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

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INTRODUCTION

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Introduction

Climate change, urbanization, and biodiversity

The climate emergency is fundamentally an urban crisis, affecting every aspect of city life. With over 55% of the global population living in cities—expected to exceed 67% by 2050—urban areas face increasing vulnerability to climate change. Rising temperatures, sea levels, and extreme weather events are straining infrastructure, disrupting services, and impacting housing, livelihoods, health, and wellbeing. These pressures are exacerbated by rapid urbanization, population growth, migration, rising poverty, inequality, and biodiversity degradation. Addressing these interconnected issues through urban climate adaptation and resilience building remains one of the most significant challenges faced by cities, particularly in the global South.

Over 90% of cities lie within the world's 36 global biodiversity hotspots, where urban expansion threatens both biodiversity and climate resilience. The loss of natural habitats accelerates as human settlements expand, further exacerbated by climate hazards. Cities are increasingly recognizing the importance of spatial planning and urban land management in safeguarding ecosystems and natural assets. These strategies not only support biodiversity but also enhance climate resilience, delivering co-benefits for both people and nature. Effective spatial planning is crucial to prevent the degradation of settlements that rely on the ecosystem services that biodiversity provides. Targeted pro-biodiversity interventions are urgently needed, both within and beyond urban areas, backed by robust tools and strategies.

UN-Habitat emphasises the necessity of a multidimensional, multidisciplinary approach to understanding and addressing these overlapping challenges in cities, with a focus on building resilience for the one billion urban poor in informal settlements. These marginalized communities are particularly vulnerable to climate hazards and disaster risks, living in fragile areas where unplanned urban growth encroaches on natural habitats. Informal urbanization deepens their vulnerability, while also intensifying the challenges of climate change, urban poverty, and biodiversity loss.

Addressing urban poverty, spatial inequality, and informality is crucial to building systemic climate resilience and promoting sustainable urban futures.

Resilient settlements for the urban poor programme

In a rapidly urbanizing world facing the climate emergency, RISE UP is UN-Habitat's flagship programme, driving critical investments to build climate resilience and create sustainable urban futures. Supported by key partners such as the Adaptation Fund, Green Climate Fund, the Spanish Agency for International Development Cooperation (AECID), and the Swedish International Development Cooperation Agency (SIDA), RISE UP has mobilized over USD 150 million to accelerate global climate action, particularly in cities most vulnerable to climate change.
RISE UP projects range from constructing flood-resistant infrastructure in South-East Africa to enhancing green spaces in Malaysia and restoring mangrove ecosystems in urban Cambodia. These efforts underscore the interconnectedness of climate resilience and biodiversity. Urban ecosystems like wetlands and green spaces play a critical role in mitigating climate impacts and providing essential services for human wellbeing. Since 2019, RISE UP has worked in over 28 countries, reinforcing UN-Habitat's commitment to urban resilience and biodiversity conservation. RISE UP delivers impact through the following key pillars:

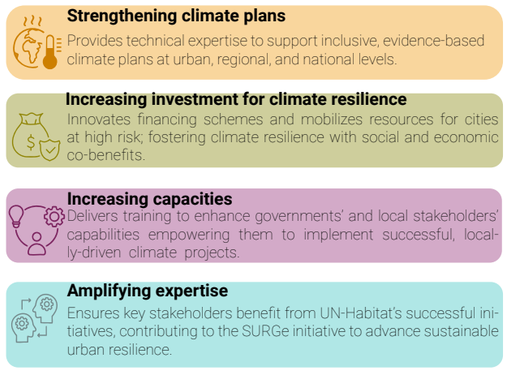


Fig. 1: RISE UP objectives

Through these initiatives, UN-Habitat fosters transformative urban resilience and impactful climate action for a sustainable, inclusive future.

Assessing multi-layered vulnerabilities in cities and urban areas

Multi-layered vulnerabilities in urban environments encompass various interconnected challenges that extend beyond physical infrastructure to include spatial, social, economic, climatic, environmental, political, and technological dimensions. Issues like income inequality, environmental degradation, inadequate housing, and insufficient emergency preparedness contribute to a city's multidimensional vulnerabilities.

In this context, multi-layered vulnerability refers to the extent to which an urban system, community, or ecosystem is exposed to, sensitive to, and unable to cope with the adverse impacts of interrelated climate change, urbanization, and biodiversity loss. Factors such as geographical location, socio-economic status, infrastructure quality, and governance structures influence this vulnerability.

The aggregation of multiple and cascading vulnerabilities exacerbates the overall susceptibility, risk, and adaptive capacity of people, infrastructure, and the environment. Addressing these challenges to strengthen urban resilience requires comprehensive urban planning and management strategies. Policymakers and practitioners face several obstacles in conducting multi-layered vulnerability assessments, including:

- The fragmentation of climate change, biodiversity, and urbanization in policy and practice.
- A lack of evidence-based approaches to mapping multidimensional and interrelated vulnerabilities.
- Limited capacities and resources for conducting comprehensive assessments.
- The urban poor and residents of informal settlements being the most affected yet least engaged in decision-making processes.
- Insufficient tools for predicting future land-use changes and urban growth patterns.
- A lack of coordination and cooperation in trans-boundary and multidisciplinary planning.
- Minimal application of coherent, prioritized interventions and solutions.

These challenges highlight the need for a more integrated approach to vulnerability assessment and management. To address this, UN-Habitat's RISE UP programme has developed the Multi-layered Vulnerability Assessment (MVA) tool, whose purpose is to help communities, cities, and local leaders to comprehensively map and assess multi-layered vulnerabilities. The tool addresses the nexus between climate change hazards and risks, urbanization and spatial trends and characteristics, and biodiversity loss and land degradation to identify vulnerability hotspots arising from spatial overlaps and conflicts.

By deploying the MVA tool in communities, cities and urban areas, local and national leaders and policymakers in climate-vulnerable cities and communities can better plan and deliver inclusive, sustainable, and resilient urban development strategies for human and non-human inhabitants. This enables decision-makers to make informed choices about urban expansion and adapt to urgent climate-related challenges.

Implementation of the multi-layered vulnerability assessment tool

This report is part of the "Accelerating the Implementation of the Paris Agreement by Building the Climate Resilience of the Urban Poor in Bolivia, Colombia, Ethiopia, Jordan, and Tunisia" RISE UP project in collaboration with the Spanish Agency for International Development Cooperation (AECID). It presents the vulnerability profiles of the selected project cities, detailing the outcomes of Stages 1 and 2 of the MVA, including preparation, and mapping and analysis, that will inform Stage 3: action planning. The project engages communities in Cobija and Charagua in Bolivia, San Juan de Pasto in Colombia, Debre Birhan in Ethiopia, Sahab Municipality in Jordan, and Kerkennah in Tunisia.

The selection of these locations was guided by several critical factors:

1. **High vulnerability:** Each area is characterized by significant vulnerability and exposure to the impacts of climate change, urbanization trends, and biodiversity loss, highlighting the need for intervention.
2. **Community engagement:** There is a demonstrated need and interest from local communities in enhancing their adaptive capacity, ensuring that project efforts align with local resilience priorities.
3. **Government collaboration:** Each location benefits from established governmental structures and policies, facilitating effective collaboration among local stakeholders and the RISE UP headquarters team for a coordinated approach.
4. **Implementation capacity:** The Regional and Country Offices possess the capacity to support activity implementation and manage component funds, which is essential for executing the project effectively and maximizing the impact of interventions.The MVA implementation in Debre Birhan, Ethiopia, lays the groundwork for targeted climate resilience interventions. With a focus on high-risk areas, strong community engagement, and collaboration with local governments, the project leverages local capacities for effective action.

About this document

The purpose of the city context analysis is to provide a rapid, holistic assessment of the city's contextual background to identify any key characteristics, challenges or opportunities relevant to climate change, urbanization and biodiversity. This report includes a high-level examination of factors that may inform or shape the Multilayered Vulnerability Assessment. It serves to provide insights into the social, economic, environmental, and cultural dynamics that shape the urban landscape in Debre Birhan City.

Target audience

This document is designed to be valuable for a wide range of stakeholders, including national and local government authorities, key development actors, active NGOs (both international and national), donor organizations, development agencies, local community representatives, engaged youth leaders, climate change advocates, and the academic community.

Climate change, urbanization and biodiversity in Debre Birhan, Ethiopia

Ethiopia, with a population of 123 million in 2022, ranks among the top 15 most populous countries in the world and has a growth rate of 2.6%. Despite this, only 22.7% of Ethiopians live in urban areas. However, the country is experiencing rapid urbanization, with an urban growth rate of nearly 5% (UNCTAD, 2023). Debre Birhan city reflects Ethiopia's broader demographic trends. Like much of the country, it has been increasingly affected by the impacts of climate change, experiencing heightened climate hazards that have significantly disrupted livelihoods, ecosystems, and the local economy. A recent assessment highlights Debre Birhan's vulnerability to significant environmental challenges—such as climate change, soil erosion, biodiversity loss, and land degradation—threatening its livelihoods and overall resilience (Environment Team Study, 2024 SP).

Debre Birhan city, situated 130 km from the capital city of Ethiopia, is one of the top investment, innovation, and tourism destinations of the country. With the city's rapid growth and expansion as a result of urbanization, specifically after transition to region-politan level in 2021, it is imperative to look in to both developmental and environmental issues that impacts the lives of urban residents and take bold actions in building clean, green, compact, inclusive and resilient city while adapting the impacts of climate change. The city was selected for this MVA study due to a range of factors. The city is characterized by significant vulnerability and exposure to the impacts of climate change, urbanization trends, and biodiversity loss, highlighting the need for intervention. Furthermore, the city is the centre of internally displace people (IDPs) from different region of the country with different cultures, climate, and way of life. For the last six years there has been internal conflict in the country by different rebel groups and the government forces that result is IDPS and Bebre Birhan city is the main displacement are particularly from Oromia region, Wollega part. Furthermore, the city is a key hub for internally displaced people (IDPs) in Ethiopia, hosting individuals from various parts of the country who have been uprooted by conflict and the impacts of climate change. The majority of these IDPs are vulnerable groups, including children, women, and the elderly. Based on OCHA report, 2023 these IDPs have been suffering from flooding and cold temperature during the main rainy season. Based on OCHA, 2024, in Debre Birhan, over 23,000 IDPs reside in three camps and close to 7,700 IDPs live outside camps. While partners are providing shelter and rental support, it is not nearly enough. In addition to shelter, priority needs are food (currently at irregular distribution) and non-food items (sleeping mats and blankets, considering the cold weather in Debre Birhan). In addition, the city administration has prepared comprehensive structural plan that moves the city forward (2024-2034) and climate change impacts is one of the major issues identified for immediate intervention. The city has good experience in mobilizing local stakeholders and facilitates effective collaboration with national and international partners.

Climate change is one of the major threats in Debre Birhan with frequent flooding events, extreme temperatures resulting in heat waves and droughts among other climate hazards. The city faces diverse circumstances as it is home to a mix of residential areas, industrial zones, and commercial centres, creating a complex urban landscape. Its population has been steadily growing, placing demands on infrastructure, services, and resources. Additionally, the municipality has experienced the influx of IDPs, further shaping its demographic makeup and posing additional challenges. Rising temperatures, water scarcity, biodiversity loss, and the risk of extreme weather events are some of the climate related hazards in the city. Like many areas in Ethiopia, Debre Birhan experiences rising temperatures, leading to extreme heat events. Further climate induced issues such as susceptibility to water stress, urban flooding, and drought create substantial threat to the health and wellbeing of citizens. Vulnerable groups, such as the urban poor, women and children, IDPs are particularly susceptible to shocks and stresses in Debre Birhan.

Emperor Zera Yacob founded Debre Birhan in 1454 and established it as his royal capital. Born in Shewa, central Ethiopia, on October 4, 1398, he pursued traditional education and studied various subjects. He ruled Ethiopia from 1434 to 1468, spending 12 of his final 14 years in Debre Birhan. Debre Birhan was the first permanent town in the medieval history of Ethiopia. Its current name, Debre Birhan is believed to have been bestowed during Emperor Zera Yacob's reign, inspired by a miraculous light said to have appeared near the site of the present-day Debre Birhan Selassie Church.

Source: Debre Birhan City, Ethiopia , (c) DB city communication office

02

CITY CONTEXT ANALYSIS

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Location and geography

Debre Birhan Regio-Politan city is one of the fastest-growing emerging cities in Ethiopia, located 130 kilometers northeast of Addis Ababa, the capital (Figure 2). It is situated in the North Showa zone of the Amhara National Regional State, and is approximately 693 kilometres from the regional capital city, Bahir Dar. Currently, the city serves as the seat of Northern Showa Zone Administration. Over the past few years, Debre Birhan has experienced a rapid and dramatic increase in population, becoming a key hub for investment, business activities, residential developments, and industrial growth. As a result of this unprecedented boom and significant transformation, the city was granted Regio-Politan status by the Amhara National Regional State Council in 2021. The city has expanded both in administrative area that is approximately 124,245 hectares—and in population size, projected to be around 436,711 in 2024. Notable physical changes have also been observed in the last decade, leading to the city's reorganization into five sub-cities with 24 urban and 13 peripheral sub-urban rural kebeles (Figure 3).

The topography of Debre Birhan is dominated by different landscape features. The city's centre and built-up area begin around Selassie Church and extend along the main highway leading to Addis Ababa, Jiru, Ankober, and Dessie. Situated on a plateau within the central Ethiopia highland system, the city lies approximately 15km west of the Great Rift escarpment, at an average elevation ranging between 2,800 to 2,845 meters above sea level. The city is located at 9°45'N latitude and 39°31'E longitude with mean minimum and maximum temperatures ranging from 6.6 to 24°C and an average precipitation of 964 mm. The landscape is generally characterized by variations in elevation, with 86% of the city being relatively flat, followed by valleys (10%), and mountains (4%).

The predominance of flat terrain facilitates horizontal development, positively impacting expansion areas, accessibility, and transportation. This topographical advantage also contributes to lower construction costs for buildings and streets, as well as improved proximity to social and urban services.

The slope in percent of Debre Birhan Regio-Politan city is classified into five classes as follows (Figure 3): slopes less than 5, between (5-10), (10-15), (15-30), and greater than 30 % were approximately 46886.84 ha (36.86%), 36141.42 ha (28.41%), 16714.79 ha (13.14%), 22061.66 ha (17.35%), and 5386.99 ha (4.24%) portion of the city, respectively.

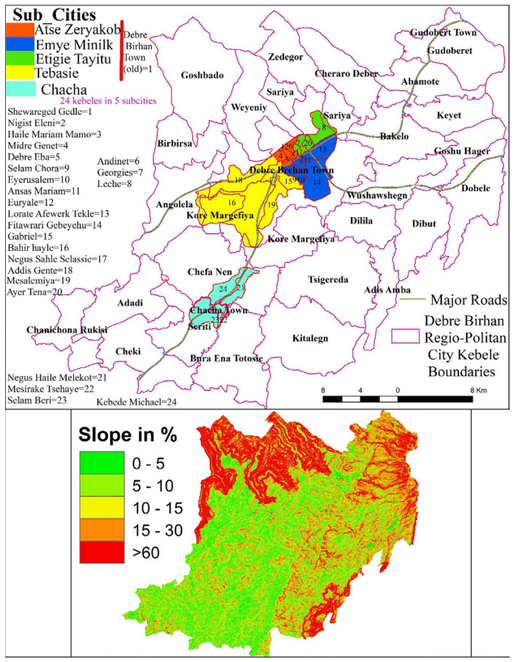


Fig. 2: Debre Birhan regio-politan city sub-cities, kebeles and slope analysis.

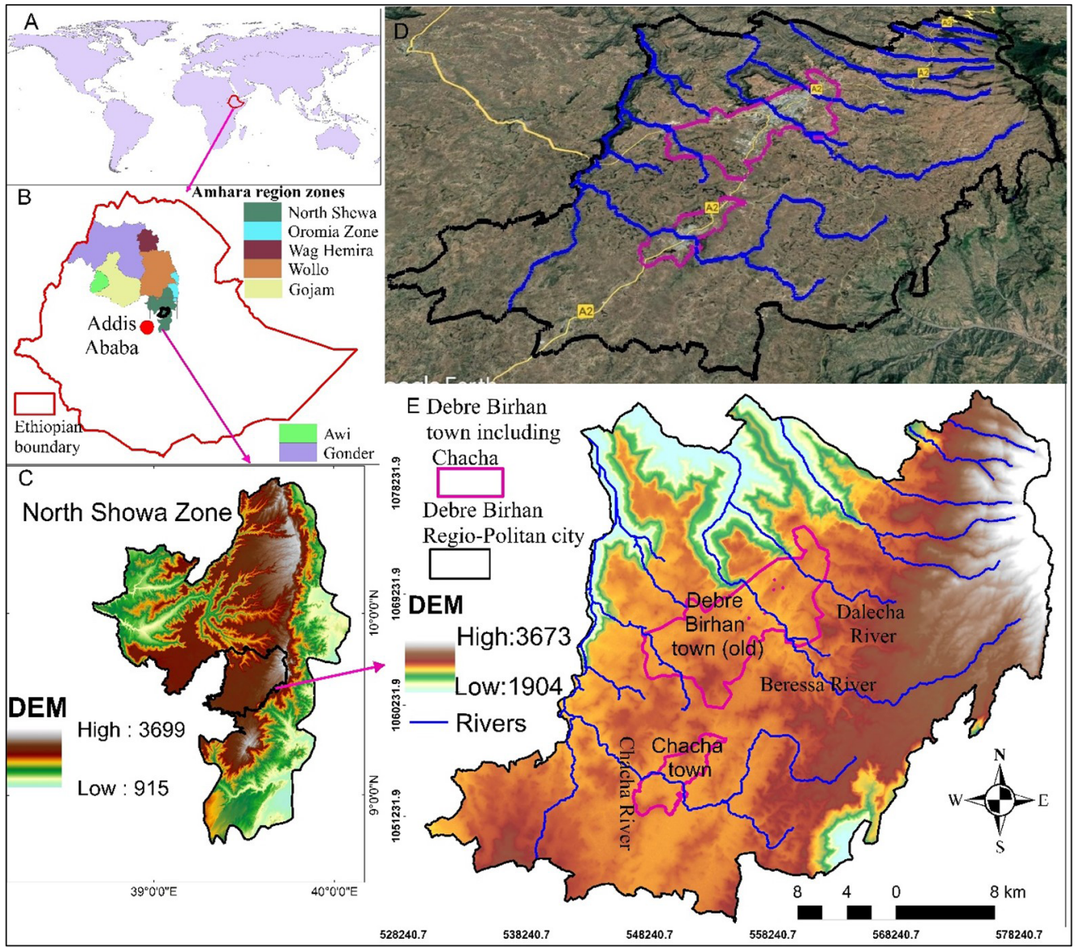


Fig. 3: Regional Land Administration in Amman Governorate as Perceived by MOLA

History of city development and growth

Debre Birhan is one of Ethiopia's oldest cities, established in 1454 and has been a centre of geopolitical activity. However, despite gaining municipality status in 1941, its development has lagged behind due to various factors. Over time, Debre Birhan has undergone several stages of urbanization and passed through several master or structure plans. The first Structural Plan (SP) was prepared in 1972/73 with a 20-year outlook, followed by a second plan prepared by the National Urban Planning Institute (NUPI) in 1996, covering 1996-2014. The third SP was prepared in 2014 and covered 10 years from 2014 to 2023. The new SP is expected to guide the city's dynamics in the following 10 years. The fourth Structural Plan is currently in preparation and will steer the city's development from 2024 to 2034.

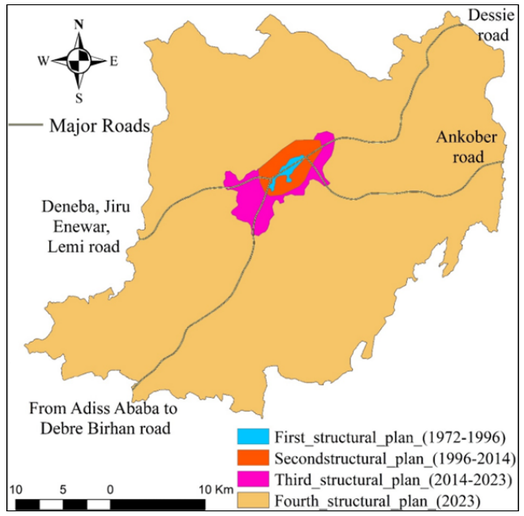


Fig. 4: Area coverage of previous master plans and the current map.

Demographics

According to the Ethiopian Central Statistical Agency, Debre Birhan's population was 25,635 in 1984, 38,717 in 1994, 65,231 in 2007, and 310,254 in 2021. Recent population growth, driven by high investment and the inclusion of new rural kebeles, has significantly increased the city's population. A 2024 study by the city administration estimates the population at 436,711 across 24 urban and 13 rural kebeles (Table 1, Figure 3). This growth led to Debre Birhan gaining "Regio-Politan" status in 2021, as designated by the Amhara Regional State.

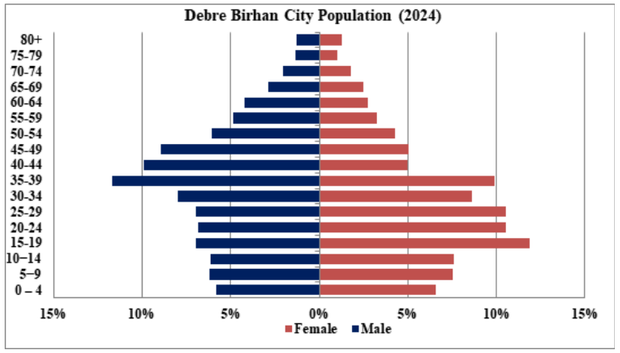
Table 1. Population trends in Debre Birhan (2021-2024)

Year	Total Population								
	Number			Percentage		Urban		Rural	
	Total	Male	Female	Male	Female	Number	Percent	Number	Percent
2021	310,254	142,710	167,544	46	54				
2022	404,089	195,945	208,144	48	52	316,886	78	87,203	22
2023	420,924	203,856	217,068	48	52	333,203	79	87,721	21
2024	436,711	211,283	225,428	48	52	348,399	80	88,312	20

Source: Socio-economic team, Debre Birhan SP project office

The 2024 population includes 211,283 males (48%) and 225,428 females (52%). Urban residents account for 80% of the population (348,399), while rural residents comprise 20% (88,312).The city's age structure has evolved, with children (aged 0-14) decreasing from 26% in 2021 to 20% in 2024. The working-age population (15-64 years) has risen from 69% to 73% in the same period, while the elderly population (65 years and above) increased from 5% to 7%.

Fig. 5: Age-sex distribution of Debre Birhan in 2024.



Source: Socio-economic team, Debre Birhan SP project office

Table 2. Crude Population Density in 2023

	Population		Area in sq. km		Population Density per sq. km	
Year	Urban population	Rural population	Urban	Rural	Urban	Rural
2023	333,203	87,721	87	1,155	3,835	76

In 2022, Debre Birhan's urban population density was 3,835 people per square kilometer, while the rural population density was 76 people per square kilometers.

Population projections

Debre Birhan's average annual population growth rate between 2022 and 2024 was 2.5%, with urban growth at 3.3% and rural growth at 0.5%. By 2034, under high-growth scenarios, the city's population is projected to reach 690,477, with 91.3% of residents living in urban areas.

Key economic sectors

Debre Birhan's economy is driven by government employment, small and micro-enterprises, and service industries such as transport and hospitality. Key sectors include agriculture, manufacturing, tourism, construction, and communication.
Areas of significant economic growth include manufacturing and tourism, supported by the city's cultural and religious heritage. However, challenges remain, such as poor coordination between sectors, underutilization of historical assets, income inequality, and low environmental awareness.

