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**Climate Change and Its Impact on Population Movement: An
Applied Study on Al-Obeid Administrative Unit (2000–2020)**

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Abstract

This study, entitled "Climate Change and Its Impact on Population Movement: An Applied Study on Al-Obeid Administrative Area (2000–2020)", aimed to identify the causes of population movement towards Al-Obeid, examine the relationship between climate change and urban expansion, and assess how climate fluctuations affect urban growth. It also investigated the link between rainfall variability, rising temperatures, and the decline of biomass in agricultural, livestock, and forest sectors, as well as identifying optimal strategies to mitigate population movement towards Al-Obeid. The study employed historical, descriptive, and statistical-analytical methods and used both primary data (observations and interviews) and secondary sources (books, journals, reports, and relevant websites). The findings indicated a decline and fragmentation of tree cover between 2000 and 2020, which affected plant diversity. Agricultural productivity also changed significantly due to fluctuating rainfall and rising temperatures. Environmental degradation and pressure on natural resources drove rural populations to urban centers, contributing to the expansion of urban areas in Al-Obeid. The study recommended strengthening the role of institutions and volunteer organizations to reduce the impacts of climate change on rural populations, promoting drought-resistant crops to curb forced migration, and managing urban expansion through sustainable urban planning to meet growing population needs.

Keywords: Climate Change, Population Movement, Urban Expansion, Al-Obeid, Sustainable Planning, Rural Migration

Introduction

Climate change has become a tangible global reality, manifested through the increasing frequency of droughts, floods, tropical cyclones, and wildfires, particularly since the Industrial Revolution and the rising use of fossil fuels. This has led to higher average temperatures and changes in the amount, intensity, and seasonality of rainfall, which have negatively impacted the livelihoods of traditional rain-fed agricultural producers, especially in semi-arid areas of Sudan such as North Kordofan State and the city of Al-Obeid (Elagib & Elhag, 2011). Temperature directly affects the formation of plant communities, as maximum and minimum temperatures control the growth of plant species and their transition from vegetative to reproductive stages. Water is also one of the most critical environmental factors influencing plant growth and distribution. Rainfall varies spatially and temporally; light-intensity rains are considered most beneficial due to the soil's ability to absorb them almost entirely. However, in semi-arid regions such as central Kordofan, rainfall is unevenly distributed throughout the year, leading to reduced biomass productivity and negatively affecting traditional agricultural production (Al-Awadat et al., 1997). The persistence of these climatic conditions has diminished the capacity of traditional producers to meet their needs, whether from crops or grazing resources. This has pushed rural populations to seek alternative livelihoods in urban areas. Between 2000 and 2020, the city of Al-Obeid witnessed a noticeable increase in population movement from surrounding villages and rural areas, where migrants engaged in non-agricultural professions such as trade, services, and handicrafts, in addition to seeking basic services like water, health, and education (United Nations Environment Programme, 2007). Recent studies have confirmed that the degradation of natural resources and ecosystems has made rural communities more vulnerable to forced migration, thereby accelerating urban transformation and increasing pressure on infrastructure and services in regional cities. A study by the Tufts Feinstein International Center indicated that the reduction of pasturelands and the loss of traditional livestock, resulting from recurrent droughts and changing climate patterns, has driven pastoral communities toward internal migration to regional cities, contributing to the expansion and growth of urban centers in Al-Obeid (Tufts Feinstein International Center, 2013).

From this perspective, climate change is not merely an environmental phenomenon but a pivotal factor reshaping settlement patterns and internal migration in Sudan. The link between the degradation of



natural resources in rural areas and rapid urban growth in regional cities such as Al-Obeid reflects the impacts of climate change on social and economic stability and underscores the need for integrated development policies to manage natural resources and enhance the adaptive capacity of rural communities and cities receiving migrants.

Research Problem: Climate change has resulted in rising average temperatures, increased evaporation rates, and greater exposure of the land surface to solar radiation. Consequently, the productivity of biomass in the agricultural, livestock, and forestry sectors has declined due to the irregularity and spatial-temporal variability of rainfall. These environmental changes have created difficult living conditions for traditional producers in rural areas, compelling populations to migrate from climate-affected regions in search of alternative livelihoods in regional cities.

The research problem is reflected in the following questions:

1. What are the main factors leading to the increasing rates of population movement toward Al-Obeid Administrative Unit?
2. What is the relationship between climate change and the expansion of urban centers in the city?
3. How do rainfall variability and rising temperatures affect biomass productivity in the agricultural, livestock, and forestry sectors?
4. What approaches and strategies are being adopted to reduce population movement toward Al-Obeid Administrative Unit?