Environment, biodiversity and climate

Debre Birhan city is endowed with rich natural resources and a diverse ecosystem that provide numerous benefits to both residents and the environment. However, like many rapidly urbanizing and industrializing cities, it faces significant ecological challenges, including the degradation of natural habitats, pollution, and loss of biodiversity. Studies highlight critical issues such as land degradation in the upper catchment areas, biodiversity loss, and pollution of rivers and groundwater potential zones. Key drivers of these environmental issues include poor solid and liquid waste management, improper handling of environmentally sensitive areas such as wetlands, deforestation along rivers and upper catchments, unmanaged urbanization, and limited awareness among residents and city administrators.
The environmental consequences are profound, manifesting in degraded water quality for drinking and urban agriculture, biodiversity loss, flooding, gully formation, high sediment loads in the Beresa River, and soil and groundwater contamination.
Despite these challenges, Debre Birhan is home to a rich array of wildlife, including endemic species like the Ethiopian Wolf and the Gelada Baboon.
The city's climate zones are also diverse, with three distinct zones identified: Weyna Dega (midlands), Dega (highlands), and Wurch (upper highlands) (Figure 6). The Dega zone covers the largest portion of the city, accounting for 82.8% of the area, with an average temperature of 11-17°C and crops such as barley, wheat, highland oilseeds, and pulses being prominent. The Wurch zone, which covers 5.8% of the city, experiences cooler temperatures below 11°C, with barley and grazing pastures dominating its agricultural landscape. The Weyna Dega zone, with an average temperature of 17-20°C, covers 11.4% of the city and is characterized by the cultivation of crops like maize, sorghum, teff, rice, wheat, and barley.

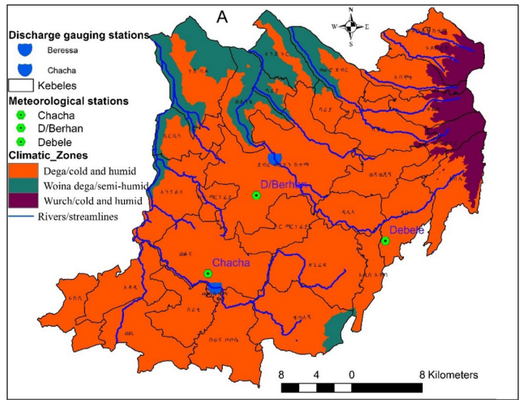
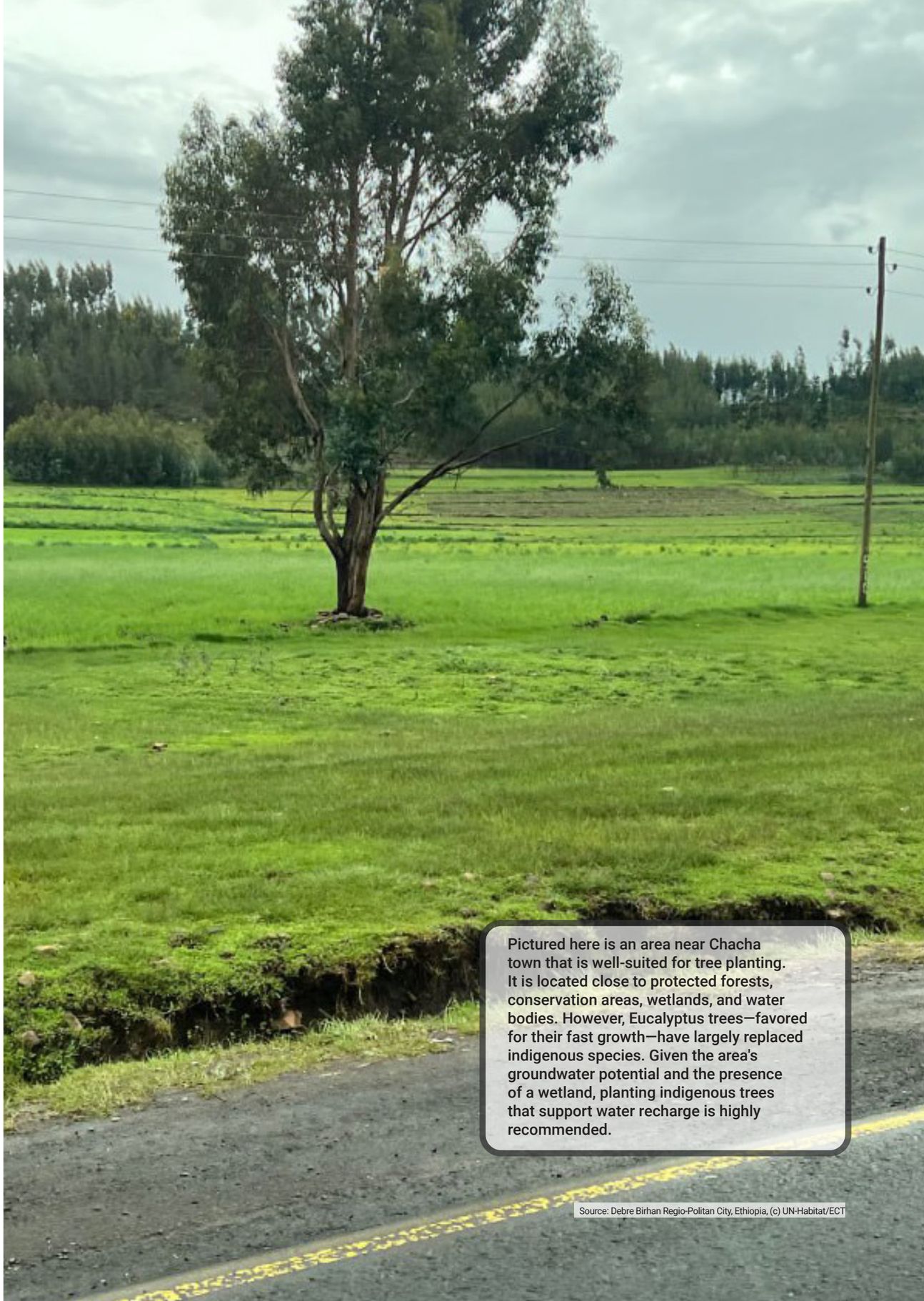


Fig. 6: Climate zones of Debre Birhan Regio-Politan City.

The identification of conservation sites and critical environmental challenges is essential for the city's structural planning. While detailed data on conservation sites is limited, there are existing plantation forest sites in kebeles such as Keyete, Gudeoberte, Goshu Hager, and Wushawushegn, as well as reservoirs, wetlands, rivers, and scenic landscapes that offer potential for biodiversity conservation and ecotourism. These areas could be leveraged to enhance biodiversity in the watershed and support local livelihoods through ecotourism.
However, the city's watershed is highly vulnerable to climate change, soil erosion, and land degradation. Current trends and projections indicate an increasing risk of drought, heavy precipitation, and flooding, exacerbated by inadequate infrastructure. Rising temperatures have already led to water shortages, increased evapotranspiration, reduced soil moisture, and discomfort for the population. High precipitation and streamflow variability necessitate climate-smart biological soil and water conservation measures to regulate water flow and support species regeneration in the watershed. Without effective adaptation measures, these extreme hydro-climatic impacts could reverse development progress in the city.



Pictured here is an area near Chacha town that is well-suited for tree planting. It is located close to protected forests, conservation areas, wetlands, and water bodies. However, Eucalyptus trees—favored for their fast growth—have largely replaced indigenous species. Given the area's groundwater potential and the presence of a wetland, planting indigenous trees that support water recharge is highly recommended.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Observed precipitation

The annual average precipitation of Debre Birhan (1986-2022), Chacha (1986-2022), Debele (2000-2022), and the average of the three stations showed high variability as indicated in the following Figure 7. The annual precipitation for the three stations ranged from 648.3 to 1126 mm and the overall annual mean precipitation was 896.1 mm. According to the MK test, the three stations' annual precipitation showed an insignificant decreasing trend with the rate (Sen's slope) of -1.3 mm. The annual precipitation of Chacha station exhibited the highest insignificant decreasing trend with a rate of -4.5 mm, whereas Debre Birhan and Debele stations showed insignificant increasing trends with a rate (Sen's slope) of 2.05, and 0.22 mm, respectively. Generally, it can be noted that the annual precipitation trend of Debre Birhan Regio-Politan City from (1986-2022) has generally been insignificant, in contrast to the temperature.

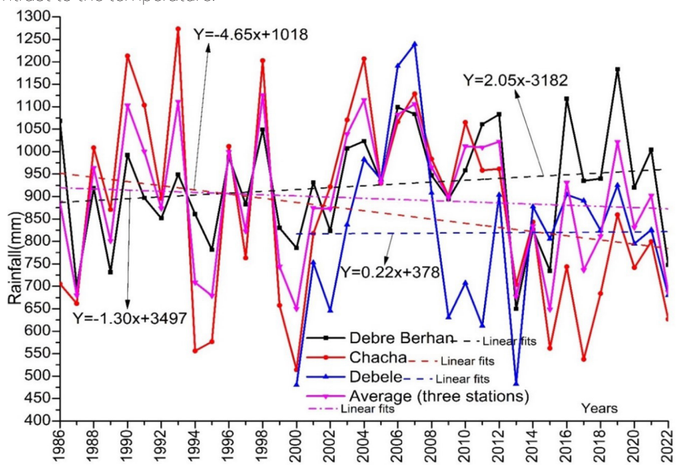


Fig. 7: Annual precipitation pattern of Debre Birhan, Chacha, Debele, and the average of the three stations.

Environmental quality in Debre Birhan city

The environmental quality of Debre Birhan City is under significant strain due to various interconnected challenges. As the city emerges as an industrial hub for the country, rapid and unregulated urbanization has compounded these issues. Industries are scattered without strategic planning, and most lack effective waste management systems. This has resulted in inadequate solid and liquid waste management, neglect of environmentally sensitive areas such as wetlands, deforestation in upper catchments and along rivers, and widespread environmental pollution. These challenges have far-reaching ecological consequences, including degraded water quality for drinking and urban agriculture, soil and groundwater contamination, increased air and noise pollution, and significant biodiversity loss.

Water and Soil Pollution

Recent assessments highlight significant sources of water and soil pollution in Debre Birhan city. Contributing factors include improperly managed household waste, unscientific use of fertilizers and pesticides on farmland, the rapid expansion of industries, and the improper discharge of industrial wastewater. Additional sources include human and animal excreta, untreated wastewater from households and hospitals, oil spills from garages, traditional leather processing near water bodies, and the dumping of solid waste near water sources and farmland. Furthermore, the city's rapid urban growth and extensive construction activities have exacerbated the issue, with discarded construction materials often left as residues in the soil. These pollutants have severely compromised soil fertility, resulting in decreased agricultural productivity and posing a broader threat to environmental and public health.

Water pollution is a critical issue in Debre Birhan, primarily driven by the discharge of untreated industrial and municipal wastewater into the environment. The city's rivers are not utilized for recreational or productive purposes but instead serve as dumping sites for household and industrial waste. While the upstream sections of these rivers remain relatively clean, the downstream areas are heavily polluted with plastics, diapers, organic materials such as wood and vegetables, and other waste originating from households, industrial sewage, urban agriculture, and urban runoff. Environmentally sensitive areas, including wetlands and groundwater reserves, are increasingly turning into pollution sinks due to contamination from nearby residential and industrial activities. These trends threaten not only local ecosystems but also water quality and public health.

Wastewater management

Wastewater management in Debre Birhan City is severely inadequate, with no structured or safe wastewater reuse practices in place. Liquid waste is often disposed of on open land, leading to environmental degradation and public health

Source: Debre Birhan City, Ethiopia , (c) DB city communication office

risks. The issue is particularly pronounced in condominium and slum areas, where resources and reliable infrastructure are lacking. Many condominium drainage systems were constructed without connections to a central wastewater treatment facility, exacerbating sanitation challenges and contributing to the city's overall poor hygiene conditions. Recently, the city administration in partnership with the World Bank is constructing a faecal sludge treatment site, which is under construction.

While some industries in Debre Birhan, such as Habesha Brewery, Dashen Brewery, and Chacha Liquor Factory, have established well-equipped wastewater treatment plants and utilize treated water for activities like backyard farming and aquaculture, many others lack proper waste management systems. Numerous factories and institutions discharge untreated waste directly into watercourses, with little regard for environmental impact. The practical measures employed to remove toxic components are often insufficient and ineffective, largely due to unwillingness to invest in more robust treatment mechanisms. Additionally, wastewater from households and commercial centers significantly contributes to environmental pollution. Waste from garages, government, and private hospitals, and various industries is frequently dumped into nearby ditches or rivers. Consequently, river water becomes heavily contaminated, depleting oxygen levels and rendering it incapable of supporting aquatic life, further exacerbating ecological degradation.

Air pollution

Although comprehensive data on air quality in Debre Birhan city is lacking, a recent assessment by the city's structural plan preparation team has identified key sources of ambient air pollution. Major contributors include vehicle emissions, particularly from aging, fuel-inefficient diesel vehicles, and the burning of solid waste, such as expired drugs at Debre Birhan General Hospital. Additional sources include dust from unpaved roads, waste from condominiums and households, cattle waste, open trash burning, and home heating and cooking using wood or charcoal. Industrial emissions, notably from Juniper Glass and Ethal Aluminum Industries, also release toxic gases into the atmosphere. Both mobile (vehicles) and stationary (industrial) emission sources contribute to air pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), coarse particulate matter (PM10), and fine particulate matter (PM2.5). The combustion of wood and charcoal releases particulate matter, soot, and black carbon, which are potentially carcinogenic compounds.

A recent household survey (2023 baseline data) revealed that 51.5% of households rely on traditional fuels like firewood and charcoal for cooking. This widespread use of firewood and charcoal contributes significantly to indoor air pollution, posing health risks to a substantial portion of the city's population.

Noise Pollution

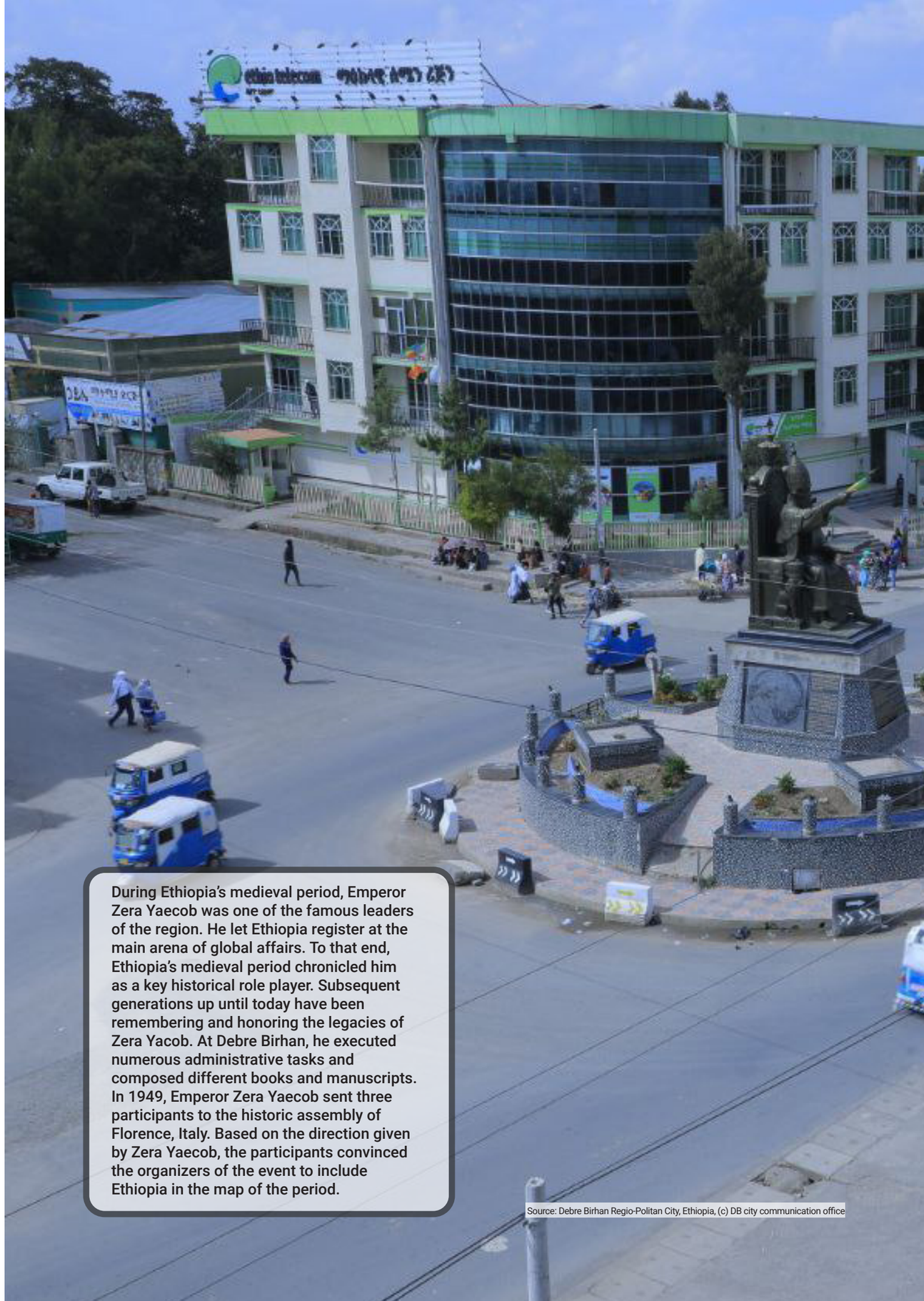
In addition to water and air pollution, noise pollution has become a significant issue in Debre Birhan, impacting public life and creating widespread challenges. An assessment by the structural planning team identified several sources contributing to elevated noise levels, including music shops, mixed-use buildings such as condominium complexes, industries, and vehicles. Notably, noise levels from music shops were found to exceed permitted standards.

Wood and ironworks, which produce loud, dissonant sounds, are ideally meant to be located at the city's periphery. However, many such activities are carried out indiscriminately across sub-cities. In condominium areas, the mixed-use buildings—combining residential spaces with noise-generating establishments like bars, music shops, and pubs—further exacerbate the problem. Although laws exist to regulate noise pollution, enforcement remains minimal, and practical measures to address the issue are lacking. This gap in implementation continues to disrupt urban life and hinder efforts to create a more livable city environment.

Aesthetic/visual pollution

Visual pollution refers to any man-made structures or elements that are unattractive and detract from a person's ability to enjoy their surroundings. In Debre Birhan, key sources of visual pollution include excessive and overcrowded advertisements, tangled and unmanaged telecommunication and electric wires and poles, poorly placed or maintained billboards, and poorly designed buildings. Other contributors include smoke-emitting factory chimneys, improper architectural designs, open trash storage, reflecting mirrors, and mismatched or inappropriate building colors. The city's streets are cluttered with a variety of advertising images, reflecting mirrors, and inconsistent building colors, but there is little awareness of their psychological impact. Studies suggest that such visual clutter can cause mental disturbances, reduce intellectual focus, and, over time, lead to mental distress and illness (Ahmadi et al., 2015). Visual contamination encompasses anything in the environment that causes discomfort or an unpleasant viewing experience (Amini and Darvish, 2015). Addressing these issues is essential for improving the city's aesthetic appeal and promoting mental well-being among its residents.

Improving the environmental quality of Debre Birhan City requires a concerted effort from all stakeholders. In 2023, the municipality allocated a significantly larger budget to the environmental department to address urban environmental issues. Additionally, promising initiatives have been launched in collaboration with partners and collaborators. However, these efforts face several challenges. Projects often lack integration, suffer from insufficient financing, and are hindered by limited community awareness and participation at the grassroots level. Poor monitoring and evaluation systems, weak implementation of the structural plan, and ineffective project management further exacerbate the situation. A lack of technical expertise and insufficient involvement of ecological experts in policy and decision-making processes remain critical obstacles. Addressing these challenges is essential to achieve sustainable environmental improvements in the city.

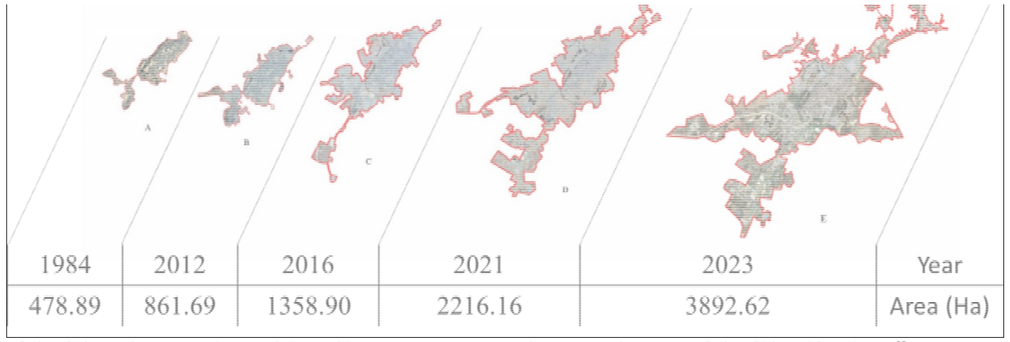


During Ethiopia's medieval period, Emperor Zera Yaecob was one of the famous leaders of the region. He let Ethiopia register at the main arena of global affairs. To that end, Ethiopia's medieval period chronicled him as a key historical role player. Subsequent generations up until today have been remembering and honoring the legacies of Zera Yacob. At Debre Birhan, he executed numerous administrative tasks and composed different books and manuscripts. In 1949, Emperor Zera Yaecob sent three participants to the historic assembly of Florence, Italy. Based on the direction given by Zera Yacob, the participants convinced the organizers of the event to include Ethiopia in the map of the period.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

Urbanization trends

Between 1984 and 2023, Debre Birhan's urban area expanded dramatically. From 1984 to 2012, the city grew by 382.8 hectares, but from 2012 to 2023, it added an additional 3,030.93 hectares, an eightfold increase (Figure 8). From 1984 to 2012, 2016, 2021, and 2023, the city's area coverage increased from 478.89ha to 861.69ha, 1358.90ha, 2216.16ha, and 3892.62ha, respectively. As mapped above the city spatial footprint is expanding very fast even well over the population increase, especially in the lasty decade.



1984	2012	2016	2021	2023	Year
478.89	861.69	1358.90	2216.16	3892.62	Area (Ha)

Fig. 8: Debre Birhan urban expansion trend since 1984.

Source: Land use team, Debre Birhan SP project office

Physical and social infrastructure assets

The water supply system for Debre Birhan City is sourced entirely from groundwater, with 15 functional boreholes currently providing water to the city. These boreholes have an average daily production capacity of approximately 8,100 m³/day. The city's water supply scheme has been developed incrementally, beginning in 1991 and continuing through to 2022. Water from the boreholes is pumped directly into four pressure zones, including one that is under expansion, before being distributed to consumers via private yard connections and public fountains. The location of both the existing and newly drilled boreholes is illustrated in Figure 9.

The city's water distribution system consists of a network of pipelines, including primary, secondary, and tertiary pipes. According to data from the city's water and sewerage office, the distribution network comprises PVC (Polyvinyl Chloride) pipes with diameters ranging from 32 mm to 350 mm (Figure 10). As sanitation systems, most of the buildings and houses in the city use septic tanks and pit latrines.

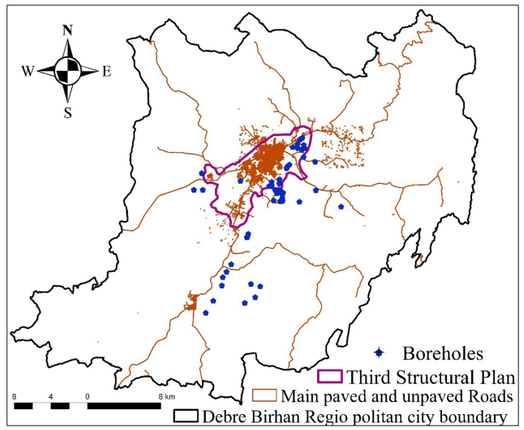


Fig. 9: Boreholes, main unpaved and paved roads.

Source: Infrastructure and utility team, Debre Birhan SP project office

This is Zara Yaqob Square (Adebabay), located at the center of the city, and named after King Zara Yaqob. The area is close to Zara Yaqob Palace and Debre Birhan Selassie Church.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

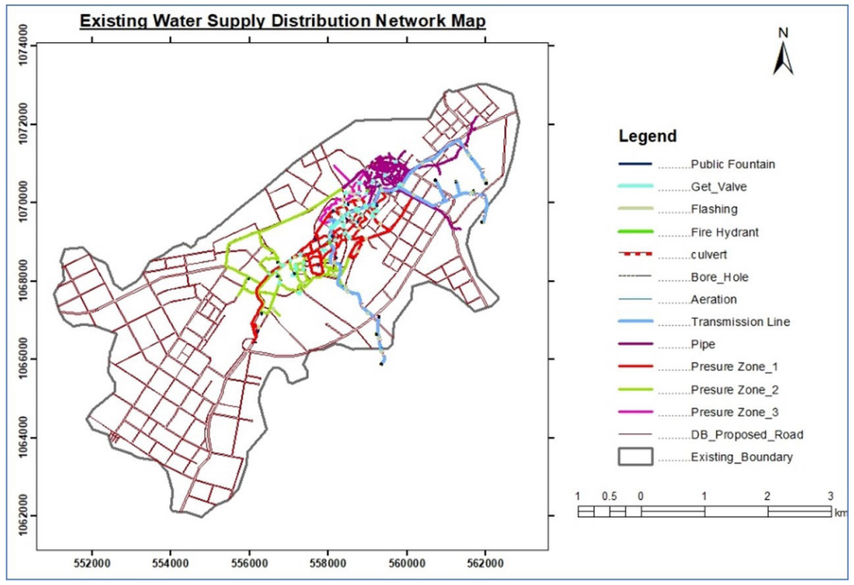


Fig. 10: Third structural plan based water supply network line of old Debre Birhan town.

Source: Infrastructure and utility team, Debre Birhan SP project office

Debre Birhan's healthcare infrastructure faces several significant challenges. The city's health care facilities are inadequate, poorly distributed, and often in a state of disrepair. The healthcare delivery system is inefficient, heavily skewed towards curative services, and lacks coordination. It is also highly centralized, with limited local participation and involvement of the private sector or community beneficiaries. The city suffers from acute shortages in both human and material resources, and the available resources are not efficiently utilized.

Educational infrastructure in Debre Birhan includes pre-primary, primary, secondary, and tertiary institutions. However, assessments indicate that the distribution of schools is uneven across sub-city levels, with some areas being underserved. Moreover, many schools are constructed from mud, wooden and straw materials that are vulnerable to flood events. Moreover, schools or houses are earthen with traditional design and in plain areas that make them vulnerable to flooding. Building materials can quickly degrade when exposed for prolonged periods to water Therefore, raising awareness about house design and material to ensure all house materials or elements are securely fastened together and firmly anchored to the foundation to be resilient to flooding is vital.

Debre Birhan is also home to several environmentally sensitive areas, including dams, rivers, and wetlands.

These water-rich regions are critical not only for the city's water supply but also for maintaining local biodiversity and environmental health. Proper management and conservation of these areas are essential for sustaining the city's natural resources.

Dams: There are two dams for agricultural purposes in Debre Birhan City, which are negatively impacted by surface runoff, flooding, and sedimentation, as well as the disposal of liquid and solid waste from nearby villages. The accumulation of sediments from the surrounding highlands, carried by runoff and floods, contributes to the reduction of the dams' area coverage and depth.

Rivers: The Rivers within Debre Birhan City administration include the Chacha, Beresa, Dalecha, Gunagunit, and Mush rivers. The rivers are meandering and perennial type with inconsistent depth and width. These rivers are highly vulnerable to human activities and are experiencing increasing levels of pollution from various sources, such as poor waste disposal practices by individuals, households, industries, and the wider community. The areas along the riverbanks are seasonally affected by flooding, erosion, and sedimentation, which can damage agricultural lands, crops, and even residential buildings near the rivers.

Wetlands and groundwater well fields: Several wetlands in the city are also highly sensitive to both natural factors (e.g., climate change) and human activities (e.g., overgrazing and conversion into farmlands by local farmers). While relatively protected, these wetlands are still open to grazing and animal husbandry, leaving them vulnerable to degradation. Without proper management and conservation efforts, these wetlands risk losing their ecological value, diminishing biodiversity, and reducing their overall benefit to the community.

A major concern for Debre Birhan Regio-Politan City is poor liquid waste management, which poses significant threats to public health and the natural environment. Both on-site and off-site wastewater management require urgent improvements. The city lacks proper facilities for wastewater treatment and disposal, and the absence of a designated disposal site further exacerbates the issue. The city's sanitation infrastructure is generally inadequate and in need of significant upgrades.

Institutional and policy frameworks

Organizational structure of Debre Birhan city administration

Debre Birhan (DB) city administration's organizational structure was recently modified by having 1 urban level government, 5 Sub cites and 37 Kebeles (the lowest government structures in Ethiopia). The City administration is accountable and responsible to the city council. It is empowered to control and mange different offices and sectors through decentralized form of governance. The council mayor system of governance allows it making local policies and major decisions at local level by the city council. The overall organizational structure is shown below.

The City Council (CC) is comprised of members elected through free, direct, fair, and anonymous elections for a five-year term. They are elected by voters within a city. The number of voting districts or representatives from adjacent satellite towns determines the size of CC membership. The size of CC membership is determined by the number of voting districts or representatives from adjacent satellite towns/kebeles. The Amhara National Regional State (ANRS) city proclamation mandates a minimum council size of eleven members. The CC is responsible for overseeing the executive functions of the Urban

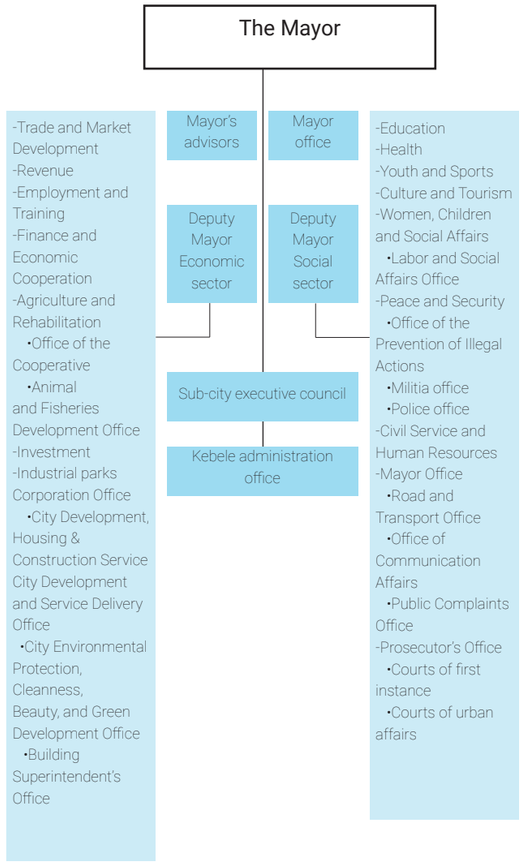


Fig. 11: Debre Birhan city administration government service institution's organizational structure

Center. The mayor, as the chief executive and chairman of the mayor's committee, along with representatives from the city administration, is elected from among the city council members, following the recommendation of the majority political party or coalition. The Mayor and Mayor's Committee serve as the primary body overseeing day-to-day activities in Urban Centers. They play a pivotal role in the preparation and implementation of urban planning. The mayor's office also has vast power to dispose of its executive leadership.
The sector offices also have common duties and responsibilities in their respective jurisdiction. It is expected of them to cause the proper implementation of laws, the federal & regional governments, policies and directives and that the city administration issues as well as the decisions. In addition, they are required to submit periodic work plans, performance and financial activity reports to the mayor and to the city administration.

Source: Debre Birhan City's current administrative building,Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

Powers and duties of Debre Birhan city administration

According to article 11 of proclamation No.245/ 2017, Debre Birhan City Administration as an urban centre possesses a range of powers and duties. These include the authority to issue local regulations and directives, as well as executive and judicial powers over city-related affairs, in accordance with the constitution and other laws. The proclamation also vested power relating to plan preparation. It provides that any urban administration, in as far as its capacity allows have the authority to prepare or cause to be prepared and to approve through its council and to follow up its implementation its own city plans following the planning principles and standards laid down for the purpose by the regional state (Article 85 of Proclamation No. 245/2017). The proclamation also states that urban residents shall have the right to participate in all stages of the planning process.

Kebele administration

In the new structure of Debre Birhan city, there are 37 (24 urban and 13 peri-urban) kebeles by which each kebele has its own council. Each kebele administration also has legislative, executive, and judiciary organs. An elected council represents every kebele, and since these councils create the CC, the CC is the outcome of the kebele council elections. Sub-cities or kebele administration have a direct line of communication with the local populace and can act as a gateway for initiatives and programs to be implemented correctly. However, they are constrained by material, personnel, and financial capacities to plan, execute, and implement development programs at the local grassroot level.

Institutional set-up for urban Environmental Management:

In Debre Birhan Regio-Politan City, the Environmental Protection, Cleanness, Beauty, and Green Development Office is the primary body responsible for managing urban environmental issues. This office operates through three key departments at the city level: the Pollution Control and EIA Evaluation Team, the Green Development Monitoring and Control Team, and the Solid Waste Disposal Team. At the sub-city level, two departments oversee green development and solid waste management.

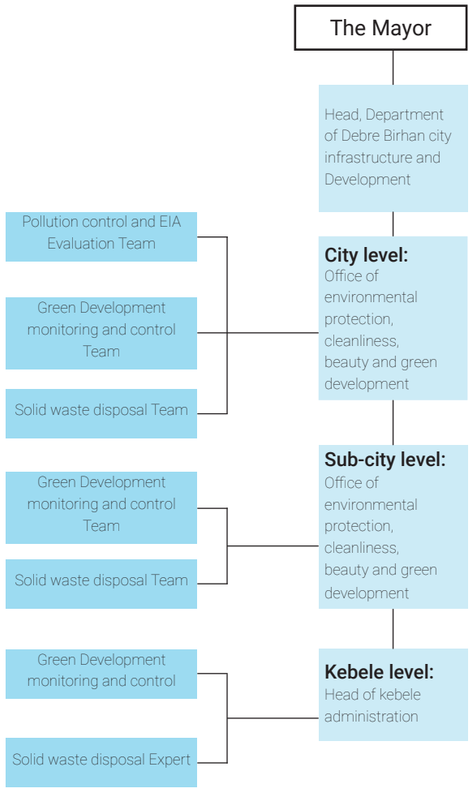


Fig. 12: Organizational structure of green development, monitoring, and control in Debre Birhan City.

While the office has, clear legal mandates and authority to achieve its objectives, its organizational structure has not yet been extended to the Kebele level (Figure 12).

Some of the legal frameworks and policy documents guiding climate action in Ethiopia and Debre Birhan include:

1. Third National Communication to the UNFCCC (2023)
2. Nationally Determined Contribution (2021)
3. Ethiopia's National Adaptation Plan (2019)
4. Ten Years Development Perspective Plan (2021-2030)
5. Ethiopia's Vision for a Climate-Resilient Green Economy (CRGE) by 2025
6. Climate Change Education Strategy of Ethiopia (2017-2030)
7. The Vision of the Urban Sector in Ethiopia in 2035 (NUDSP, 2016)
8. Ethiopian Cities Sustainable Prosperity Goals (ECSPGs) - 2025
9. Debre Birhan City Structural Plan, 2024

Source: Debre Birhan City Future Administrative Building design, Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

Constitution of the federal democratic republic of Ethiopia

The Constitution of the Federal Democratic Republic of Ethiopia (FDRE) is the foundation for all development-related policies, laws and related outcomes within the country. The Constitution creates a governance structure comprising of the Federal Government and member States with clear division of powers and functions (Chapter Five of the FDRE constitution). The Federal Government is responsible for, inter alia, formulation and implementation of the country's policies, strategies and plans in respect of overall economic, social and development matters; national standards and policies for public health; and enactment of national laws for the utilization and conservation of natural resources. In this regard, the formulation of environmental policies, laws and standards fall within the domain of the Federal Government. The States (including the two city administrations) on the other hand are obligated to administer the environment and natural resources in accordance with Federal laws. The Federal Constitution guarantees every person in Ethiopia the right to a clean and Healthy environment (Article 44 (1) of the Constitution). For the attainment of this right, the Constitution outlines the following four environmental objectives (Article 92 of the Constitution):

- Government shall endeavour to ensure that all Ethiopians live in a clean and healthy environment.
- The design and implementation of programs and projects of development shall not damage or destroy the environment.
- People have the right to full consultation and to the expression of views in the planning and implementation of environmental policies and projects that affect them directly.
- Government and citizens shall have the duty to protect the environment.

Environmental policy of Ethiopia

The overall goal of the policy is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through sound management and utilization of natural, human-made and cultural resources and the environment. The policy outlines several specific objectives, key among them being the prevention of pollution to land, air and water in the most cost-effective way. Among the key policy statements is that environmental laws should be consistent with Article 44 of the Constitution and assure all people living in the Ethiopia of their fundamental right to an environment adequate for their health and well-being. The Environmental Policy provides a number of guiding principles that require adherence to the general principles of sustainable development.

Environmental impact assessment proclamation

This Proclamation (Proclamation No. 299/2002) establishes the framework for assessment of possible impacts on the environment, prior to the approval, of social and economic development projects by providing an effective means of harmonizing and integrating environmental, economic, cultural and social considerations into a decision-making process in a manner that promotes sustainable development. It obligates all persons engaged in any project that requires environmental impact assessment (EIA) as determined in a directive issued pursuant to this Proclamation, to seek authorization from the FEPA or from the relevant regional environmental agency. Such authorization is only grantable upon submission by the project proponent of an EIA study report, which as a minimum must contain: a description of: the nature of the project, including the technology and processes to be used; the content and amount of pollutant that will be released during implementation as well as during operation; source and amount of energy required for operation; information on likely trans-regional impacts; characteristics and duration of all the estimated direct or indirect, positive or negative impacts; measures proposed to eliminate, minimize, or mitigate negative impacts; contingency plan in case of accident; and procedures of self-auditing and monitoring during implementation and operation.

Upon review of the EIA study report, and taking into account public comments, the FEPA or the regional environmental agency may make any of the following decisions:
a) Approve the project without conditions and issue authorization if it is convinced that the project will not cause significant negative impacts;
b) Approve the project and issue authorization with conditions that must be fulfilled in order to


Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

eliminate or reduce adverse environmental impacts or reduce adverse impacts to insignificance if it is convinced that the negative impacts can be effectively countered; or
c) Refuse implementation of the project if it is convinced that the negative impact cannot be satisfactorily avoided.

The FEPA or the relevant regional environmental agency is mandated with monitoring the implementation of an authorized project in order to evaluate compliance with all commitments made by, and obligations imposed on the proponent during authorization. Violations of the provisions of the Proclamation and/or conditions of authorization amount to offenses punishable by administrative action and/or imposition of fines.

Environmental pollution control proclamation

This Proclamation (Proclamation No. 300/2002) aims to eliminate, and where not possible, mitigate the impacts of pollution as an undesirable consequence of social and economic development activities. This regulation to prevent industrial pollution was developed by the Federal Environmental Protection Authority to ensure compatibility of industrial development with environmental conservation. This Proclamation includes comprehensive industrial pollution standards for a range of industrial and mining activities. It prohibits persons/institutions from engaging in any activities that pollute the environment by violating the relevant environmental standards. The proclamation requires ongoing activities to implement measures that reduce the degree of pollution to a set limit or quality standard. Thus, one of the dictates of the proclamation is to ensure, through inspection, the compliance of ongoing activities with the standards and regulations of the country through an environmental audit.

The Federal EPA or the relevant regional environmental agency, may take administrative or legal action against a person/institution who violates the law by releasing any pollutant into the environment. Persons/ institutions engaged in any activity, which is likely to cause environmental pollution is required, upon a decision to that effect by the EPA or the relevant regional environmental agency, to install appropriate technology that avoids or reduces, the generation and emission of pollutants.

Ethiopian water resources management proclamation

The conservation, utilization and development of water resources in the country at present is regulated by the Water Resources Proclamation (Proclamation No. 197/2000) and the water resources regulation (Regulations № 115 of 2005). The Proclamation 197/2000 ensures that the water resources of the country are protected and utilized for the highest social and economic benefits of all citizens, to supervise that they are duly observed, and to ensure that harmful effects of water are prevented and that management of water resources is carried out properly. This Proclamation protects water bodies from improper disposal of wastes originating from various sources. Among other articles, the proclamation clearly indicates requirements on watershed management and prevention of harmful effects on water resources in the articles 24 and 25 of the proclamation. The supervising body (the Ministry Water and Energy), in collaboration and in consultation with the appropriate public body (Ministry of Agriculture and Ministry of Irrigation and Lowland Development) may:

- Delimit the boundaries of the watersheds of certain water bodies;
- Prohibit clearing and cutting trees or vegetation and construction of residential houses within the delimited banks of water bodies;

The appropriate public bodies would, before allowing or causing the founding of towns or villages, request the supervising body for technical advice in order to prevent or avoid damages, adverse impacts or accidents which may occur as a result of floods and other factors related to water.
The Water Resources Proclamation aims to ensure that the water resources of the country are duly conserved and protected from harmful effects and utilized for the highest social and economic benefits of the country. The proclamation prohibits the release of any waste that endangers the lives of humans, animals or plants into water bodies. In addition, it prohibits watershed deforestation and vegetation clearance, which degrades the water resources.
Related to the utilization of water resources, the proclamation establishes a system of water resource utilization based on permits. It states that a water use permit may be terminated or suspended if the water resource in use is temporarily or permanently depleted, or if the usage of the water resource has caused negative impact on the environment.


Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

The aims of this law are as follows: (a) to conserve and protect the water resources and river system for the beneficial utilization of the public; (b) to enable smooth and safe waterways navigation along rivers and stream; (c) to contribute to the development of the state economy through improving water resources and river system; and (d) to protect environmental impact.

Health Policy of Ethiopia

The health policy lists several priorities; inter alia, the promotion of environmental health and occupational health and safety. One of the general strategies for achieving these priorities is the prevention of environmental pollution with hazardous chemical wastes. These include appropriate waste management strategies.

Sustainable Land Management and Soil and Water Conservation Policy, Strategy and Manuals

In addition to issuing policies and strategies, the government of Ethiopia has also put in place institutions that are responsible for guiding the implementation of these policies and strategies formulated to achieve environmental goals. In 2013, the government established the Environment, Forest, and Climate Change Ministry, which was restructured in 2018 to function as a Commission. Currently, it is split into two institutions (Environmental Protection Authority and Forest Development) with the former having regulatory responsibilities concerning the environment, and the latter with a mandate to lead the forestry sector development including restoration of degraded landscapes, increase forest cover, reduce deforestation, and thereby contribute to the mitigation of and adaptation to climate change. In fact, not only the environment and forest institutions, but also all sectoral ministries are obliged to include climate change mitigation and adaptation plans in their respective work plan as elaborated in the CRGE strategy. Regional bureaus are also expected to do the same. Ethiopia has established the CRGE Facility to coordinate the mobilization of financial resources needed to implement priority climate and environmental interventions. The facility has enabled Ethiopia to access funds from bilateral and multi-lateral development partners (GCF 2016). For instance, Ethiopia is one of the few countries that secured funds for its large-scale REDD+(Reducing Emissions from Deforestation & forest Degradation) Investment Programme. REDD+ is a global policy framework under the UNFCCC for climate change mitigation in the forest sector.

- •Ethiopia's Climate Resilient Green Economy (CRGE) CLIMATE RESILIENCE STRATEGY AGRICULTURE AND FORESTRY. FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA.
- •Green Legacy Initiative for Sustainable Economic Development in Ethiopia

The mass tree-planting program called the Green Legacy Initiative (GLI) was launched by the Prime Minister of Ethiopia in 2019 with the objective of restoring degraded lands, increase the forest cover and reduce the impact of climate change.In addition to the CRGE, GLI, and the GTP II, the other principal climate relevant policies and strategies are:

- • National Adaptation Plan of Action (NAPA),
- •Nationally Appropriate Mitigation Actions (NAMAs),
- •Climate Resilience Strategy: Agriculture and Forestry (2015),
- •Intended Nationally Determined Contribution (INDC), 2015,
- •Environmental Policy (1997),
- •National Energy Policy (1994),
- •Ethiopian Programme of Adaptation to Climate Change (2010),
- •REDD+ strategy,
- •National Policy and Strategy on Disaster Risk management, 2013.
- •THE SUSTAINABLE DEVELOPMENT GOALS (SDGS) AND AFRICA'S AGENDA 2063
- •Goal 6 (Clean water and sanitation), 11 (sustainable cities and communities) and 13 (Climate action), and 15 (life on land, minimize degradation, drought)
- •Haile, M. (2006). Sustainable Land Management: A New Approach to Soil and Water Conservation in Ethiopia. https://www.semanticscholar.org/paper/Sustainable-land-management%3A-A-new-approach-to-soil-Mitiku-Herweg/95fe3878c19f8514ff21d89a367b778b47479739
- •Lakew Desta, Carucci, V., Asrat Wendem-Ageňehu and Yitayew Abebe (eds). 2005.
- •Community Based Participatory Watershed Development: A Guideline 1, 2. MoARD. Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

Source:Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

A Guideline 1, 2. MoARD. Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia. https://www.yumpu.com/en/document/view/37942194/community-based-participatory-watershed-development
César, E. Ekbom, A. (2013). Ethiopia Environmental and Climate Change Policy Brief. Sida's Helpdesk for Environment and Climate Change.
Garfias Royo Margarita, Loan Diep, Dr Joe Mulligan , Pascal Mukanga , Dr Priti Parikh, Linking the UN SDGs and African Agenda 2063: Global goals and local priorities for Africa, World Development Sustainability (2022), doi: https://doi.org/10.1016/j.wds.2022.100010
Bekele, M., Gebre, Y., Mohammed, Z., Zewdie, S., Tebikew, Y., Brockhaus, M. and Kassa, H. (2015). The context of REDD+ in Ethiopia: Drivers, agents and institutions, Occasional Paper 127. Bogor, Indonesia: CIFOR.
Birhanu, A. (2014). Environmental Degradation and Management in Ethiopian Highlands: Review of Lessons Learned. Journal of Environmental Protection and Policy, 2, 24-34. http://dx.doi.org/10.11648/j.ijepp.20140201.14.

There are several proclamations

Environmental protection organs establishment proclamation

This Proclamation (Proclamation No. 295/2002) establishes a system for coordinated but differentiated responsibilities among environmental protection agencies at federal and regional levels. The Proclamation establishes the Environmental Protection Authority (EPA) as an autonomous public institution of the Federal Government responsible for; inter alia, formulation, implementation and enforcement of environmental policies, strategies, laws and standards. The proclamation indicates duties of different administrative levels responsible for applying federal law. One of the duties of the EPA is to coordinate measures to ensure that the environmental objectives provided under the Constitution and the basic principles set out in the Environmental Policy of Ethiopia are realized.

Public health proclamation

The Public Health Proclamation (Proclamation No. 200/2000) aims at promoting the health of the society and creating a healthy environment for present and the future generations.

Environmental impact assessment proclamation

This Proclamation (Proclamation No. 299/2002) establishes the framework for assessment of possible impacts on the environment, prior to the approval, of social and economic development projects by providing an effective means of harmonizing and integrating environmental, economic, cultural and social considerations into a decision-making process in a manner that promotes sustainable development.

Environmental pollution control proclamation

This Proclamation (Proclamation No. 300/2002) aims to eliminate, and where not possible, mitigate the impacts of pollution as an undesirable consequence of social and economic development activities

Prevention of industrial pollution: council of ministers regulation

This Regulation (is subsidiary legislation to the Environmental Pollution Control Proclamation (Reg. No. 159/2008).