Significance of the Study

Climate change is one of the pressing global issues confronting governments and international organizations, due to its negative impacts on people's livelihoods and traditional means of subsistence in the agricultural, livestock, and forestry sectors. Identifying the extent of environmental and economic impacts resulting from climate change contributes to estimating the efforts and resources required to mitigate its effects and address the associated challenges.

Furthermore, understanding the scale of population movement and internal migration caused by the degradation of natural resources helps policymakers assess the essential needs of the affected populations, whether in terms of basic services such as water, health, and education, or in providing alternative employment opportunities. From this perspective, the study contributes to providing accurate and detailed information on the relationship between climate change and population mobility in the study area. Such insights can serve as a foundation for formulating developmental strategies and environmental and social policies capable of mitigating the effects of this phenomenon in regional cities such as Al-Obeid.

Research Objectives: The study aims to achieve the following:

1. To identify the factors driving population movement toward Al-Obeid Administrative Unit, with a focus on the associated environmental, social, and economic aspects.
2. To examine the relationship between climate change and the expansion of urban centers, and to analyze how climate variability influences urban growth in the city.
3. To explore the relationship between rainfall variability, rising temperatures, and the decline of biomass in the agricultural, livestock, and forestry sectors.
4. To determine the most effective approaches and strategies that can be adopted to reduce population movement toward Al-Obeid Administrative Unit, by proposing mitigation measures based on environmental, developmental, and social policies.

By pursuing these objectives, the study seeks to provide a clear scientific framework for understanding the impact of climate change on internal migration and urban expansion in Al-Obeid, thereby enabling well-informed strategic decision-making to minimize the adverse effects of this phenomenon.

Research Hypotheses

the research problem and objectives Based on the following hypotheses have been formulated to examine the relationship between climate change and population movement in Al-Obeid Administrative Unit:

1. There are both natural and human-induced causes of climate change, which in turn drive population movement toward nearby urban areas in search of alternative livelihoods.
2. The decline in rainfall rates leads to rising temperatures, thereby pushing populations toward areas less affected by climate change.
3. Rainfall variability and rising temperatures result in reduced biomass productivity in the agricultural, livestock, and forestry sectors, which increases the vulnerability of rural livelihoods.
4. There are currently no effective measures or strategies in place to reduce population movement toward the study area, which in turn accelerates the expansion of urban centers and increases pressure on infrastructure and services in the city.



Research Methodology

In line with the objectives of the study, the researchers adopted a set of integrated research methods to achieve an in-depth understanding of climate change and population movement in the Al-Obeid Administrative Unit, as follows:

Historical Method: This method was employed to trace climate change during the study period (2000–2020) by examining documents, reports, and previous statistics. It provided insights into the temporal evolution of the phenomenon.

Descriptive-Analytical Method: This method was applied to describe the phenomenon of climate change in the study area, and to analyze and interpret the collected data in order to reach clear and detailed findings regarding the impact of climate change on biomass productivity and population movement toward the study area.

Statistical-Analytical Method: This method was used to summarize numerical data and statistics related to climate change and internal migration, and to present them in the form of tables, charts, and illustrative figures, thereby facilitating the analysis of results, comparison across different periods, and assessment of environmental and social impacts.

Data Collection Sources

The study relied on multiple data sources to ensure the collection of accurate and comprehensive information on climate change and population movement in the Al-Obeid Administrative Unit. These sources were classified as follows:

Primary Sources:

Field Observation: Used to monitor the impacts of climate change during the study period, including changes in agricultural and forested areas, as well as the resulting expansion of urban settlements due to population movement toward the city.

Personal Interviews: Conducted with officials responsible for the administration of Al-Obeid, as well as with long-term residents and recent arrivals who migrated to the city during previous drought waves. These interviews provided direct insights into urban expansion, the causes of internal migration, and local adaptation strategies to climate change.

Secondary Sources:

Secondary Data: Included official documents, government reports, and previous studies related to climate change and internal migration in North Kordofan State.

Information Technology Tools: Satellite imagery was used to study variations in areas covered by biomass and urban spaces resulting from population movement, thereby enabling a precise analysis of urban expansion over time.