Standards for industrial pollution control in Ethiopia

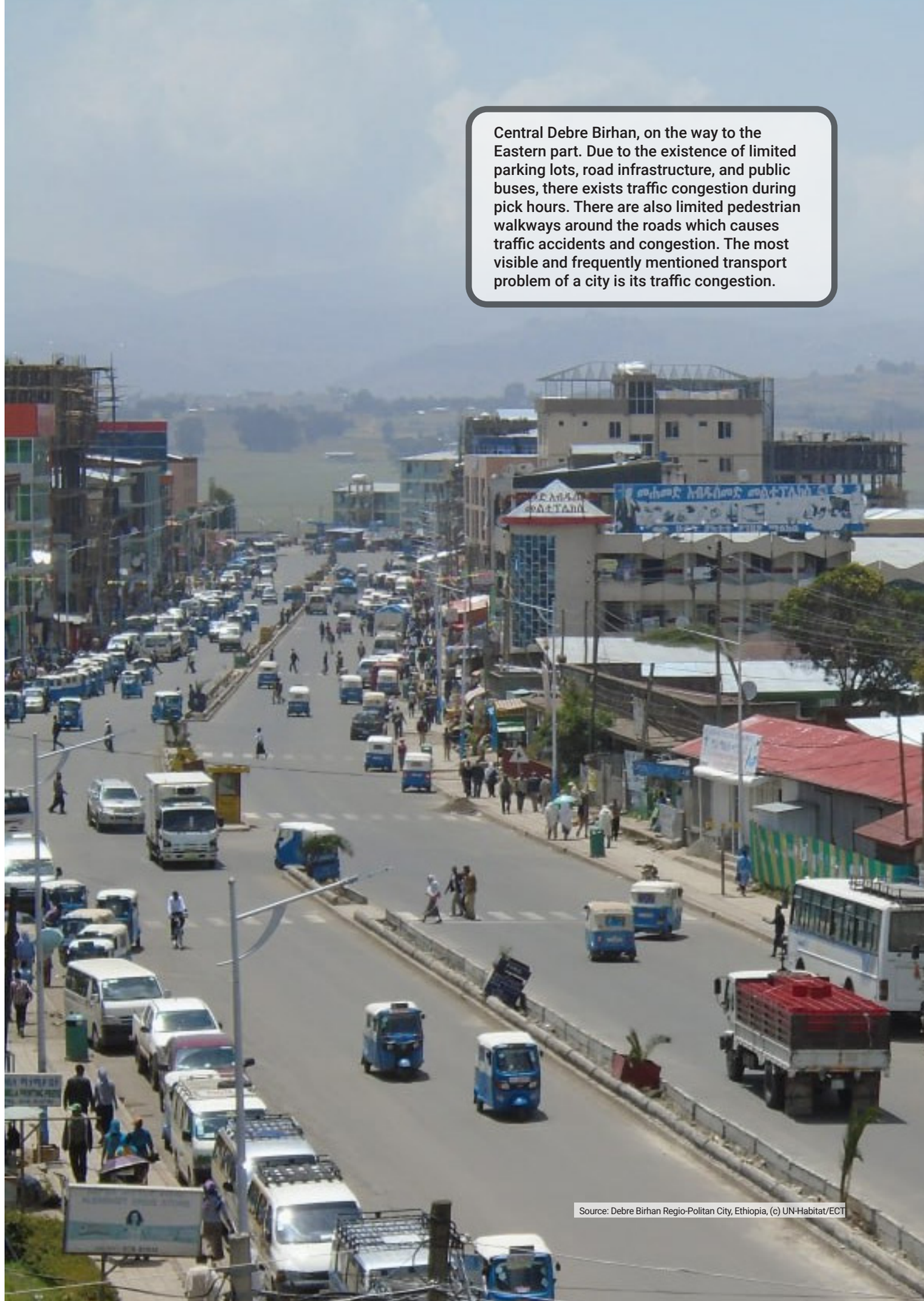
These Standards establish emission limit values for discharges to receiving water bodies in the case of effluents and to the atmosphere for gaseous emissions for manufacturing industries.

Irrigation water users' association proclamation no 841/2014

Proclamation No 841/2014 irrigation water users association proclamation issued by the legislative body

Public health law

It is concerned with protection of people's health by controlling the quality and cleanliness of food, drugs, environmental sanitation, epidemic diseases and regulation of private clinics.



Central Debre Birhan, on the way to the Eastern part. Due to the existence of limited parking lots, road infrastructure, and public buses, there exists traffic congestion during pick hours. There are also limited pedestrian walkways around the roads which causes traffic accidents and congestion. The most visible and frequently mentioned transport problem of a city is its traffic congestion.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Pesticide Registration and Control Proclamation (No. 674/2010)

The proclamation is to provide for the registration and control of pesticides which states the use of pesticides for different purposes such as for raising crops, animal breeding and the protection of public health has been growing steadily.

Lack of legal framework, policy to conserve and protect Lake, Rivers and wetlands in
Ethiopia caused degradation of those resources and loss of biodiversity (Zekarias et al., 2021)
For Debre Berhan Regio-Politan City, design conservation, rehabilitation, greenery strategy and manuals considering the key issues like
Climate and land use cover change; Invasive species; Buffer of river, lack wetland and conservation sites; Natural and anthropogenic disruption of disturbance (fire, flood, land use planning, settlement, etc.); Water quality and quantity and Data collection and database creation.

Sustainable development could only be achieved when articulated and an efficient way of eco- friendly implementation strategy is identified. This, primarily, includes the wellbeing of the environment. As the plan of action starts to be set on place, a crucial backup from legal background is needed to check basic principles are not violated.
In Ethiopia, the environmental soundness of any project and program will be checked and evaluated by Environmental Protection Authority (EPA) and/ or in the case of regions, the competent authority like EFPA. Overall, the implementation of different international, national and regional bindings, and legal guidelines must be evaluated for most development activities. The following section will describe these legal instruments for this management plan.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

03

METHODOLOGY

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Approach and methodology

The Multilayered Vulnerability Assessment (MVA) tool employs a three-stage methodology designed to help countries, cities, and communities effectively incorporate, adapt, and operationalize the assessment. This structured and phased approach facilitates improved resilience planning and decision-making. Each stage comprises specific steps and activities, outlined as follows (Figure 13):

Stage 1: Preparation

This stage focuses on establishing the groundwork for the MVA and the framework for the assessment process. Key contributors are identified, and relationships necessary for completing the MVA and analysis are established. This initial phase is crucial for ensuring that the assessment is comprehensive, well-organized, and aligned with the goals and objectives of the organization or community involved. Stage 1 consists of three steps (e.g., Step 1.1: Set up delivery team and steering committee; Step 1.2: Conduct rapid diagnostic of the city or urban area) and eight activities.

Stage 2: Mapping and Analysis

This stage involves sourcing and applying data to provide a detailed analysis of vulnerability hotspots within urban areas, examining factors related to climate change, biodiversity, and urban dimensions. The maps produced in this stage are key outputs of the MVA, allowing for the overlaying of outputs to identify and analyse areas of conflicting vulnerabilities and vulnerability hotspots. Stage 2 is articulated in five steps (e.g., Step 2.2: Data acquisition and collection; Step 2.3: Mapping historic, current, and future vulnerabilities; Step 2.5: Interpretation and analysis of vulnerability hotspots) and encompasses 19 activities.

Stage 3: Intervention Planning

In this final stage, the findings from Stage 2 are transformed into bankable projects aimed at enhancing resilience to current and future climate, urban, and biodiversity shocks and stresses. Collaborating with a diverse range of stakeholders, this stage involves developing 10 to 12 resilience-building actions that are both financially and technically feasible, addressing the intersecting vulnerabilities identified in the MVA. Stage 3 comprises three steps (e.g., Step 3.1: Visioning and objective setting; Step 3.2: Develop resilience action plans) and includes 12 activities (Figure 13).

The MVA provides a clear, phased methodology that guides countries, cities, and communities through effective resilience planning. The tool's three-stage approach; preparation, mapping and analysis, and intervention planning; provides a clear framework for systematically identifying urban vulnerabilities and transforming insights into actionable, bankable projects. This method ensures that resilience-building actions are well-targeted, feasible, and aligned with local priorities, making it a critical tool for addressing the complex challenges posed by climate change, urbanization, and biodiversity loss.

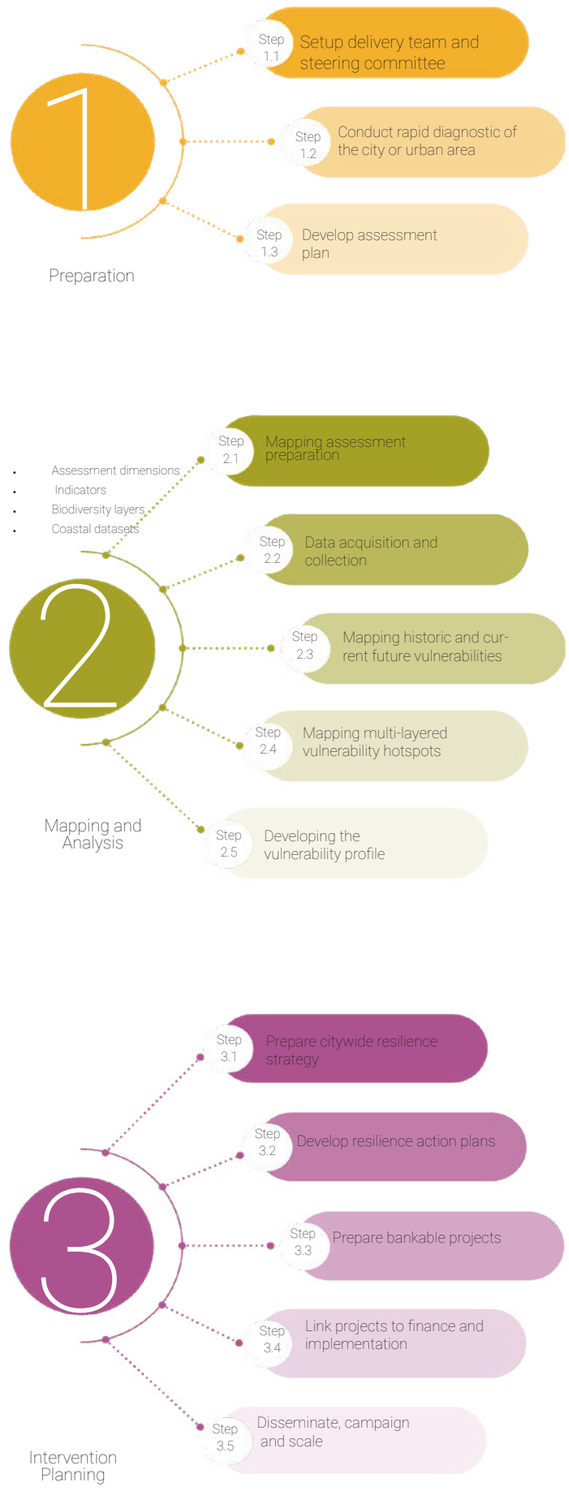


Fig. 13: Stepwise MVA analysis and three main stages from technical handbook.

Pictured here is central Debre Birhan, near the Debre Birhan Referral Hospital. The image shows several unmanaged green spaces surrounding the nearby land uses, indicating potential for improved landscaping or community use.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Vulnerability assessment

Vulnerability is a concept used to express the complex interaction of climate change effects and the susceptibility of a system to its impacts (IPPC, 2022). In other words, the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. As indicated in Figure 14, high vulnerability means a situation where the exposure to climate hazard is high, the sensitivity of the system is high, and the adaptive capacity is low. Exposure is the extent to which a region, resource or community experiences changes in climate. Exposure is the presence of resources/human/infrastructures that could be affected by CC. It is characterised by the magnitude, frequency, duration and/or spatial extent of a weather event or pattern. Sensitivity is the degree to which a system is affected by, or responsive to, climate changes. Adaptive capacity refers to the ability of the system to change in a way that makes it better equipped to manage its exposure and/or sensitivity to a threat.

Debre Birhan Regio-Politan city is exposed to flood, drought, soil erosion, temperature rise and other climate extremes, while the city is sensitive because of its livelihood reliant on climate affected natural resources use sectors, high population density, poor governance and environment. The adaptation capacity of the city is also limited that it has limited/lack or no infrastructure, finance, knowledge/skill, social capital, health care, access to service, and other essential resources.

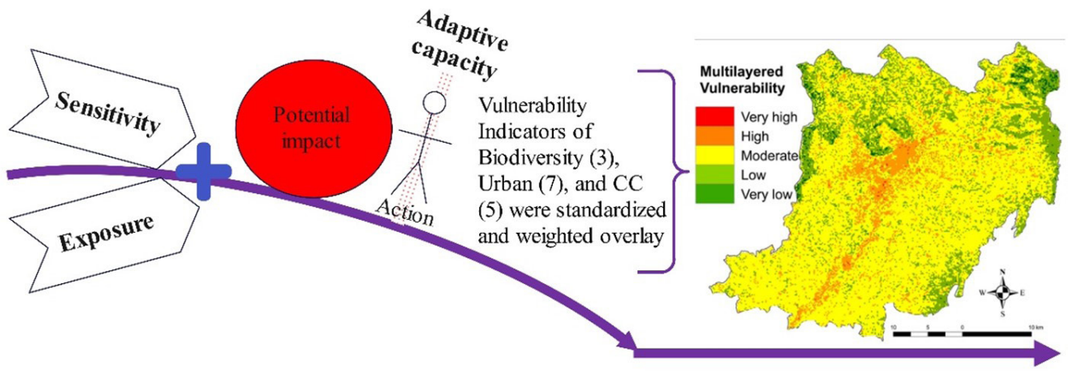


Fig. 14: Varables describe vulnerability as function of exposure, sensitivity and adaptive capacity.

Based on the three dimensions of MVA (urban, biodiversity, climate change), several datasets were collected and processed using ArcGIS and Analytical Hierarchy Process in a multi-criteria decision analysis tool. As indicated in Figure 15, from biodiversity, dimensions component like land use land cover (LULC), Normalized Difference vegetation Index (NDVI), and climate-topographic based biodiversity connectivity were analyzed to generate the biodiversity vulnerability spatial map. Similarly, for urban dimension about seven vulnerability indictor datasets such as population /population density, LULC, access to service, socioeconomic vulnerability, informal settlement, slum area and historical sites were processed to generate the urban vulnerability spatial map. For climate change dimension five vulnerability indicator datasets (flood, soil erosion, maximum temperature, minimum temperature, and drought) were analyzed generate the climate change vulnerability spatial map. Through combining the thematic indicators into datasets for each dimension, then simply using an equal weighted overlay of each dimension, the final multilayered vulnerability assessment (MVA) and the overlapping vulnerability among each dimension were completed.

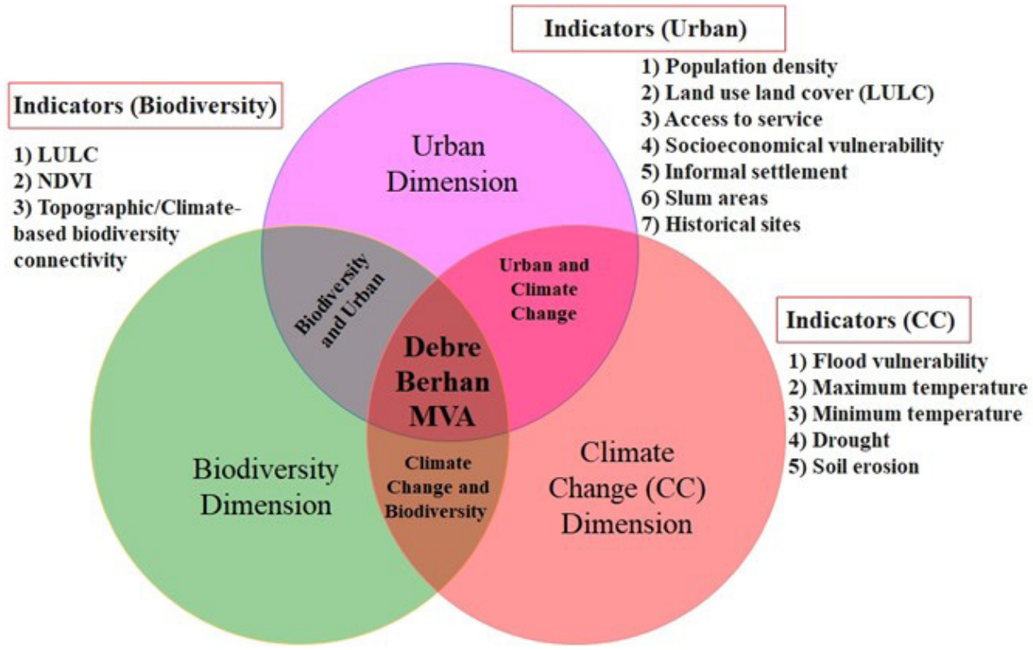


Fig. 15: Indicators used for the three dimensions (biodiversity, urban and climate change) of Debre Birhan city MVA assessment.

Geographic scope

After extensive discussions with city leaders and stakeholders, the geographical scope of the MVA study has been finalized to align with the current city boundary. This decision was unanimously approved by both the steering committee and the city mayor. As previously noted, the city's boundaries were redrawn in 2021 during its transition to a regio-politan level. Following this promotion, a comprehensive structural plan for the city was initiated, with most of the available data corresponding to the new boundary. Notably, two of the three identified climate risk hotspots—areas with documented exposure and vulnerability to climate change—are located within the current city limits. Additionally, key ecological zones, including wetlands and protected areas, lie outside the former boundary. These factors led to the unanimous decision to adopt the current city boundary as the geographical scope for the MVA study.

04

VULNERABILITY DIMENSION

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Vulnerability dimensions

Urban dimension

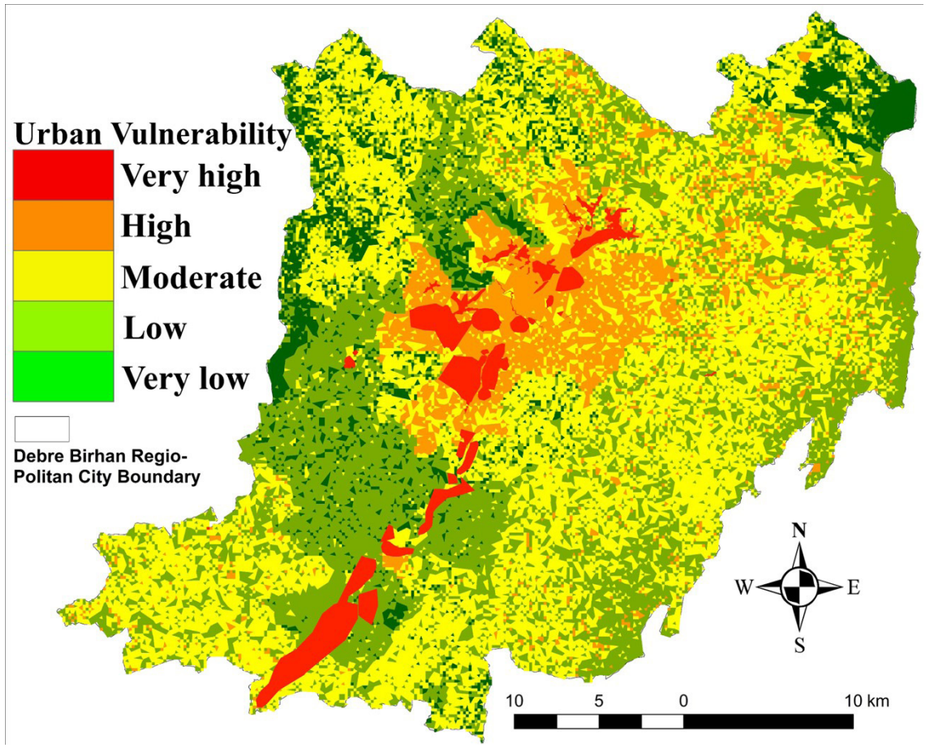


Fig. 16: Urban vulnerability level of Debre Birhan Regio-Politan city.

The fastest-urbanizing region in the world, sub-saharan africa (ssa), is expected to rise by 60% in its urban population by 2050, which is also the most vulnerable to climate-related hazards due to its high exposure, and low adaptive capacity (combes et al., 2023; Delpiazzo et al., 2022). Debre birhan regio-politan city is one of the ssa city that is characterized by rapid population growth, high rates of rural to urban migration, large informal settlements, and slum areas with limited development assets and critical infrastructure. The city, once known as debre birhan town, was quickly industrialized and urbanized, and as a result it has recently been renamed as debre birhan regio-politan city (dbrp city). The city has become an industrial hub of amhara region and the influx of population from the nearby rural area is overwarming mostly for job opportunities that leads to informality in most of the prospects. The recent widespread internal conflict in the country triggered waves of internal displacement communities compounded in the city that also created a limited service within cities. Economic development, through investment in city-based industrialization and the livelihood opportunities they offer, attract rural migrants (yimer, 2019). Land availability for housing is unaffordable for low–income communities, resulting in informal settlement. The expansion of informal settlements and slum areas have increased significantly in recent years (asefa, 2020). Unplanned urban expansion, mostly through the subdivision of agricultural land, is also another challenge that compromises basic urban services such as sewerage networks, drainage, public space, and public transportation, thus exposing the settlers to climate related hazards (yimer, 2019; kefale et al, 2023). Overall, the rapid growing population in the city are accompanied by a lack of housing and infrastructure, fragmentation, social-economic disparities, loss of governability, as well as environmental degradation that triggers serious disruptive events and impacts.

The Constitution of the Federal Democratic Republic of Ethiopia (FDRE) is the foundation for all development-related policies, laws and related outcomes within the country that endeavour to ensure all Ethiopians live in a clean and healthy environment with fairness and equity. The government of Ethiopia accepts and implements different international, regional, and continental initiatives, laws, regulations, policies, and strategies (UN Sustainable Development Goals (SDGs), Africa Agenda 2063) in addition to its cascaded laws, and policies (Green Legacy Initiative (GLI), National Adaptation Plan of Action (NAPA), Climate Resilient Green Economy (CRGE), sustainable land management regulation, National growth Transformation Plan (GTP I, II)). These regulations and laws focus on the sectors that have been identified as most vulnerable, namely: agriculture, forestry, health, transport, power, industry, water and urban. These polices, law, strategy and regulations ensure improved infrastructure, equity, safety, affordability of resources and services in a sustainable way to employ practices to minimize impacts and protect resources to "make city and human settlements inclusive, safe, resilient and sustainable" as of SDG 11. There may be a number of legislative and regulatory matters that need to be resolved when it comes to urban land management. However, lack of political commitment, lack of legal enforcement and action, corruption, and mismanagement are the main challenges in the city that development/urbanization in the city is a head of planning, which creates informal activities and vulnerability in the city. Moreover, a poor linkage and information sharing among concerned institutions is another challenge in the city. One of the dimensions of multi-layered vulnerability assessment (MVA) is urban and a few urban vulnerability indicators were considered for this study such as population density (PD), land use land cover (LULC), access to service, socio-economical vulnerability to industrial development, informal settlement (IS), slum area and historical sites. As indicated in Figure 16, the urban vulnerability level was classified as very high, high, moderate, low and very low. The above-mentioned indicators were combined in a GIS platform using weighted overlay to generate the urban vulnerability map (Figure 16). Given the five classes and the seven urban indicators, out of each indicator barren land/ urban area, densely populated city with population per kilometer square from 436-2486, population with no access to service (water and sanitation, power, transport, hospital/clinic, school), industrial area neighborhood, slum, informal settlement and historical areas were assigned as very high urban vulnerability with equal weight. After that with no consideration of other urban indicators, densely populated city with population per kilometer square from 160-436 as well as barren, urban areas, and NDVI value zero to 0.3 levelled as highly vulnerable class with equal weight. Likewise, population density with population per kilometer square from 93-160, and agricultural lands were levelled as moderately vulnerable, whereas population density (74-160), and grasslands considered as low vulnerable. Very low urban vulnerability classes were forestlands/ sparse vegetation, and population density (55-74).Based on vulnerability indicators 50.85, 134.94, 547.31, 438.3, and 100.5 km2 area of the city were considered as very high, high, moderate, low and very low susceptible to climate change, respectively (table 3).

Table 3. Urban vulnerability classes

Urban Vulnerability Level	Area (square (km	Percentage
Very high	50.85	3.99
High	134.94	10.61
Moderate	547.31	43.03
Low	438.3	34.46
Very low	100.5	7.90

Indicators
I.Population density & distribution

Population density in Debre Birhan Regio-Politan city (DBRP) city ranges from 55 persons per square kilometre to 2486 persons per square kilometre (Figure 17). The divisions used for this analysis in descending order were 436-2486, 160-436, 93-160, 74-160, and 55-74 that were considered as very highly, highly, moderately, low and very low vulnerability to climate change, respectively. Population density was selected as an indicator partly due to the availability of high-quality data. Population density is a useful vulnerability indicator to climate change because highly populated areas are highly sensitive to climate related hazards. Highly populated urbanized areas are reliant on external food production (rural agriculture and imported goods), which are susceptible to changing climate and market conditions. In most cases, forest, biodiversity and other natural resources are limited in densely populated area due to building and other infrastructures that are exposed to climate hazards.

In Sub-Saharan Africa, urbanization leads to a concentration of opportunities in more concentrated areas, as well as an increase in population, economic activity, and hazards because of mounting demand on scarce development resources and vital infrastructure. As a result, in development shortfall, environmental degradation along with vulnerabilities exacerbate climate risk, which are becoming higher in frequency and magnitude contributing to rising economic and human losses and impacts.

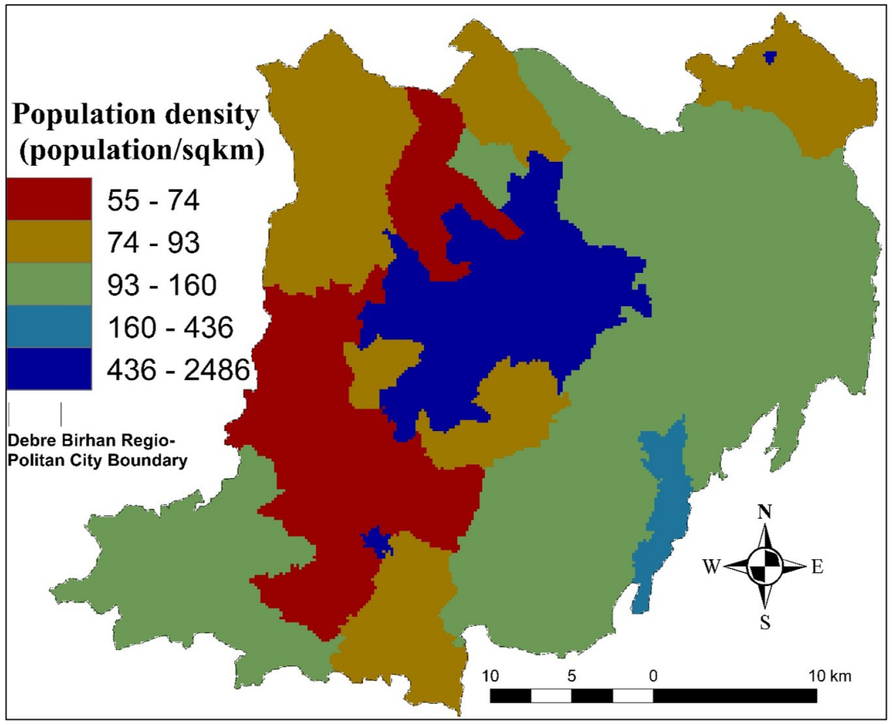


Fig. 17: Population density of DBRP city.

II.Land use land cover (LULC)

The land use land cover indicator was selected for this study because of its easily availability and processability from sentinel satellite imagery. The land use land cover of DBRP city was processed using sentinel imagery of 10-meter resolution for the period for 2024. The land use land cover map shows the different features of found in the city that some of the features are highly vulnerable to climate change like urban and natural resources areas, while others namely forest and vegetation areas have less susceptibility to climate change. Accordingly, the land use classes of the city such as water bodies, urban/degraded, agricultural were assigned as very highly, highly, and moderately, whereas sparse vegetation/forest, and grasslands classes classified as low and very low vulnerability to climate change respectively (Figure 18). The land use land cover (LULC) map exhibited that forest areas are found in the eastern, northern, and western peripheries of the city covering an area of 21133.7ha. Only forest land and shrubland, which covers 19 and 17% of the total area of the city. Over half (52.63%) of DBRP city is covered with cultivated land which indicates that it is moderately vulnerability to climate change. Built-up or settlement areas are found around the centre and along the major roads of the city in very highly and highly urban vulnerable areas to climate change.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

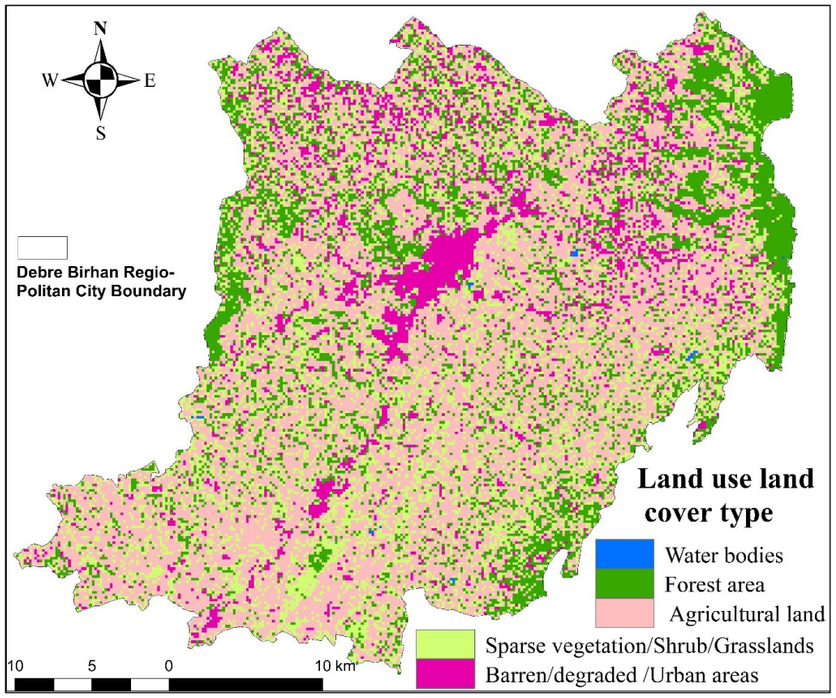
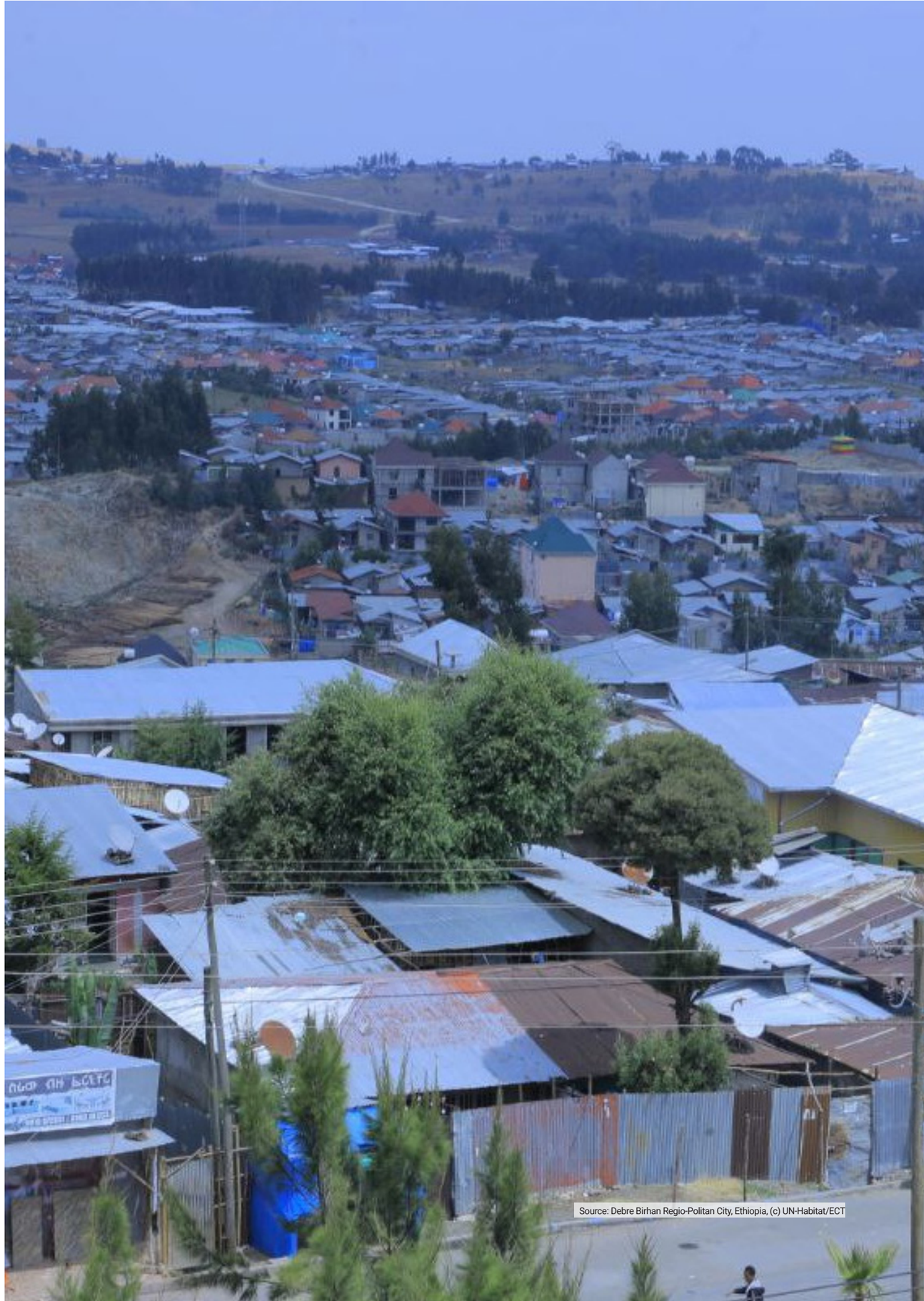


Fig. 18: The LULC types of DBRP city.



Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

III.Access to services

Access to service infrastructure such as water and sanitation, power, transport, hospital/clinic, and school were considered to assess the population's proximity to the service in case of any climate hazard. Urban vulnerability is considered to be low and very low where populations have good and/or consistent access to services, while population with limited to no access to service is leveled as highly and very highly vulnerable to climate change hazards (Figure 19).

IV.Socioeconomical vulnerability/ pollution indicator

Socio-economic vulnerability is a function of a community's characteristics and the potential changes in natural resources and ecosystems. Community within 300- and 150-meters proximity to the industry/factor were considered as highly and very highly vulnerable correspondingly because of the pollution/ hazardous/toxic wastes, and other challenges from the factories, while communities faraway from industry are supposed to be safer relatively (Basal Consulting, 2021). Relatively, communities affected by urban developmental programs without enough compensation were also considered as very highly vulnerable (Figure 19).

V.Informal settlements

The informal settlements are found in the peripheries or suburban areas and the urban fringe of the city. Over the past decades, informality has been a dominant issue in most cities of the developing world (Guevara 2014). It is believed that economic, political, and legal exclusionary practices lead to informality. It arose when governments the fails to directly contribute to expanding the amount of land needed for housing. They often have no or limited infrastructure and services and are very highly vulnerable to climate related hazard and other disasters. Particularly, in DBRP city the informal settlements have been badly affected by hydro-climatic extremes such as flood, drought and water stress. Informal settlements are observed at different parts of the city. This type of settlement covers 587.47ha (15.09%) of land in the main old city (Figure 19). The majority of informal settlement is commonly observed either in the plan boundary or in the outer agricultural lands. Informal settlement, in both cases, is an impediment for good urban planning and development. Consequently, both informal settler and slum dwellers face a wide range of climate-related hazards.

VI.Slum areas

Slum dwellers are found in most sub-cities of DBRP city characterized by overcrowding, poor quality housing, food insecurity, poor drainage network, congested living spaces, inadequate access to potable water, poor sanitation/ education, and lack of socio-economic infrastructure that made them very highly vulnerable to climate related hazard (Figure 19). Overall, both informal settler and slum dwellers do not have weather proper place to live or enough budget to build proper house so that they find homes in the urban spaces such as areas liable to flood and swampy areas, public dumpsites and reservations along roads or other infrastructures.

VII.Historical sites

Historical sites are also very highly vulnerable to extreme hydro-climatic events such as temperature rise, flood and drought. Therefore, for this study historical sites of the city were considered as very highly vulnerable to climate change like that of informal settlement and slum areas (igure 19).

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

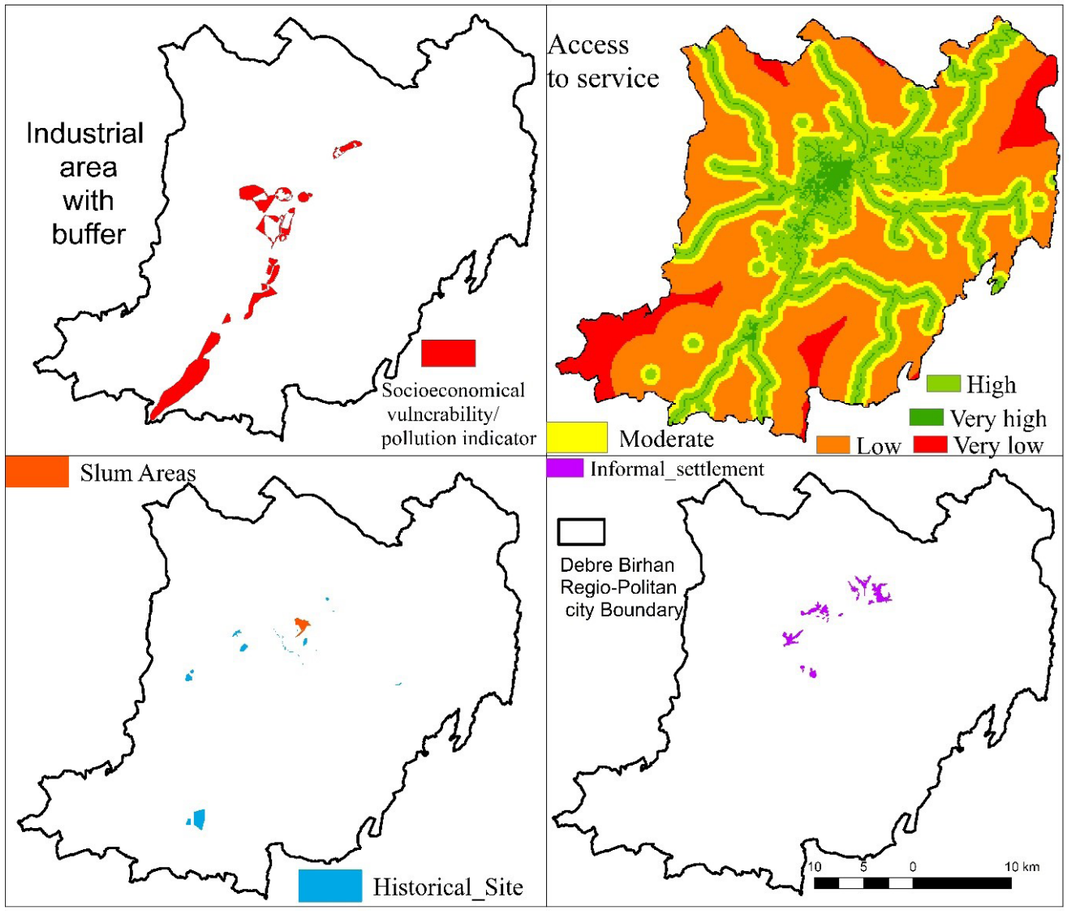


Fig. 19: Urban indicators (pollution indicator, access to service, slum area, historical sites, and informal settlement).

Urban dimension analysis

The urban vulnerability map presented in Figure 16 indicates the current state of the city that informal settlements, slum, neighbourhood next to the industry, and densely populated areas, along with historical sites are very highly/highly vulnerable hotspot areas. Urban poor is always the most affected community by climate change and other developmental activities due to their low adaptive capacity and usually they are located in the peripheries/marginalized areas. Urban poor is mostly located in area where not well developed, with no or little infrastructure that expose them to most of developmental or global changes in the city.

Since the population density, access to service, socioeconomically vulnerability, informal settlement, slum areas and LULC indicators used for this analysis dynamically changed through time that the historical, current and future urban vulnerability goes the same way. In other words, the population density, industry, informal settlement, slum areas have increased in the city from the past and it is expected to increase in the future so that the urban vulnerability has been comparatively small in the historical than current. It is anticipated that the urban vulnerability hotspot will expand and become more severe in the future.
The geographic location of the city exposes it to hydro-climatic extremes such as river flood, runoff flash flood, droughts, rainfall anomaly, extreme dry/cold day, soil erosion, and rising temperature. The community in DBRP city is highly sensitive to climate change and/or variability effects because their livelihood is highly reliant on seasonal rainfed-agriculture (crop production and livestock). If the seasonal rainfall becomes late or not come for a season the livestock death and crop production, become quite high leading to starvation. Rainfed-agriculture and sometimes irrigation if the rivers have water are the only survival to the community in the DBRP city. Therefore, the community is highly sensitive to climate change, as they do not have other means to survive. The city or communities coping capacity is limited because of no infrastructure for example there is no water harvesting infrastructure hold water in case of drought/water stress, and there is no drainage system, dike or other infrastructures that alleviate flood in the city. The houses are also made with low materials and most of them are wooden made ground villa houses that are vulnerable to flood, thus the coping capacity has been simply immediate humanitarian aid. The exposure and sensitivity are mapped in the urban vulnerability map assuming that the communities coping capacity is limited.

Urban future vulnerabilities

Urbanization in Ethiopia is highly vulnerable to climate change now and expected to be exacerbate in the future because of unplanned development and its shortfall that expands in the expanse of natural resource. The development in DBRP city is so unplanned that the informal settlement and slum areas are expected to be expand in the future without infrastructure development that worsen the future urban vulnerability relative to now. The current urban vulnerability hotspot areas are anticipated to be expand along the main asphalt road northeast and southwest direction. Future climate risk depends not just on future climate change but also on non-climatic components, such as future exposure and vulnerability. Debre Birhan Regio-Politan city (DBRP city) is highly exposed and vulnerable to climate risks with limited or non-adaptive capacity, unless a proactive adaptation pathway prepared ahead of time hotspot areas will be expanded with high severity. According to a city urban trend analysis, the city's built-up area has increased eightfold over the past 11 years, adding 3030.93 hectares, and its vulnerability has increased due to insufficient infrastructure development. The unplanned built-up areas and other informalities are expected to increase in the future, exacerbating the urban vulnerability hotspot areas. In addition to climate-induced floods, droughts, and rising temperature, the urban environment alters the radiative properties of the region, increasing the area's sensitivity and vulnerability to global warming and climate change.

Climate Change Dimension

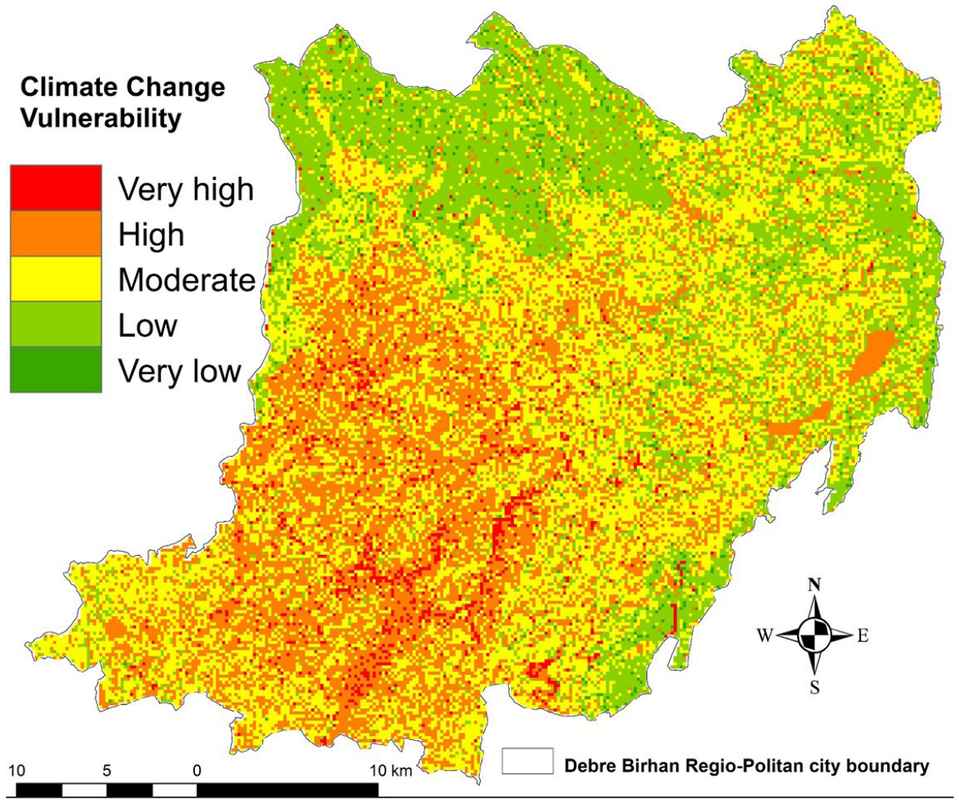


Fig. 21: Climate change vulnerability level of Debre Birhan Regio-Politan city.

Climate change is already a reality and its local manifestations differ from place to place with communality that temperature is rising worldwide (IPCC, 2021). Characterizing and quantifying climate change impacts in DBRP city is vital. The rising temperature is already intensifying hydro-climatic extremes in the city (Kassahun et al., 2021). Climate change is increasing the frequency, severity, and magnitude of hydro-climatic extreme events (flood, drought, temperature rise etc.) (Getahun et al., 2023). There is a consensus that due to climate change, wet areas or seasons are getting wetter and drier areas or seasons are getting drier so that the frequency and severity of flood, temperature rise, and drought has been increasing in DBRP city in recent years (Feng and Zhang, 2015; IPCC, 2021). On the other hand, unplanned rapid urbanization with no drainage system is the major cause of flooding in the city, and continued urbanization will further exacerbate flooding in the city. The existing serious environmental issues and poor living circumstances brought on by previous decades' increasing urbanization will be made worse by climate change. It will have an impact on urban residents' human security, household incomes, and the physical and economic growth of cities in the short and long terms.
Acknowledging the seriousness of the issue, i.e. the alarming decline in agricultural production over time, flooding and rising temperature that affects the entire community because of climate change, the Ethiopian government have been accepting and implementing different international, regional, and

continental initiatives, laws, regulations, policies, and strategies (UN Sustainable Development Goals (SDGs), Africa Agenda 2063). Yet, the existing law and regulations could not adequately address the country's concerns about climate change. Therefore, timely and appropriate local level regulation is vital to tackle climate change. Moreover, there are national, regional and district level cascaded laws, strategy, regulation, and policies such as Green Legacy Initiative (GLI), National Adaptation Plan of Action (NAPA), Climate Resilient Green Economy (CRGE), National growth Transformation Plan (GTP I, II)). These regulation and laws focus on the sectors that have been identified as most vulnerable, namely: agriculture, forestry, health, transport, power, industry, water and urban. These polices, law, strategy and regulations ensure improved infrastructure, equity, safety, affordability of resources and services in a sustainable way to employ practices to minimize climate impacts, protect resources, and increase productivity. Similar to urban vulnerability cases, political commitment, lack of legal enforcement and action, corruption, and mismanagement are the main challenges in the city.
One of the dimensions of multi-layered vulnerability assessment (MVA) is climate change and a few vulnerability indicators were considered for this study such as flood, maximum temperature change, minimum temperature change, soil erosion and drought. Like urban vulnerability, the climate change vulnerability dimension was classified as very high, high, moderate, low and very low (Figure 20).

Indicators

A.Flood vulnerability

Flood is one of the most common natural disasters that affect the livelihood of most communities in the DBRP city as they have low adaptive capacity. Human activities such as deforestation, urbanization, climate change, poor planning, improper development and poorly designed infrastructure, particularly drainage systems, are capable of increasing the impact of flood events and vulnerability to flood. Flood hazards can cause enormous damage to human society and the environment. The main natural hazards affecting DBRP city are floods, rising temperature, soil erosion, and drought. Flood vulnerability was selected as climate change vulnerability indicator because it is the main or first kind of climate related hazard that affects the city. Most part of the Debre Birhan Regio-Politan (DBRP) city is highly impacted by either river or runoff flash flood during the main rainy season (June, July, August and September). For flood susceptibility mapping about 13 flood causing factors/parameter namely slope, elevation (DEM), drainage density, land use land cover, rainfall, topographic wetness index (TWI), normalized difference vegetation index (NDVI), stream power index (SPI), curvature, distance to river, distance to road, population density and soil type were processed using GIS and analytical hierarchy process (AHP) for flood vulnerability mapping of the city (Rimba et al., 2017; Sarkar et al., 2020; Das, 2020; Hamidiet et al., 2022).

A pairwise comparison matrix of the multi-criteria approach was used to evaluate factors affecting flood via a series of judgments based on experts' points of view. A scale of relative influence ranges from a value of 1 to 9 that is used in AHP to indicate whether the two factors are equally important or one is more important than others are. A pairwise comparison of factors was performed and normalized to assign the parameter weight and get eigenvalues. The random consistency index (RI) proposed by Saaty (1980) was applied to check the consistency ratio (CR) that validates the consistency of factors, and the RI value for 13 factors is 1.56. In order to compute the flood susceptibility map, the assigned AHP based factors were normalized and weighted overlay to determine the flooding level.

Flooding is one of the major natural hazards in the city, which disrupts the prosperity, safety and amenity of human settlements, so that in the city 9.55%, 31.1%, 32.2,% 19.1%, 8.14% of the area is very highly, highly, moderately, low and very low vulnerable to flood, respectively (Table 4, Figure 21).