Research Delimitations

To define the scope of the study and ensure focus, the researcher adhered to the following boundaries:

Temporal Boundaries: The study covered the period from 2000 to 2020, which was divided into three main phases:

1. Phase one (2000–2005): During this period, no significant levels of population movement toward the Al-Obeid Administrative Unit were recorded.
2. Phase Two (2006–2012): This period witnessed a noticeable increase in population movement, influenced by recurring drought waves and the decline of biomass.
3. Phase Three (2013–2020): Characterized by peak levels of population movement, clearly reflected in the significant urban expansion experienced by the Al-Obeid Administrative Unit

Spatial Boundaries

The study was limited to the Al-Obeid Administrative Unit, which is one of the eight administrative units of Sheikan Locality. The research was confined to its recognized geographical boundaries, covering an area of approximately 421 square kilometers.

Previous Studies

Study of Khadija Younis (2000):

This study addressed climate variability and its impact on agricultural production in Dilling Province, South Kordofan. It aimed to examine farmers' behavior toward climate change and the extent to which they benefit from local adaptation methods. The findings indicated that crop diversification enhances production rates, while rainfall variability led to declining productivity. The study recommended the establishment of dams in addition to meteorological monitoring stations to cope with climate change.

UNEP Study (2007) on Sudan: Post-Conflict Environmental Assessment

This study concluded that recurrent droughts and ongoing land degradation in Kordofan and Darfur had created significant environmental, social, and economic pressures. It highlighted that the expansion of unsustainable rainfed agriculture contributed to the decline of rangelands and the loss of vegetation cover, which in turn intensified resource-based conflicts. The study also revealed that these conditions forced



large numbers of rural residents to migrate toward urban centers, particularly the city of Al-Obeid, which serves as an attractive urban hub. It concluded that resolving such conflicts requires the sustainable management of natural resources.

Study by EL Tahir, Fadl, & Doka (2010) on Forest Biodiversity in Kordofan:

Impacts of Climate Change and Human Activities

This study focused on the relationship between climate change and biodiversity loss in the forests of Kordofan. It indicated that climatic factors, such as drought, along with human activities like deforestation and agricultural expansion, contributed significantly to forest degradation. The results showed that the loss of forest cover weakened rural livelihoods dependent on forest products. The study also highlighted that this degradation prompted many communities to migrate toward cities, including Al-Obeid, in search of alternative sources of income.

Study by Saleh (2011) on the Impacts of Climate Variability on Rainfed Agriculture in Some Areas of Sudan

This study examined how climate variability and change affect rainfed agriculture, with implications for conflicts and social unrest, through the distribution, seasonality, and quantity of rainfall. It emphasized community-based land management practices, such as fallowing and migration to urban areas, as well as engagement in marginal work. The study recommended implementing early warning systems, enhancing water harvesting techniques, developing drought- and pest-resistant crop varieties, and promoting greater flexibility in agricultural management to adapt to climate change, alongside conducting further research.

Study by Elagib & Elhag (2011) on Key Climate Indicators of Persistent Drought in Sudan

This study highlighted a significant decline in rainfall and a rise in temperatures in Sudan over recent decades, with central stations such as Al-Obeid recording repeated drought events. The findings indicated that the persistence of these climatic conditions led to reduced food production and increased vulnerability of agricultural and pastoral communities. The study also noted that the loss of adaptive capacity drove many residents to seek alternative livelihoods in urban areas, concluding that internal migration has become one of the most prominent consequences of climate change in Sudan.

Tufts Feinstein International Center (2013), *Sustaining Wealth: Pastoral Livestock Production and Local Livelihoods in Sudan*

This study examined the pivotal role of livestock in supporting the livelihoods of pastoral communities in Darfur and Kordofan. It highlighted that recurrent droughts and changing rainfall patterns reduced pasture areas and weakened livestock production. The study also indicated that environmental degradation contributed to increased conflicts between herders and farmers over limited natural resources. It concluded that these challenges pushed many herders and their families to migrate toward cities, particularly Al-Obeid, altering the demographic landscape of the region.

Study by Abdel Rahim (2017) on Adaptation Strategies to Climate Change in Traditional Rainfed Agriculture in North Kordofan

This study aimed to identify the main strategies employed to adapt to climate change in traditional rainfed agriculture. It found that the region experienced climatic changes leading to drought, and that farmers used practices such as "al-'Ain" and "Tarmeel" as adaptive measures. The study recommended the development of investment projects to increase rural incomes while strengthening traditional adaptation strategies to cope with climate change.