Table 4. Overall flood vulnerability level of the city

Urban Vulnerability Level	Area (square (km	Percentage
Very high	121.528	9.55
High	395.4343	31.09
Moderate	408.9136	32.15
Low	242.5271	19.07
Very low	103.5144	8.14


Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

B.Maximum and minimum temperature changes

The Climate Hazards Group Infra-Red Precipitation with Station data (CHIRPS) annual mean maximum and minimum temperature dataset were downloaded and processed from 1990-2021. The course datasets were resampled to 12.5-meter resolution using GIS tool. Both, the annual mean maximum and minimum temperature exhibited a significant increasing trend in the city with a maximum temperature increase from 0.54-0.62°C, while the minimum temperature increase from 0.2-0.33 °C in the entire city (Figure 21). The west and southwest part of the city showed the highest annual mean maximum temperature increase i.e. 0.62 °C, while the lowest increase was observed on the northwestern part of the city i.e. 0.54 °C. For the last 31 years, the highest annual mean minimum temperature increase showed in the western periphery i.e. 0.33 °C, while the lowest annual mean minimum temperature increase was noticed in the eastern periphery i.e. 0.2 °C.

The annual mean maximum and minimum temperature changes were selected as indicator for climate change vulnerability because they are the primary indicators of climate change and data availability in raster format, except a simple resampling to minimum the course resolution. Variation in temperature may be considered as one of the major components responsible for climate change and plays a vital role for policymakers in ensuring food security, agriculturalists and crop breeders. The highest mean annual maximum and minimum temperature changes areas were considered as very highly vulnerable to climate change, while the lowest increase areas were considered as very low vulnerable to climate change.

C.Drought

Standardized Precipitation Index (SPI) to characterize the rainfall deficit in multiple time scales that are used to detect and monitor drought for a particular area was applied for this study using 40-year (1983-2022) CHRIPS satellite rainfall data. Several studies in Ethiopia have used the SPI to evaluate meteorological drought (Zeleke et al. 2017; Teweldebirhan et al. 2019). The SPI is not only flexible and uses rainfall data only but is also suitable for complex topography and climatic conditions. The SPI normalizes the variation of rainfall at multiple accumulation periods (1–48 months) at a particular location using the long-term average. The shorter time scale of SPI from 1 to 6 months is used to monitor the occurrence of meteorological droughts and the longer time scale of SPI from 12 to 24 months accumulation period are often used as proxies for agricultural as well as hydrological droughts (Munagapati et al. 2018).

D.Soil erosion vulnerability level

To determine the likelihood of soil erosion in DBRP city, an empirical RUSLE model using ArcGIS was used. The RUSLE model is the most widely used, simple, and applicable in limited data conditions, and utilizes basic factors such as rainfall patterns, soil type, DEM, land cover (cover management), and soil conservation support practice to estimate soil erosion. It was challenging to test alternative models that required intensive data because of the detailed data scarcity in the DBRP City. The RUSLE model is an expansion of the USLE in which certain parameters have been changed to better represent the local environment. For instance, the USLE's rainfall was modified by the rainfall erosivity factor. The model represents soil erosion risk by considering five factors, where each of the functions is expressed numerically, forming an equation to predict soil loss. All these factors were mapped in GIS raster format. The equation is presented as:

$$ASL = R \times Ks \times SL \times C \times Sp$$

where ASL is the average annual soil loss (t ha-1 yr-1), R is rainfall erosivity (MJ mm ha-1 yr-1), Ks is soil erodibility (t ha-1 mm-1), SL is the slope length and steepness factor, C is the vegetation cover management factor, and Sp is the support practice. Factors without dimensions are SL, C, and Sp. Concerning the soil loss estimation, the prepared input factors for the empirical Revised Universal Soil Loss Equation (RUSLE) model were integrated into the ArcGIS raster calculator for generating the soil loss map for the study area. The empirical model RUSLE includes factors that represent how land cover, climate, soil, topography, and LULC affect soil erosion caused by raindrop impact and surface runoff. To assess the effect of these parameters, the overlay of all factors (R, Ks, Sp, SL, and C) in a single scene was made.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

An assessment of the risk of soil loss at various spatial scales, including the city level, is essential to sustainable land use management.

For this study, RUSLE empirical model containing rainfall erosivity, soil erodibility, slope length and steepness, conservation support practice, and vegetation cover-management were applied in ArcGIS platform to generate soil loss/erosion severity map of DBRPC. The soil loss severity classes were categorized as slight, moderate, high, very high, severe, and very severe with the soil loss rate of less 5, between 5-10, 10-20, 20-40, 40-80 and greater than 80 ton/ha/year, respectively (table 5, Figure 21). The soil loss rate of greater than 80 ton/ha/year, which is very severe type of soil loss was noticed in the northwest and northeastern areas of the city that includes Weyeniy, Goshbado, Keyete, Gudoberet, Zendegor, Sariya, Cheraro Deber and north of Birbirsa (Figure 21). However, slight type of soil erosion risk with the soil loss rate less than 5 ton/ha/year was observed in the flat landscapes of the city like Cheki, Adadi, Chefa Nen, Angolela, Koer Margefiya as well as central Chacha and Debre Birhan towns. The overall, average annual estimated soil loss in the city was 38.5 t/ha/year. An extensive part of the land in the north, northwestern, eastern peripheries of the city showed a higher slope, which makes the area prone to severe soil loss risks. Generally, the soil erosion rate is highly influenced by topography such as LS and P factors. Apart from the steep slope, changes in land use and urbanization also contribute to high rates of soil loss in the city.

Table 5. Soil loss estimation severity class in the Debre Birhan Regio-Politan city

Soil erosion risk	(Soil loss rate (ton/ha/year	(Area (hectare	(%) Area
Slight	5 >	34408.48	27.1
Moderate	5-10	14621.31	11.5
High	10-20	20691.84	16.3
Very high	20-40	17611.35	13.8
Severe	40-80	15041.44	11.8

The five climate vulnerability indicators were classified into five class as indicated in table 6 and weighted overlay to generate the climate vulnerability map with the weight of 40 %, 20%, 14%, 13%, and 13% for flood, soil erosion, drought, maximum temperature and minimum temperature, respectively.

Vulnerability class	Indicators				
	Flood (e.g. Slope in degree and likewise other 12 factors were classified	(Drought (SPI	Soil loss rate ((ton/ha/year	Maximum temperature (0c)	Minimum Temperature (0c)
Very high	0-3	2≥	40<	0.61-0.62	0.30-0.33
High	3-8	to -1.99 -1.5	20-40	0.60-0.61	0.28-0.3
Moderate	8-12	to -1.49 -1.0	10-20	0.58-0.60	0.26-0.28
Low	12-20	to -0.5 -0.99	5-10	0.56-0.58	0.24-0.26
Very low	20<	0.5 ≥ 0≥-0.5	5 >	0.54-0.56	0.20-0.24

Table 6. Climate vulnerability indicators and their class

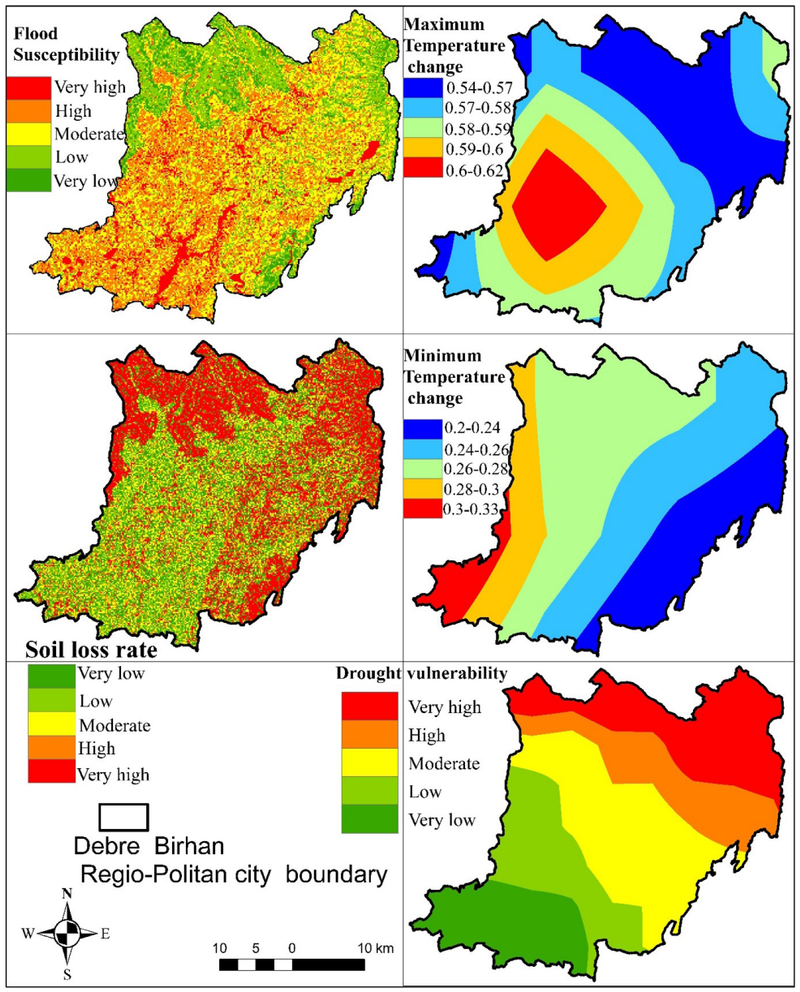


Fig. 22: Climate change vulnerability indicators.

Climate change dimension analysis

The climate change vulnerability map presented in Figure 20, indicated the historical and current state of the city that very high flood susceptibility, highest increase maximum and minimum temperatures, sever soil erosion and drought affected areas were considered as very highly climate change vulnerable hotspot areas, whereas there reverse were classified as very low vulnerable to climate change. During the stakeholder discussion it was emphases that flood is one of the most common climate disasters in the city so that during weighting overlay more weight has been given to flood compared to other indicators. As indicated in Figure 20, these climate change vulnerable hotspot areas have been historical meaning that climate change has been affecting those areas in the past and now. The severity, extent, and amplitude of the city's current climate-related dangers are increasing due to climate change, and it is anticipated that the future will be worse than the present. The vulnerable hotspot areas are consistent in each the two periods (i.e. historical and current) as there are no adaptation strategies develop to alleviate the hazard. The future is expected to be worst with increase in severity and extent unless pro-active adaptation pathways are developed to minimize the risk of in the city.
DBRP city is located in disadvantageous area when it comes to climate hazards and the community is very poor to adapt except to be relay on immediate humanitarian aid. East Africa with the city latitude and longitude as well as rugged topography the city is known with heavy and intense rainfall, during July and August that results in flash and river flood. Moreover, the rainfall in the city is erratic and highly anomalous. In the dry season, there is drought, high temperature and water shortage in the city that geographically makes the city exposed to climate hazards. The city's population is heavily dependent on seasonal rainfed agriculture (livestock and agricultural production), making them extremely vulnerable to the effects of climate change and/or fluctuation. Starvation results from a high rate of crop production and livestock mortality if seasonal rainfall is delayed or absent throughout a season. The community's only means of subsistence in the DBRP city is rainfed agriculture, and occasionally irrigation if the rivers have water. Since they have no alternative means of survival, the community is extremely vulnerable to climate change.

Some residents of the city are reliant on government employment and business, and they cannot survive unless the rural community produces well. The community's coping capacity is limited because of limited infrastructure for example there is no water harvesting infrastructure hold water in case of drought/water stress, and there is no drainage system, dike or other infrastructures that alleviate flood in the city. There isn't much industrial or mining activity that can support the community's way of life. Since the majority of the dwellings are wooden ground villas that are susceptible to flooding and are constructed with inferior materials, the only way to cope has been to provide quick humanitarian assistance. The exposure and sensitivity are mapped in the climate change vulnerability map assuming that the communities coping capacity is limited.

Climate change future vulnerabilities

The three General Circulation Models (GCMs) of the six-assessment report (AR6) such as IPSL-CM6A, HadGEM3-GC31, and GFDL-ESM4 with three scenarios SSP1-2.6, SSP2-4.5, and SSP5-8.5 for the period of 2035 (2025-2044), 2073 (92063-2082), and 2092 (2082-2100) were used for this study.
Climate change poses a serious threat to sustainable urban development, placing many cities at risk. The worldwide rate of so-called natural disasters has almost magnified in the last decades years, resulting in escalating human and economic losses. Despite many doubts concerning the magnitude and frequency of hazards, and their specific impacts, climate change will necessarily increase the susceptibility of urban societies if no effective adaptation takes place. Therefore, analysing climate change for urban planning is vital using the preferred nine climate scenarios namely IPSL-CM6A/SSP1-2.6, IPSL-CM6A/SSP2-4.5, IPSL-CM6A/SSP5-8.5, HadGEM3-GC31/SSP1-2.6, HadGEM3-GC31/ SSP2-4.5, HadGEM3-GC31/SSP5-8.5, GFDL-ESM4/SSP1-2.6, GFDL-ESM4/SSP2-4.5, and GFDL-ESM4/SSP5-8.5.
The monthly patterns of observed temperature is well captured by the GCMs with the steady increase

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

of monthly and annual temperatures, as shown in Figure 22, bottom. The highest average monthly temperature was observed in June with the highest increase of SSP5-8.5 scenarios as compared to SSP2-4.5, and SSP1-2.6 (Figure 22, bottom), while the lowest was detected in November temperature. Compared to the baseline temperature the SSP1-2.6, SSP2-4.5, and SSP5-8.5 indicated an increase of average monthly temperature of 0.6, 0.9, and 1.5 oC, respectively. The projected increase in temperature under all GCMs scenarios is predicted to increase the evapotranspiration that induce water loss in the city. The annual projected temperature also exhibited an increasing trend with the highest increase of SSP5-8.5 scenarios as compared to SSP2-4.5, and SSP1-2.6 (Figure 22, top).

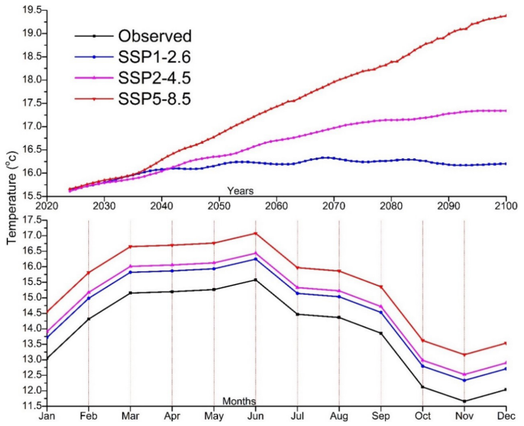


Fig. 23: Observed (1986–2022) and projected (2025-2100) average monthly (bottom) and annual (top) temperatures using three GCMs (IPSL-CM6A, HadGEM3-GC31, and GFDL-ESM4).

Figure 23 indicated, the monthly projected rainfall for the three periods such as 2035 (2025-2044), 2073 (92063-2082), and 2092 (2082-2100) using average of (IPSL-CM6A, HadGEM3-GC31 and GFDL-ESM4) under SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios. All the nine scenarios (IPSL-CM6A/SSP1-2.6, IPSL-CM6A/SSP2-4.5, IPSL-CM6A/SSP5-8.5, HadGEM3-GC31/SSP1-2.6,HadGEM3-GC31/SSP2-4.5, HadGEM3-GC31/SSP5-8.5, GFDL-ESM4/SSP1-2.6, GFDL-ESM4/SSP2-4.5, and GFDL-ESM4/SSP5-8.5) indicated an increase of rainfall during July and August, whereas the rainfall in the minor rainy season (February, March April and May) decreases. Based on the climate projection the highest increase of rainfall will be observed in July that is climatological rainy meaning that there will be a probability of flood and heavy rainfall so that early warning mechanisms are important. The highest rainfall in Kiremt or major rainy season(June, July, August and September) might cause flooding in the city so implementing proper management and infrastructures is important, while the decrease in rainfall might cause drought. Based on three-projection periods, in July and August almost all GCMs scenarios indicated higher rainfall compare to the average observed rainfall (i.e. 310.8 mm/month). For example, in month July using SSP5-8.5 scenario for the 2035, 2073 and 2092 periods the average projected rainfall were 322.3 mm/month, 331.9 mm/month, 348.2 mm/month, respectively. The highest projected rainfall was detected in July (348.9 mm/month), followed by August with average monthly rainfall of 316.1 mm/month. The projected rainfall showed decreasing rainfall pattern during Belg or minor rainy season (February, March April and May).

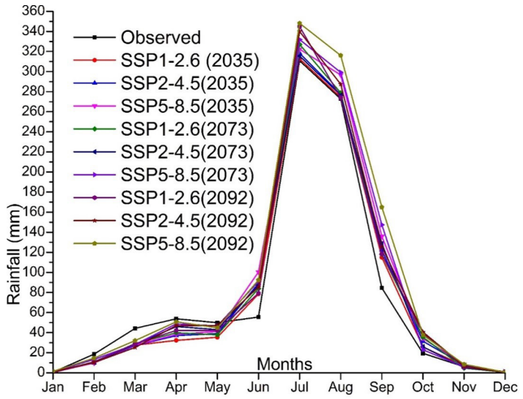


Fig. 24: Observed monthly rainfall (1986–2022) and projected GCMs (2025–2100).

The projected rainfall is computed as percentage changes with reference to the GCMs baseline and the projected GCMs as indicated Figure 24. All GCM scenarios showed the highest rainfall percentage changes in the far future 2092 (2082-2100) period. Using all the projection periods and scenarios, the dry season exhibited the highest percentage change due to the high rainfall variably/ erratic rainfall. The projected rainfall in the major rainy and dry seasons showed an increasing/positive pattern, whereas the minor rainy season indicated a decreasing/negative pattern. The positive or negative percentage changes of rainfall in all the seasons were consistent with projected rainfall for all GCMs and three projection periods. The projected increase or decrease in rainfall could lead to different situations. In one way, it would provide

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

abundant water supply for a growing population in the city. However, projections of rainfall increase in the major rainy season will induce higher risks of flooding, but, on the contrary, rainfall decrease in the minor rainy season increases the possibilities of water stress so appropriate water management and planning is vital considering climate scenarios. Based on the percent change computation, the major rainy season are expected to increase with all scenarios ranging from 7.9% of SSP1-2.6 for 2035 (2025-2044) to 27.4 % of SSP5-8.5 for 2092 (2082-2100).

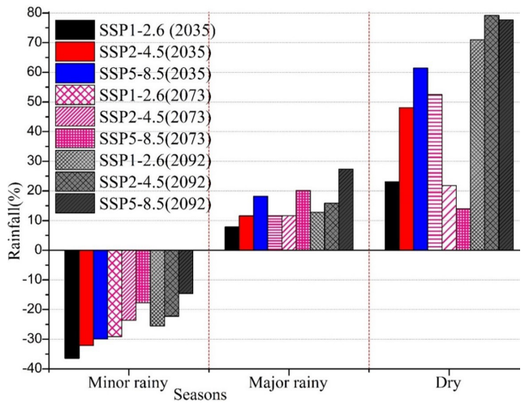


Fig. 25: Percentage changes of seasonal rainfalls using GCMs for periods of 2035 (2025-2044), 2073 (92063-2082), and 2092 (2082-2100).

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Biodiversity dimension

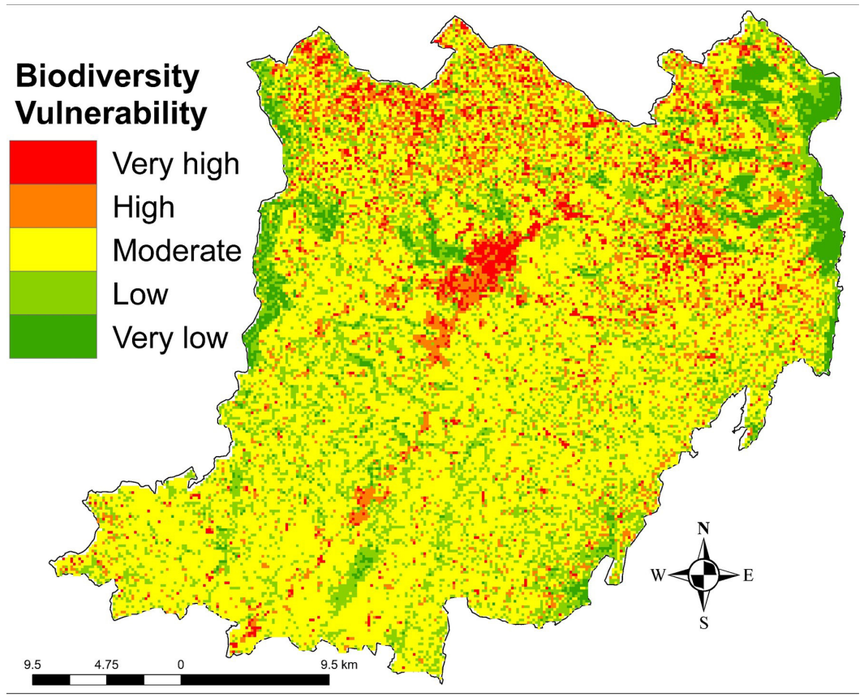


Fig. 26: Biodiversity vulnerability level of Debre Birhan Regio-Politan city.

Urban biodiversity has an important and expanding role in helping cities adapt to and mitigate the impacts of changing climate as well as to provide better ecological services (Solecki and Marcotullio, 2013). However, rapid population growth, urbanization, agricultural expansion, pollution, and climate change pose threat to urban biodiversity (Muluneh, 2021). Evidences are increasing that there is a huge loss in biodiversity in Ethiopia (Wassie, 2020; EBI, 2023; Getahun et al., 2024; Moges, 2024). Biodiversity worldwide is being lost, and in some areas at an accelerating rate. Ensuring food security and urban expansion without affecting biodiversity is the biggest contemporary global governance challenge (Jiren et al, 2018). Vicious circle one affects the other loss of biodiversity affects productivity, urbanization, and climate change while the reverse is true. Addressing these two issues together is essential to ensure that measures to combat the one do not endanger the other. The increase of biodiversity not only vital to sequester carbon to mitigate climate change but also absorbs water when it became excess and reduce flood risk in the urban environment (Muluneh, 2021). Additionally, that absorbed water increases recharge to groundwater and surface water system to alleviate the effect of drought/water shortage in the city. Therefore, utilizing urban biodiversity as a means of adaptation and mitigation will contribute to the development of more resilient, sustainable, and liveable cities and urban areas. Assessing biodiversity vulnerability to urbanization and climate change is essential for developing robust adaptation strategies.

In Ethiopia; the supreme law (FDRE, 1995), the constitution, environmental policy (FDRE, 1997), Green legacy Initiative, National Growth and Transformation development strategy (FDRE, 2011), Climate resilient

This open solid waste dumping site in Etegie Taitu Sub-city is a major source of environmental degradation in the surrounding area. Historically, the site was used as a quarry, but it has gradually transformed into an unmanaged landfill. The nearby Dalecha River is heavily impacted, facing significant water pollution due to runoff from the waste. Additionally, the presence of small-scale flour processing enterprises in the vicinity raises concerns about potential organic contamination affecting food production. Informal waste pickers and nearby livestock owners frequently access the site, further exacerbating the pollution and sanitation challenges.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

green development initiatives (2011) are some of the national laws that give the regions and municipalities strong incentives to focus on greener development. For instance, the constitution has clearly described the focus to be given for environment and development and how to ensure the benefit of the public in its article 43, 44 and 92; and the link of making any policy, plan, program and projects with the constitution article 85(1) (FDRE, 1995). There are also some Environmental Protection Proclamation/ Standards establishes a system for coordinated but differentiated responsibilities among environmental protection agencies at federal and regional levels. However, as usual there is no legal enforcement and commitment to implement those law and regulations to increase biodiversity. Moreover, there is still lack of policy, regulation in protecting or creating buffer zone to each of water bodies, forest and other potential biodiversity areas in the city.

In general Debre Birhan Regio-Politan city is rich in biodiversity that have forest areas, wetland, grassland and several rivers/streams, but there is no data or detail study carried out about species composition, mean species abundance, and other, especially that can be used as raster data. Therefore, general biodiversity vulnerability indicator datasets were utilized for this study like satellite remote sensing output and topographic landscapes.

Sentinel satellite data of Land use land cover (LULC) and Normalized Different Vegetation Index (NDVI) for the year 2024, and extracted forest as well as grassland areas were used for this biodiversity vulnerability assessment. Thus, biodiversity vulnerability of forest/spares vegetation and grasslands were levelled as very low and low, respectively, whereas agricultural lands assigned as moderately biodiversity vulnerable. Biodiversity vulnerability of degraded or barren land and urban area with NDVI value less than zero were classified as very high, while barren and settlement/urban areas with NDVI value zero to 0.3 levelled as highly vulnerable. Therefore, land use land cover, NDVI, topographic/ climate-based biodiversity connectivity, forest and grassland areas were considered as biodiversity vulnerability indicators for this assessment (Figure 26). Three climate zones were recognized in Debre Birhan Regio-Politan City: Wurch (upper highlands), Dega (highlands), and Weyna Dega (midlands). The Dega (cold and humid)/highland climate zone of the city covers the largest part with dominate agricultural, spares vegetation, and grasslands, whereas the Wurch /upper highlands climate zone covers about 5.8 % with the dominate crop of Barley pulse grazing pasture and forestlands (Figure 26). The midland climate class covers about 11. 4% of the city with the major crops including Maize, Sorghum, Teff, rice, Insent rare, Wheat, Nug, Dagussa and Barley. In Dega climate, the major staple crops include barley, Wheat, highland oilseeds, and highland pulses. Moreover, the dominate livestock and biodiversity types are different from one climate to another.

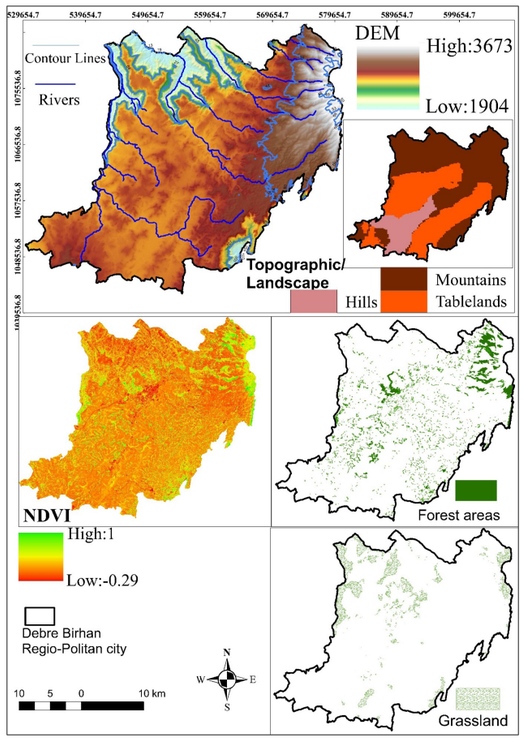


Fig. 27: Biodiversity vulnerability indicators of DBRP city

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

Biodiversity dimension analysis

Degraded/barren land, urban areas, and lower NDVI values were levelled as highly and very highly vulnerable, according to the biodiversity vulnerability map shown in Figure 27. It also detailed the current state of the city using topographic landscape/climate-based connectivity, land use cover, NDVI, forest, and grassland areas. On the other hand, grasslands and forest/spare vegetation were rated as having very low and low vulnerability to biodiversity. The biodiversity vulnerability indicators were weighted overlay to generate the biodiversity vulnerability map (Figure 27). Given the concerning development and degradation in the city, it is expected that the number of biodiversity-vulnerable hotspot locations is higher now than it was in the past. Research revealed that urbanization, deforestation, and agricultural expansion have reduced the amount of city forest and grassland in recent years. The future grassland, sparse vegetation, and forest areas are anticipated to be decrease due to industrialization, urbanization and other unplanned developmental activities in the expanse of natural resources in the city. The vulnerable hotspot areas are consistent in each the two periods (i.e. historical and current) as there are no adaptation strategies develop to alleviate the biodiversity deterioration, except the extent variation in the three period. The future is expected to be worst with increase in severity and extent unless pro-active adaptation pathways are developed to protect and conserve each species in the city.

While the city has a wealth of biodiversity and a diverse range of species, it is also extremely vulnerable to the effects of climate change, and the majority of species are vulnerable to the rising temperatures, urbanization, and water scarcity without adequate coping mechanisms or policies. Species and habitat tolerance levels to global change (climate and land use cover changes) is quite less meaning that they are sensitive to climate risk (rising temperature, extreme cold/dry day, flood, and drought) with limited coping capacity (knowledge, skill, finance, technologies, planning, political will, policy commitment, and management tools). The exposure and sensitivity are mapped in the biodiversity vulnerability map assuming that the communities coping capacity to minimize the negative impact of climate change on biodiversity is limited so that most of the species at risk of extinction.

Biodiversity future vulnerabilities

Natural ecosystem like forest, mountain, wetlands, waterbodies, and grasslands have been the centre for human existence that play an important role in making cities and towns more liveable. These have been the most common centres for human growth owing to easy availability of water source for drinking and other purposes, food resource, transportation and other basic necessities for human existence. They help clean water, reduce flood risk, filter stormwater, replenish groundwater supplies, reduce the urban heat island effect, offer habitat to important plant and animal species, and provide critical access to green spaces in areas that are often dominated by the built environment. Despite of all these advantageous the forestlands in the city are highly deteriorated due to urban, industry, and agricultural expansions besides to climate and land use cover changes. Due to the developmental activities in the city, rivers or wetlands are highly polluted and affected with invasive species. The wetland restoration, protection around Debre Birhan is quit less, and face greater barriers. Conservation, buffering and restoration of wetland/ rivers and plantation areas that requires law, policy, and multi-sectoral cooperation harness urban biodiversity and ecosystems as adaptation and mitigation solutions will help achieve more resilient, sustainable, and liveable outcomes for cities and urban regions. When pressures by climate change and human actions like habitat destruction interact, the negative impact on biodiversity is expected to be much worse. This loss of biodiversity reduces the health and function of ecosystems. Moreover, it will affect their resilience and ability to absorb and recover from climate-related hazards, like drought, flooding or storms. This means that a decrease in biodiversity will lead to an increase in climate vulnerability of our landscapes. The biodiversity vulnerability hotspot areas will be worst in the future due to urbanization, industrialization, and unplanned developmental activities in the city. Better biodiversity areas area expected to be urbanized in the future with the current urban trend. Therefore, proactive nature-based solution, restoration and natural resources protection is quite vital for to have resilience and sustainable city.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

05

OVERLAPPING VULNERABILITIES

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

Urban and climate change vulnerabilities

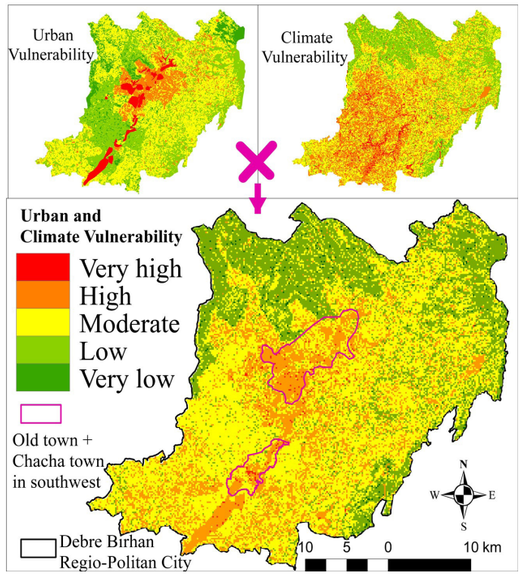


Fig. 28: Urban and climate change vulnerability level of DBRP city

The overlapping vulnerability of urban and climate change showed that urbanized areas with limited biodiversity are very highly and highly vulnerable to climate change (flood, soil erosion, temperature rise (maximum and minimum), and drought). Very high vulnerability is exhibited in Chacha area and peripheries of the city as it was implicated and validated during the stockholder workshop. Furthermore, Chacha area is mostly known by flooding, while others parts of the city suffer with maximum and minimum temperature as well as soil erosion. As it is indicated by the map and generally true that the none-vegetation areas as a result of urbanization are exposed to rising temperature and other climatic extremes. Therefore, the urban and climate vulnerability map indicated that densely populated areas around the main city (service and infrastructure), slum, informal settlements and historical sites are very highly and highly susceptible (Figure28). For example, croplands and houses around Chacha and Berresa rivers had been distracted and damaged in past years. In the main city informal settlements, including internal displacement houses have been flooded and damaged in the previous year's floods due to poor drainage and other causes (OCHA, 2023; SymbioCity, 2020; Eyosias, 2008). It is commonly known that the poorest people in the world would be disproportionately affected by climate change. They will be negatively impacted by high heat, extreme dry or cold days, growing water scarcity, soil erosion, crop failure, flooding of low-lying areas/along rivers, and other factors because of their low coping capacity and high vulnerability. Forest, grassland and rural areas are less vulnerable to urban and climate change.

Climate change and biodiversity vulnerabilities

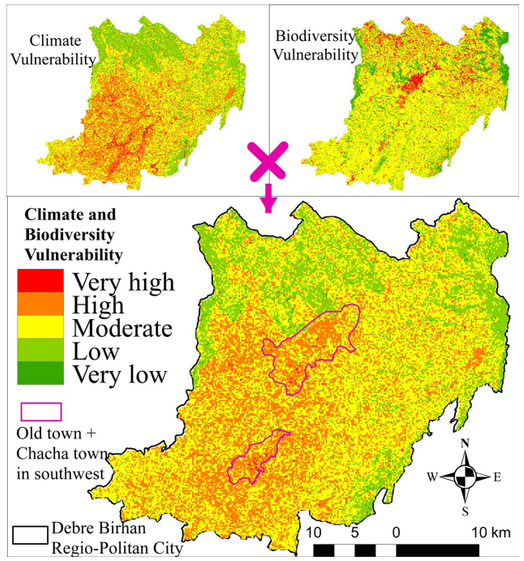


Fig. 29: Climate change and biodiversity vulnerability level of DBRP city

Degraded terrain and urban areas with NDVI values below zero and comparatively warmer, erosion- and flood-affected areas were categorized as extremely sensitive, according to this overlaid map of climate change and biodiversity vulnerability. Given that the hotspot/very highly and highly vulnerable areas

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

are result of identical weighted overlay of climate and biodiversity vulnerability, it is implied that the biodiversity of the area has been impacted in recent years by urbanization and climate change (Figure 29). For instance, there needs to be some kind of rehabilitation because the biodiversity loss in the main old city, along the roads, and the surrounding Chacha town has been severely impacted. Hence, it is expected that climate change (especially on flooding and rising temperatures) would have a major impact on plant and animal species that depend on these ecosystems for their livelihoods. Climate change and other development activities have less of an impact on the biodiversity of the city's north, northeast, and peripheries' forests, sparse vegetation, and grasslands. Thus, it is crucial that researchers and decision/ policy-makers keep an eye on this phenomenon and devise plans to lessen its adverse consequences, which include the extinction of species and loss of biodiversity. Addressing the interrelated issues brought on by climate change and environmental degradation is essential to ensuring the sustainable livelihoods of people whose main source of income depends on land. Thus, nature based solution and protection of biodiversity hotspot areas is crucial.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

Biodiversity and urban vulnerabilities

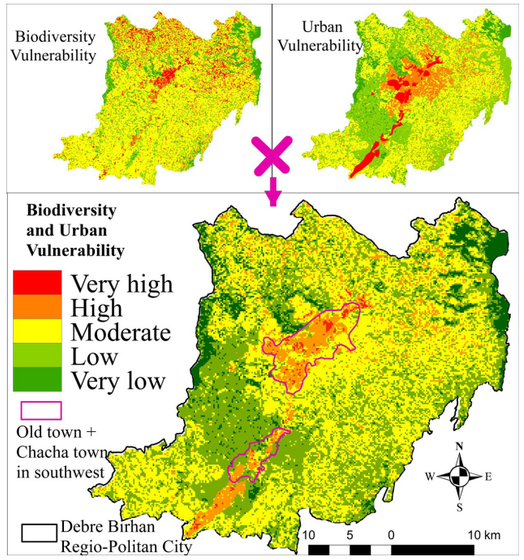


Fig. 30: Biodiversity and urban vulnerability level of DBRP city

As indicated in Figure 30, overlapping vulnerability of biodiversity and urbanization exhibited that urbanization, road and industrial developments have been very highly and highly affecting the biodiversity of the city. The hotspot, which are very highly and highly vulnerable areas revealed along the main road (road from Addis Ababa to north Ethiopia), in Debre Birhan old town including Chacha, and district town in the zone. Rapid and unplanned urbanization puts immense pressure on biodiversity hotspot areas. Rapid urbanization into this biodiversity hotspot is a significant disturbance, and even minor increases in pollution or changes in land use can have a detrimental impact on biodiversity and ecological processes in the city. Because there is little infrastructure or planning to protect natural areas, local ecosystem services are also likely to deteriorate in informal settlements. For instance, people living in informal settlements frequently rely on rivers or lakes to dispose of their household and/or toilet waste because these areas lack sewers and garbage collection services.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

06

MULTILAYERED VULNERABILITY

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

Multilayered vulnerability hotspots

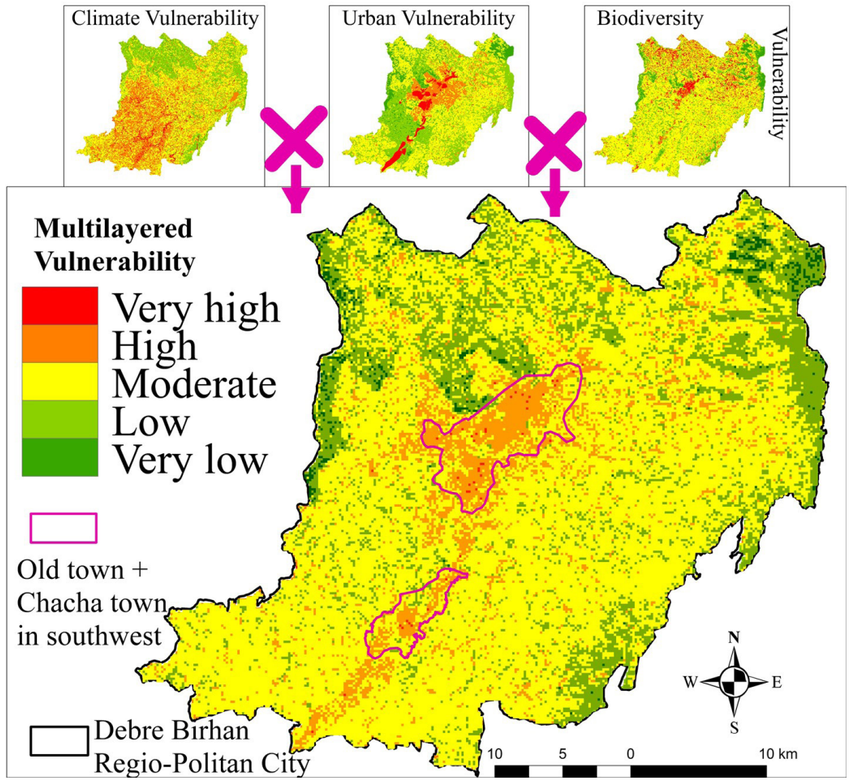
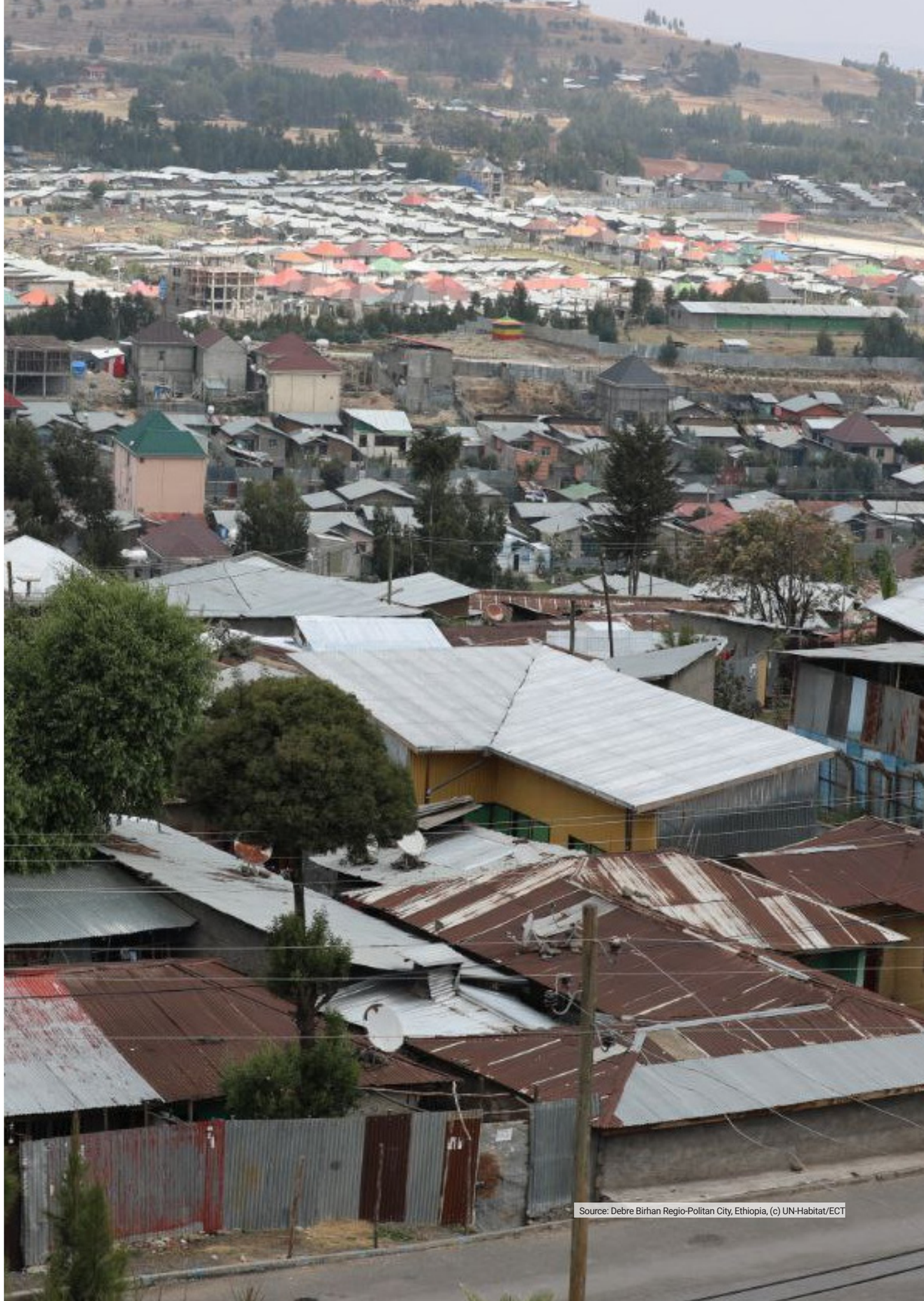


Fig. 31: Multilayered vulnerability level of DBRP city

Climate-related hazards such as flood, drought, extreme temperature, and soil erosion have long been experienced in and around Debre Birhan city. The recent rapid population growth and unplanned as well as uncontrolled urbanisation further increases climate risks with a lack of adequate urban planning, land use and governance. Figure 31, the multilayered vulnerability assessment indicated that densely populated, informal settlement, slum and degraded areas are highly and very highly vulnerable to climate change. The city is particularly vulnerable to climate change because of its unplanned expansion, fast population increase, high rate of rural-to-urban migration, sizable informal settlements, and slum regions with little access to vital infrastructure and development resources. Besides to the old main town, historically flood risk areas around Chacha town and rivers exhibited high and very high vulnerability. The city is vulnerable to climate hazards (rainfall anomaly, temperature rise, water stress, drought, and flash/river floods) because of the city's geographical location. Indeed the city is sensitive as most of the productive sectors in the city are reliant on seasonal rainfall, and natural resource that are highly susceptible to climate change with no or limited coping capacity (infrastructures, policy, skill, knowledge etc.). The climate projection indicated increase of heavy/intense rainfall particularly in the wet season of August and July that leads to flooding and as a result, several infrastructures could be affected in the city. Moreover, high temperature that affects biodiversity, road, water and other infrastructures in the city. Climate change not only affect the biodiversity of the city but also the sustenance of different infrastructures. The impact of climate change is not equal to all households that will exacerbate the already existing vulnerability of the poor, the elderly, the young and women. Therefore, it is important to have educational campaigns to increase awareness of the need to strengthen institutional frameworks, regulatory policies, and laws in order to



Source: Debre Birhan Regio-Politan City, Ethiopia, (c) UN-Habitat/ECT

achieve sustainable natural resources management. This will pave the way for more resilient, sustainable, and environmentally conscious cities, which align with the UN Sustainable Development Goals (SDGs), Africa Agenda 2063, and National (Green Legacy Initiative, Climate Resilient Green Economy (CRGE), and National growth Transformation Plan (GTP I, II)).

Multilayered vulnerability (very high and high vulnerability hotspots)

The very high and highly MVA hotspot areas are identified independently as indicated in (Figure 31 and table 7) that helps in prioritization of intervention activities. The city level multilayered vulnerability assessment and implementation of adaptation intervention is a proactive and supportive measure for the local community because climate-related hazards, such as drought and flood, are very common in Ethiopia, including Debre Birhan Regio-Politan city due to its geographical location. When these hazards occur, the community's fate is to fail under foreign humanitarian aid, which is not always good because largely participate on emergencies to save life for the time being that is not long lasting. However, this study focus on sustainable development, in order to build an inclusive and liveable eco-city that is resilient to both climate change and biodiversity loss, this study assesses the effects of climate change on biodiversity loss and urban poor and identified hotspot areas for further intervention plans (infrastructure development programs for urban poor). This should be able to establish a proactive climate hazard response and sustainable development program to put an end to emergencies with the help of this intervention plan in a well-identified vulnerability hotspot location.
Based on the city the structural plan survey study and preliminary consultation process, Weyeniy or the north part of the city (water shortage/drought affected area); old Debre Birhan town, specifically Shewareged kebele of Atse Zeryakobe along with Emye Minilk and Etigie Tayitue sub-cities as highly slum areas; and Chacha town along the river and plain areas (flood affected area) were identified as three hotspot areas of the city, which was validated with various workshops.These survey and workshop analysis exactly in lines with the physical data (raster MVA) analysis indicated that the climate change dimension indicators exhibited that the Chacha area is very highly affected by climate change and the old Debre Birhan town areas along the main roads are highly vulnerable to urban and biodiversity vulnerability. The informal settlement that covers 587.47ha (15.09%) of land in the city has to be also reduced through a continuous capacity building and legal processes. The already the existing informal settlements are a heavy burden to the communities, their governments, and other stakeholders, in terms of the required improvement toward sustainability.
For example, following the main rainy season smallholder vegetable farmers in the city loss their agricultural product almost every three years due to flooding/ lack of water availability around Chacha and along other rivers to the level with no seed for the next agriculture season. Exposure to recurrent flooding can be particularly disastrous for urban poor households that own little land and rely entirely on urban agriculture for their livelihood. Heavy and prolonged rainy season rainfall led to flooding incidents in the entire city in July, and August. Relying on agriculture, daily labour, straight market and other menial works can become tenuous during climate hazard reducing food security through crop failures and livestock losses. The same is true for slum area dwellers a little climate shock like flooding or water shortage can easily affect them and it can further bring water born and other transmission disease can affect many in the older town. In slum areas the increased rates of runoff, lack of drainage systems, lack of storage systems, overwhelming amounts of rainfall leading to flooding has been affecting the old town. Based on table 7, the hotspot (very high and high) vulnerable areas are quite large in old Debre Birhan and chacha town areas covering 4276.79 ha and 1159.39 ha, respectively. Therefore, proper intervention plan for the identified hotspot areas is vital to minimize the negative impact of climate change and loss of biodiversity to the urban poor of the city.