Study by Young, Osman, Abderahman, & Dale (2019), *Livelihood Resilience in Darfur, Sudan*

This study analyzed how livelihoods in Darfur were affected by climatic disturbances such as drought and rainfall variability. It showed that local communities adopted multiple adaptation strategies, including seasonal mobility and reliance on humanitarian assistance, but their effectiveness remained limited. The study concluded that the loss of economic and social resilience drove many households to internal migration toward regional cities, with Al-Obeid becoming a key destination due to its relatively accessible basic services. The previous studies primarily focused on the impact of climate change on agricultural and pastoral production, biodiversity loss, and traditional adaptation strategies employed by farmers and herders in Kordofan and Darfur, while also noting internal migration toward urban centers. However, these studies did not examine the impact of climate-induced population movement on the growth of urban centers, particularly the city of Al-Obeid. Therefore, the significance of the present study lies in addressing this gap by analyzing the relationship between climate change, population movement, and the expansion of Al-Obeid as an urban center.

Concepts of Climate Change:

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "forms of changes that can be expressed statistically, which may persist for consecutive decades and are the result of human activities in interaction with the internal components of the climate system." Khayar (2011) defined it as: climate change has been scientifically evidenced to mean the increase in Earth's temperature during the past hundred years, the rise in sea levels and in the oceans, the shrinking of the ice cover, and the



occurrence of severe extreme phenomena such as the increase in ocean acidity. Most of these changes are attributed to variations in solar radiation reaching the Earth's surface.

The organization Practical Action (2013) defined climate change as a change in the averages of weather elements in certain regions over the long term. It emphasizes that various human activities, especially industrial ones which have increased since the Industrial Revolution in the 19th century, are the main cause behind the significant increase of greenhouse gases beyond their natural levels, which has led to climate change.

Causes and Impacts of Climate Change

Climate change is considered one of the most pressing global environmental issues of the modern era due to its direct impact on natural systems and human activities. In recent decades, Earth has experienced unprecedented climate fluctuations, such as rising temperatures, irregular rainfall, and an increasing frequency of droughts and storms. These changes result from a combination of natural and human causes and entail wide-ranging environmental, economic, and social impacts, including declining agricultural production, biodiversity loss, and increased migration and displacement.

Firstly: Causes of Climate Change

Natural Causes:

Changes in Earth's orbit and solar radiation, which affect the amount of solar energy reaching Earth and contribute to long-term climate variations (UNEP, 2007). The sunspot phenomenon, which occurs every 11 years and increases the thermal energy emitted by the sun, influencing Earth's climate (IPCC, 2021). The El Niño and La Niña phenomena, occurring every 3–7 years, which raise ocean surface temperatures by 1–5°C, causing hurricanes and storms in the Pacific Ocean and along the coasts of California (IPCC, 2021).

Human Causes:

Global warming resulting from the increase of greenhouse gases such as carbon dioxide and methane, produced by burning fossil fuels, intensive agriculture, and deforestation (IPCC, 2021).

*Deforestation, urban expansion, and agricultural expansion, which reduce the ability of vegetation cover to absorb carbon and intensify the greenhouse effect (UNEP, 2007).

*The use of heating and cooling systems in buildings, which emit large amounts of greenhouse gases (IPCC, 2021)

Secondly: The Impacts of Climate Change

1. Rising temperatures

Leading to changes in weather patterns and an increase in wildfires (IPCC, 2021).

2. Sea level rise

Expected to increase by 10 to 20 cm by the end of this century, threatening coastal cities and islands with flooding (IPCC, 2021).

3. Increased drought and desertification

Resulting in water scarcity and reduced agricultural production (UNEP, 2007).

4. Ocean acidification

Negatively affecting marine ecosystems and putting many aquatic species at risk of extinction (IPCC, 2021).

5. Worsening poverty and displacement

Due to declining agricultural output and the spread of diseases, forcing populations into internal migration or displacement (Tufts Feinstein International Center, 2013).

6. Adverse impacts on certain industries

Such as tourism, as extreme weather conditions and the risk of flooding in cities reduce tourism activities (UNEP, 2007).

International Efforts to Combat Climate Change

Scholars agree that climate change represents one of the most serious threats to sustainable development, due to its negative impacts on human life, food security, and social stability (IPCC, 2021). Since the early 1990s, the international community has adopted several agreements and conferences to address this phenomenon and mitigate its consequences.