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

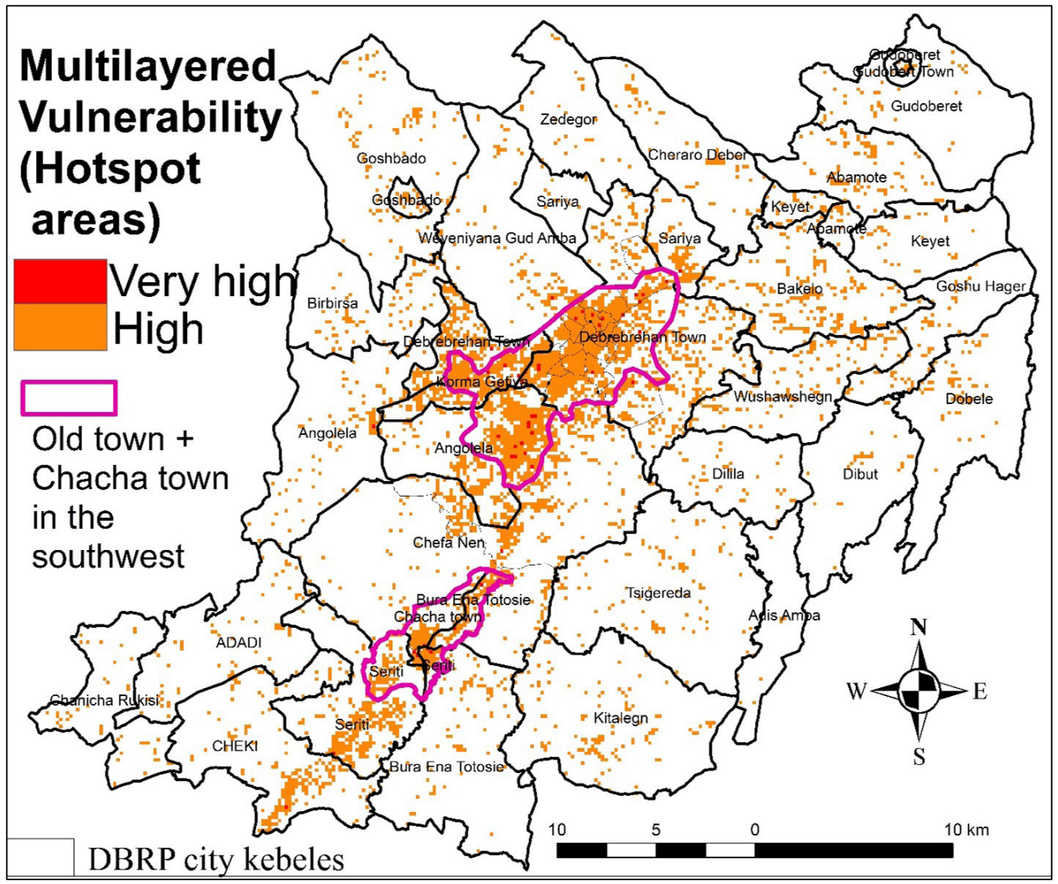
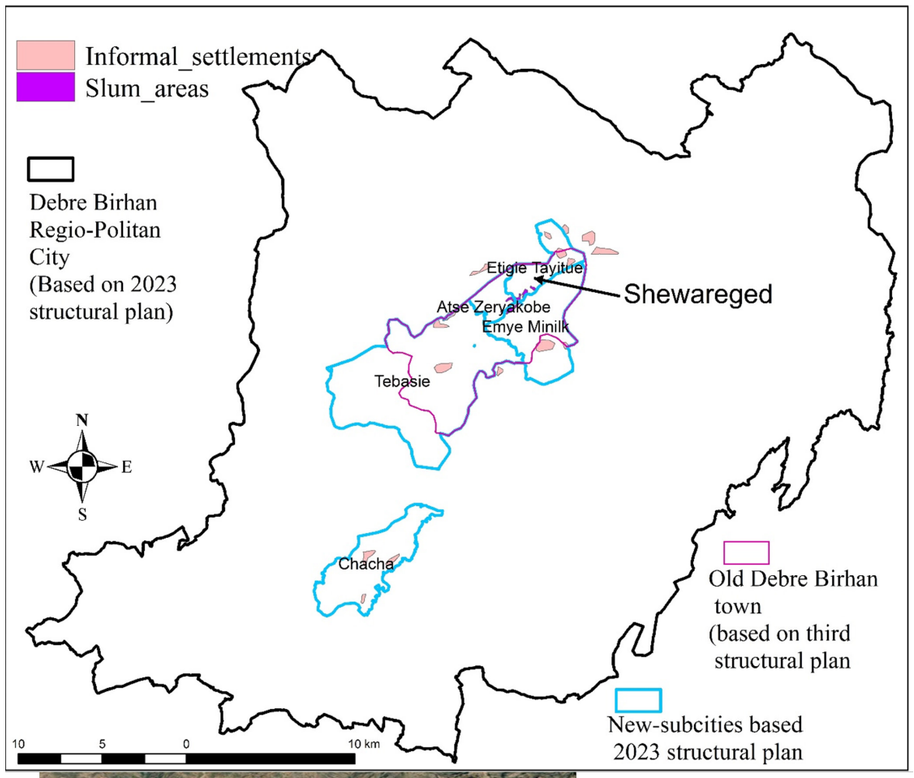


Fig. 32: Very high and highly MVA hotspot areas.

Table 7. Very high and highly MVA hotspot areas in hectare

DBRP city	(Multilayered Vulnerability level (hectare		
	Very high	High	Very high and high
	118.94	12375.49	12494.43
Old Debre Birhan town	76.59	4200.20	4276.79
Chacha town	18.21	1141.18	1159.39



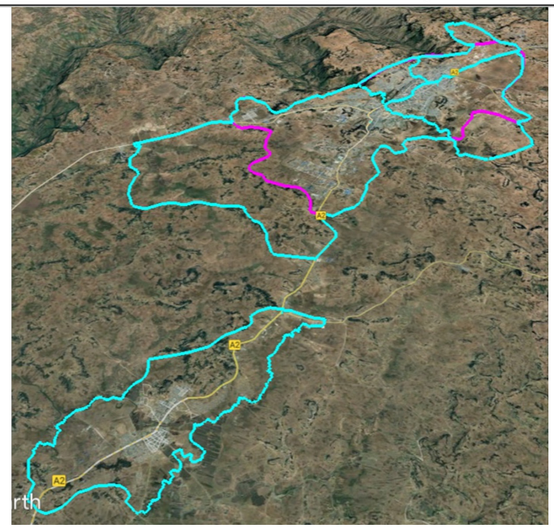


Fig. 33: Explanatory map of sub cities and towns.

07

STAKEHOLDERS ANALYSIS

Source: Debre Birhan City, Ethiopia , (c) DB city communication office

Stakeholder Engagement for MVA

After the formation of the delivery team, the MVA steering committee was established and mobilized with the following members: the focal person from the Ministry of Urban and Infrastructure Development, the Deputy Mayor of Debre Birhan City, the Director of the Debre Birhan City Environment Office, a representative from the North Shewa Zone Environment Office/ Delegate, the Climate Adaptation Department, a GIS expert from the Debre Birhan City Municipality (Urban Planner), and a representative from Debre Birhan University (Urban Planner and GIS Expert).

Stakeholder engagement is a crucial component of climate change vulnerability assessments and the climate action planning process. It plays a vital role in enhancing transparency, improving decision-making quality, fostering public trust, and promoting a sense of ownership. Additionally, effective engagement ensures the fairness and impact of interventions, which is key to the success of the project. Moving beyond just producing documentation, stakeholder engagement is essential for driving policy implementation and adaptation strategies that will build a resilient community.

Throughout the project's preparation and mapping and analysis phases, stakeholder engagement has been a priority. The goal was to enhance ownership of the climate vulnerability baseline study, making the reports more responsive to local needs. The project successfully incorporated stakeholder participation and consultation at each stage, involving a diverse group of stakeholders from various sectors, including ministries, state-owned entities, local communities, local governments, regional governments, national governments, NGOs, the private sector, civil society, and traditional leaders, with a particular focus on gender and marginalized communities. Special efforts were made to ensure the active involvement of women, youth, and representatives from climate hotspot areas. This was achieved by organizing targeted workshops that addressed their specific interests and ensuring their engagement in hands-on learning sessions.

The following tables (Table A, B, C, D) present the stakeholder list, stakeholder analysis (Influence-Interest) matrix, IAP2 spectrum of participation, and stakeholder profiles used throughout the multi-layered vulnerability assessment.

Table 8.Stakeholder List from Debre Birhan, Ethiopia for AECID RISE UP Project

Stakeholder Category	Stakeholder	Main Role in Project	(Key Engagement s (Phase I
National government level	Ministry of urban and infrastructure development Environmental Protection Authority of Ethiopia	General stakeholder Harmonizing strategies	Provision of national plans Aligning the strategies with regional plans
Amhara Regional State Government	Regional office of urban and infrastructure development Regional environmental protection office	General stakeholder coordination and resource mobilization	Selection of cities; Coordination with Local Government;
Local Administration of Debre Birhan	Mayor office City council The Environmental Protection, Cleanness, Beauty, and Green Development office The city's Water supply and Sewerage service office The city agriculture office from city to kebele level The city's land administration and investment offices	Co-leader and direct beneficiaries of the project; Counterpart to jointly execute several activities of the project	Local communities identification and selection; Community-level data collection and acquisition; Multilayered vulnerability assessment support; Development of City-wide Resilience Strategy development; Capacity development
Sub-city and kebele level administra-tions	Sub-city and kebele level administration Kebele level water shade committee	Local partner and counterpart to support project activities	Community-level data collection and acquisition; Multilayered vulnerability assessment support; Development of City-wide Resilience Strategy development; Capacity development
Local Communities	Influential individuals Community representatives living in climate hazard prone areas Vulnerable community members (women, elderly, disabled)	Participation in vulnerability profiling, identification of key challenges, needs and priorities	Community-level data collection and acquisition; Multilayered vulnerability assessment support; City-wide Resilience Strategy development
Debre Birhan University	Research and community service directorate Respective colleges and institutions	Potential partner for capacity building exercise of local administrations and knowledge sharing dissemination	Community-level data collection and acquisition; Multilayered vulnerability assessment support; City-wide Resilience Strategy development
Communi-ty-based organizations	Tesfa Berhan Child and Family Development Organization Water forum representatives youth associations Women associations Industry association representatives	Mobilize different community organizations and groups	Prioritizing actions Addressing interests

Table 9. Stakeholder analysis (Influence-Interest) Matrix from Debre Birhan, Ethiopia for AECID RISE UP Project

Possible Stakeholder categories	Stakeholder	Interest How much interest do they have over project (low, medium, high)	Influence How much influence do they have over the project?(low, medium, (high
National government	Ministry of urban and infrastructure development	High	high
	Environmental Protection Authority of Ethiopia	High	medium
Amhara Regional State Government	Regional office of urban and infrastructure development	medium	high
	Regional environmental protection office	High	low
Derbre Berhan City administration	Mayor office	High	High
	City council	Low	High
	The Environmental Protection, Cleanness, Beauty, and Green Development office	High	High
	The city's Water supply and Sewerage service office	Medium	Medium
	The city agriculture office from city to kebele level	Medium	Medium
	The city's land administration and investment offices	Medium	Medium
Debre Birhan city sub-cities and kebele administrations	Sub-city and kebele level administration	High	High
	Kebele level water shade committee	Low	Low
Local Communities	Influential individuals	High	Low
	Community representatives living in climate hazard prone areas	Medium	Low
	Vulnerable community members (women, elderly, disabled)	Medium	Low
Debre Berhan University	Research and community service directorate Respective colleges and institutions	High	Low

Table 10. IAP2 Spectrum of Participation from Debre Birhan, Ethiopia for AECID RISE UP Project

	Inform	Consult	Involve	Collaborate	Empower
Participation Goal	To provide the public with balanced and objective information to assist them m understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or .decisions	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and .considered	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution	To place final decision-making in the .hands of the public
Promise	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced .the decision	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input .influenced the decision	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the .maximum extent possible	We will implement .what you decide
Techniques	Brochures, media coverage, leaflets, reports	Consultation meetings, direct meetings, focused group discussion, key informant interview	Meetings, Workshops, exchanges of minutes, emails.	Training, data collection procedures, official letter	Participatory climate ,resilience planning
Usage	To deliver project background information. To get their insights	To enrich the content and obtain appropriate information/data, to collect feedback.	To explore ideas and concepts, to get more insight about the content of the .framework, to get advice	To partner in each aspect of decision .making	To empower to make decisions
Allocated Stakeholders	Local Communities Vulnerable community members Women associations	Debre Berhan University Tesfa Berhan Child and Family Development Organization Community representatives living in climate hazard prone areas USAID Ethiopia branch Water forum representatives	Debre Birhan city municipality Debre Birhan city sub-cities and kebele administrations Spanish Agency for International Development Cooperation (AECID	Ministry of urban and infrastructure development Environmental Protection Authority of Ethiopia Regional office of urban and infrastructure development Regional environmental protection office	Debre Birhan city municipality Local Communities

IAP2: International association of public participation

Table 11. Stakeholder profile from Debre Birhan, Ethiopia for AECID RISE UP Project

Stakeholder	Level (H-High, M-Me-(dium, L-Low		Key information	Interests	Influences	Potential contribution	Level of engagement
	interest	Influence					
Ministry of urban and infrastructure development	H	H	,promotes urban development provide technical and capacity building support to regional and municipality	Promote in plan development, plan implementation and capacity building	Decision making Technical advisory	Provision of national plans	Inform via direct meeting and reporting Consult the ministry on the existing initiative/ efforts related to climate change adaptation
Environmental Protection Authority of Ethiopia	H	M	Promote environmental sustainability at all levels	Protection, development & sustain-able use	Decision making Technical advisory	Aligning the strategies with regional plans	Inform via direct meeting and reporting
Regional office of urban and infra-structure development	M	H	Technical and capacity building support to regional and municipality	Plan development, plan implementa-tion and capacity building	Decision making Technical advisory	Selection of cities; Coordination with Local Gov-;ernment	Inform via direct meeting and reporting Consult the ministry on the existing initiative/ efforts related to climate change adaptation
Regional environmental protection office	H	L	To plan, coordinate, promote and over-see the environment conservation	Protection, development & sustain-able use	Decision making Technical advisory	Provision of regional laws, best practices and experiences	Consult the ministry on the existing initiative/ efforts related to climate change adaptation
Debre Birhan city municipality	H	H	Promote sustainable land use and eco-nomic development	Protection, development & sustain-able use	Decision making Technical advisory	Local communities identification and selection; ;Community-mobilization, MLVA support	Inform via direct meeting and reporting
The Environmental Protection, Cleanness, Beauty, and Green Devel-opment office	H	H	Environmental Protection, Cleanness, Beauty and Green Development	Greenery and Waste management	Waste collection and Monitor	Development of City-wide Resilience Strategy development; Capacity development	Inform via direct meeting and reporting
Debre Birhan city sub-cities and kebele administrations	H	H	Protection, development & sustainable use	Protection, development & sustain-able use	Decision making	Community mobilization, support in data collec-tion	Active and continuous consultations, reporting
Local Communities	H	L	-	Culture & economy	Provide information about the recent incidences and their perceptions	Support in data collection; MLVA support	Collect opinions and concerns during stakeholders meeting
Community representatives living in climate hazard prone areas	M	L	-	Culture & economy	Provide information about the recent incidences and their perceptions	Prioritizing actions Addressing interests	Collect opinions and concerns during stakeholders meeting, Target group meetings
Vulnerable community members	M	L	-	economy	Provide information about the recent incidences and their perceptions	Prioritizing actions Addressing interests	Collect opinions and concerns during stakeholders meeting, target group meet-ings
Debre Berhan University	H	L	The university has triple mandates: Teaching-learning, research a d commu-nity service activities	Using Science & technology & extension for development, resource conservation and sustainable use	Technical advisory	Community-level data collection and acquisition; MLVA support; City-wide Resilience Strategy development	Inform via direct meeting and reporting
Tesfa Berhan Child and Family Development Organization	H	L	Community based development and awareness creation	Assisting in capacity building, aware-,ness creation Conservation & demonstration	Technical advisory	Best experiences from climate vulnerability as-sessment and adaptation pathways	Collect opinions and concerns during stakeholders meeting, target group meet-ings
Water forum representatives	H	M	,Sustainable use of water Awareness creation	Water access Equitable use in link to climate and land use change	Decision making Technical advisory	Can create a bridge of communication with wider community	Collect opinions and concerns during stakeholders meeting
youth associations	H	L	Awareness creation	Inclusion of youth concerns in adap-tation measures	Technical advisory	Can create a bridge of communication with wider community	Collect opinions and concerns during stakeholders meeting
Women associations	M	L	Awareness creation	Gender sensitive adaptation mea-sures	Technical advisory	Can create a bridge of communication with wider community	Collect opinions and concerns during stakeholders meeting
Spanish Agency for International De-(velopment Cooperation (AECID	H	H	Fight against poverty and to sustainable human development	Assisting government & community in integrated development; capacity building awareness creation Conservation & demonstration	Technical advisory	Best experiences from climate vulnerability as-sessment and adaptation pathways	Inform via direct meeting and reporting
USAID Ethiopia branch	H	L	Fight against poverty and to sustainable human development				

Consultative and capacity building workshop with stakeholders

As part of the participatory approach employed throughout the project, a validation workshop was held on July 24, 2024, with key stakeholders. These included representatives from Debre Birhan Municipality (such as the Mayor, Deputy Mayor, Head of the City Environment Office, experts, Head of the City Agricultural Office, City Water Supply and Sewerage Services, Head of the City Infrastructure Office, and planners), as well as representatives from the Ministry of Urban and Infrastructure Development, Debre Birhan University, the regional office of Urban and Infrastructure Development, and other relevant governmental entities. Additionally, stakeholders from various sectors, including youth, women, and community-based organizations (CBOs), participated in the workshop to review and validate data collection efforts. The goal was to refine the analysis outputs to better address the local needs for preparing the MVA for Debre Birhan City.

The workshop began with a presentation on the findings from the city context analysis, followed by an introduction to UN-Habitat and the RISE UP flagship program. This was followed by a discussion on Multilayered Vulnerabilities in Cities, Climate Change Risks and Vulnerability Assessments, and the Multilayered Vulnerability Assessment (MVA) methodology. After the presentations, facilitators led a brainstorming exercise on data access and sources. They reviewed both available and missing datasets, as outlined in the technical handbook and MVA data collection brief, which covered base maps, climate change, urbanization, and biodiversity dimensions.

Participants were then divided into three groups and tasked with identifying potential datasets, specifying the data author, custodian, availability, and type. Based on the identified gaps in data, participants recommended potential data providers, including institutes, individuals, and organizations. These recommendations will help address the data gaps for the MVA. Throughout the session, participants shared their experiences and knowledge about MVA data and indicators. Overall, while most of the required datasets were already available, several partially existing or missing datasets were presented, and corresponding data sources were identified during the workshop.

Additionally, participants engaged in an Impact Chain Analysis exercise during the workshop. Divided into groups, they conducted impact chain analyses for three selected study areas within Debre Birhan city: Shewareged Gedle Kebele (an informal settlement), Chacha area (a flood-prone zone), and Weyneyea Kebele (a drought-prone area). The exercise involved completing impact chain analysis handouts, tracing hazards to climate change drivers, and identifying both primary and secondary impacts, while also examining their interdependencies.
Climate hazards experienced in the selected hotspot areas were identified, along with their drivers and both primary and secondary impacts. Workshop participants gained valuable knowledge, skills, and expertise on climate hazards and their complex interconnections with other local concerns. Both participants and local government officials committed their full attention to the project, ensuring its success and long-term continuity. The workshop also led to an enhanced understanding among participants of the interdependencies between various climate hazards and other critical issues affecting the area.
The results of the Chacha area climatic hazard chain analysis exercise, for instance, are completed as follows.

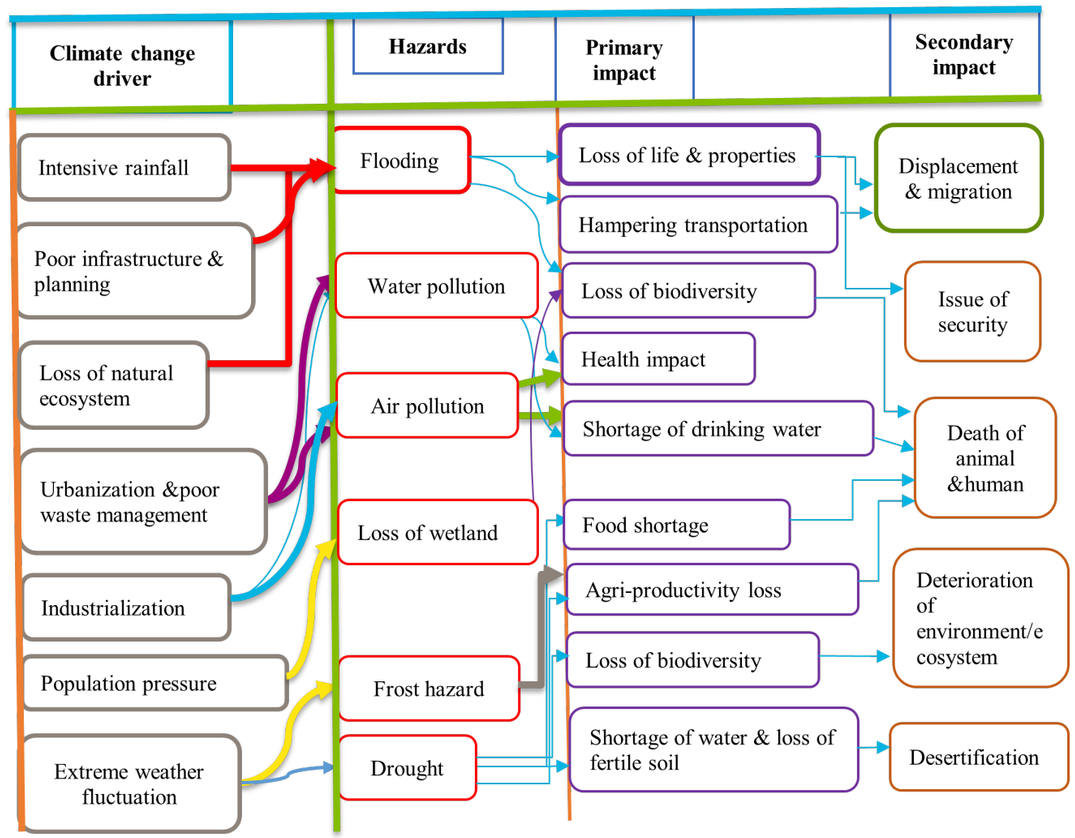


Fig. 34: Impact chain analysis

Finally, Participatory Mapping Exercise has been done by workshop participants. The workshop effectively leveraged local expertise from stakeholders to fill data gaps and enhance the analysis for the three selected study areas. Participants overlaid maps with transparent sheets, drawing layers for:

- Climate Change: Mapping hazards, impacts, and short, medium, and long-term risks, as well as future projections, identifying factors such as landslides, flood-prone areas, and cold spells.
- Urbanization: Identifying areas of existing urban vulnerabilities and areas earmarked for future growth, with a focus on informality and inequality.
- Biodiversity: Identifying current and future biodiversity vulnerabilities, including heritage sites, water bodies, and biodiversity connectivity.

In this exercise, participants mapped various hazards, including floods, droughts, and extreme heat, along with their potential future severity and direction. Critical urban infrastructure—such as primary and secondary schools, major and minor roads, telecommunications, and hospital areas—was identified and mapped. Additionally, informal settlements and heritage sites (such as churches and mosques) were also mapped. Participants delineated biodiversity-rich areas, including protected forests, conservation areas, wetlands, and water bodies. After individually mapping the three components—biodiversity, climate change, and urbanization—participants performed a weighted overlay of these layers, revealing vulnerability hotspots across Debre Birhan city. The final map overlay revealed key vulnerability hotspots across Debre Birhan city, providing a comprehensive view of the interconnected challenges facing the urban environment.
Overall, the workshop was successful in providing participants with valuable knowledge and practical

skills. They gained a solid understanding of climate hazards, learned how to overlay different maps, and were introduced to the process of conducting a Multi-layered Vulnerability Assessment (MVA) in a simple, accessible manner

Fig. 35: . consultative and capacity building workshop participants during the meeting.

Source: (c) UN-Habitat/ECT

MVA Validation Workshop

To validate the prepared Multi-Layered Vulnerability Assessment (MVA) profile of Debre Birhan city, a workshop was held on December 5, 2024, with key stakeholders. Participants included representatives from the Debre Birhan City Municipality, such as the Deputy Mayor, Head of the City Environment Office, City Agricultural Office, sub-city representatives, planners, and the Deputy Head of City Water Supply and Sewerage Services. Additionally, representatives from Ministry of Urban and Infrastructure Development, Debre Birhan University, the regional Urban and Infrastructure Development office, community-based organizations (CBOs), youth and women and other relevant governmental entities were in attendance.

The workshop began with a presentation of the city's MVA profile, followed by detailed discussions on the study's findings. Stakeholders provided feedback, specifically recommending revisiting and enhancing the groundwater potential analysis and the air pollution assessment. After thorough deliberations, the stakeholders validated and approved the MVA profile of the city for the next steps.

Fig. 36: .MVA validation workshop participants during the meeting.
Source: (c) UN-Habitat/ECT

08

ENDNOTES

Source: Debre Birhan Regio-Politan City, Ethiopia, (c) DB city communication office

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