1. United Nations Framework Convention on Climate Change (UNFCCC) – 1992

The UNFCCC was launched at the “Earth Summit” in Rio de Janeiro in 1992. It was signed by 154 countries and entered into force in 1994. The convention aimed to stabilize greenhouse gas concentrations at levels that would prevent human interference with the climate system (UNFCCC, 1992).

2. Kyoto Protocol – 1997

The Kyoto Protocol was adopted in Japan in 1997 as a legally binding extension to the UNFCCC. It required industrialized countries to reduce their emissions by 5.2% compared to 1990 levels during the period 2008–2012. It also introduced flexible mechanisms such as the Clean Development Mechanism (UNFCCC, 1997).

3. Paris Agreement – 2015

At the 21st Conference of the Parties (COP21) held in Paris in 2015, a new agreement was adopted in which all parties committed to limiting the global temperature rise to well below 2°C, while pursuing efforts to restrict it to 1.5°C. The agreement also required countries to submit Nationally Determined Contributions (NDCs) and update them every five years (UNFCCC, 2015).

4. Glasgow Climate Conference (COP26) – 2021

The 26th Conference of the Parties (COP26) was held in Glasgow in 2021. It emphasized accelerating emissions reductions, scaling up climate adaptation finance, and promoting a “just transition” toward renewable energy sources (UNFCCC, 2021).

5. Sharm El-Sheikh Climate Conference (COP27) – 2022

COP27 was held in Sharm El-Sheikh, Egypt, in 2022 under the theme “The Implementation Conference.” A landmark outcome of the meeting was the establishment of a “Loss and Damage Fund” to compensate developing countries most affected by climate change, marking one of the most significant achievements in the history of climate negotiations (UNFCCC, 2022). These conferences and agreements since 1992 demonstrate that climate change has been placed at the top of the global agenda. However, a gap remains between commitments and actual implementation, particularly regarding climate finance for developing countries and ensuring climate justice for future generations.

The Concept of Population Mobility

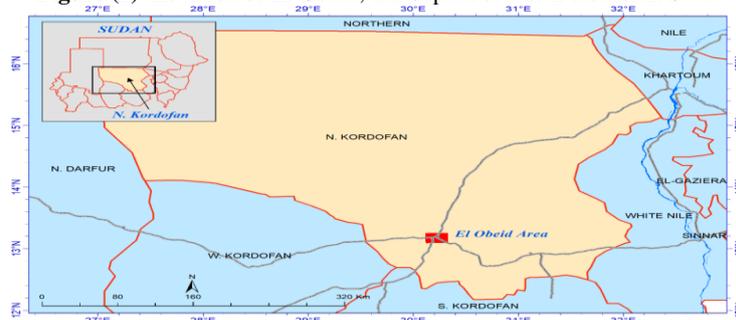
Population mobility is a universal phenomenon that is not limited to human beings. Birds, fish, and other creatures also move from one place to another. Human migration, however, is both a geographical and social phenomenon that has accompanied humankind since its appearance on earth, driven by the search for livelihood, the improvement of living standards, or the pursuit of security and stability. Migration may be seasonal or temporary and is often associated primarily with a change in the place of work. According to Barsa, as cited in the *Demographic Dictionary*, migration is defined as: “the movement of individuals or groups that involves a permanent or semi-permanent change in the place of usual residence” (Rashoud, 2003). Migration differs from cyclical mobility in that it focuses on the permanent or semi-permanent change of residence, while cyclical mobility does not require changing the place of residence. Both migration and cyclical mobility fall under a broader concept, namely population movements. The United Nations defines migration as “a type of spatial movement between one spatial unit and another, which involves a change of residence.” Migration is considered one of the most complex aspects of demographic change in terms of measurement and the prediction of its trends, especially when preparing demographic projections. Nevertheless, migration contributes to achieving a certain degree of balance by reducing spatial disparities in income and living standards, despite the social and economic implications it generates for both the areas of origin and destination.

The Study Area and Its Relation to Population Mobility

Historical Background: The origin of the city of El-Obeid dates back to the early 15th century, when it emerged as a commercial center during the era of the Kingdom of Sennar. It later became the capital of Kordofan Province under the rule of the Musabba’at in the 17th century. In 1905, during the Anglo-Egyptian administration, it was designated as the provincial capital, and in 1942 it was established as a municipal council due to its strategic location at the intersection of important trade routes. Moreover, El-Obeid has long been recognized as a prominent commercial and agricultural hub (Jabbad, 2013).

Location of El-Obeid: El-Obeid, the capital of North Kordofan State and the administrative center of El-Obeid locality, is located at the intersection of longitude 30°14' and latitude 13°12', with an average elevation of 1,920 feet above sea level. The city is situated on a generally flat plain, except for some low hills to the northeast and south, as well as sand dunes to the west (Al-Hassan, 1979).

Figure (1): Location of El-Obeid, the Capital of North Kordofan State



Source: Agricultural Research Station, El-Obeid, 2022



Climate

El-Obeid city lies within the semi-arid tropical climate zone. Walton (1980) defined aridity as the outcome of the relationship between rainfall, temperature, and evaporation, describing it as a condition in which the long-term average rainfall decreases by about 25% for a given region, causing evaporation to exceed moisture availability. The climate of this region is characterized by high variability in rainfall, increasing temperatures, strong winds, and high rates of evapotranspiration, which exceed annual precipitation levels. The combination of high evaporation, low humidity, and elevated temperatures leads to drought conditions.

The aridity index can be calculated using the following equation:

$$\text{Aridity Index} = \frac{P}{H + 10} \quad \text{Aridity Index} = H + 10P$$

Where:

*PPP = Mean annual rainfall (mm)

*HHH = Mean annual temperature (°C) For El-Obeid locality:

*2000–2010: $323.510 + 32 = 101.1 \text{ mm} \frac{323.5}{10 + 32} = 101.1 \text{ mm}$

*2011–2020: $356.510 + 35 = 101.7 \text{ mm} \frac{356.5}{10 + 35} = 101.7 \text{ mm}$

Areas with an aridity index below 40 mm are classified as arid. Since the index in this region exceeds 40 mm, it is classified as semi-arid.

Climatic Characteristics of the Study Area

Temperature:

Temperatures in El-Obeid are high, reaching their peak between March and June, with maximum average temperatures ranging from 29.9°C to 39.6°C. The lowest temperatures occur between November and February. The annual mean temperature in 2000 was approximately 34.9°C, affecting evaporation rates in the region (Aghbesh, 2005). During the period 2000–2010, the average temperature was about 32°C, increasing to approximately 35°C during 2011–2020, which influenced productivity in traditional sectors and contributed to population mobility toward El-Obeid locality (Rahma, 2022).

Atmospheric Pressure:

Atmospheric pressure refers to the weight or force exerted by the atmosphere on the Earth's surface. In other words, it is the weight of a column of air with a base area of one square centimeter extending from sea level to the upper limits of the atmosphere. The annual mean atmospheric pressure in the study area is approximately 945.2 millibars. This elevated pressure during certain months is associated with dry northern winds and the influence of cold air masses over Sudan. In contrast, atmospheric pressure decreases during May, June, and July, falling below 944 millibars due to the high temperatures experienced during the dry summer season in the study area. The aridity index for El-Obeid locality during the period 2011–2020 was calculated as follows:

$$\text{Aridity Index} = \frac{356.510 + 35}{10 + 35} = 101.7 \text{ mm} \quad \text{Aridity Index} = 10 + 35 \frac{356.5}{10 + 35} = 101.7 \text{ mm}$$

Areas with an aridity index below 40 mm are considered arid. Since the index in this region exceeds 40 mm, it is classified as semi-arid.

The study area is characterized by a semi-arid climate, which can be further understood through its key climatic elements:

Climatic Characteristics of the Study Area

The study area is characterized by a semi-arid climate, which can be described through the following climatic elements:

1. Temperature: Temperatures in El-Obeid are generally high, reaching their peak between March and June. The maximum average temperatures range from 29.9°C to 39.6°C, while the lowest temperatures occur between November and February. The annual mean temperature in 2000 was approximately 34.9°C, which affected the rates of evaporation in the region (Aghbesh, 2005). During the period 2000–2010, the average temperature was about 32°C, increasing to approximately 35°C during 2011–2020. This rise in temperature impacted productivity in traditional sectors, resulting in population mobility toward El-Obeid locality (Rahma, 2022).

2. Atmospheric Pressure: Atmospheric pressure is the weight or force exerted by the atmosphere on the Earth's surface. In other words, it is the weight of a column of air with a base area of one square centimeter extending from sea level to the upper limits of the atmosphere. The annual mean atmospheric pressure in the study area is approximately 945.2 millibars. This elevated pressure during certain months is associated with dry northern winds and the influence of cold air masses over Sudan. Conversely, atmospheric pressure decreases during May, June, and July, falling below 944 millibars due to high temperatures during the dry summer season in the study area.

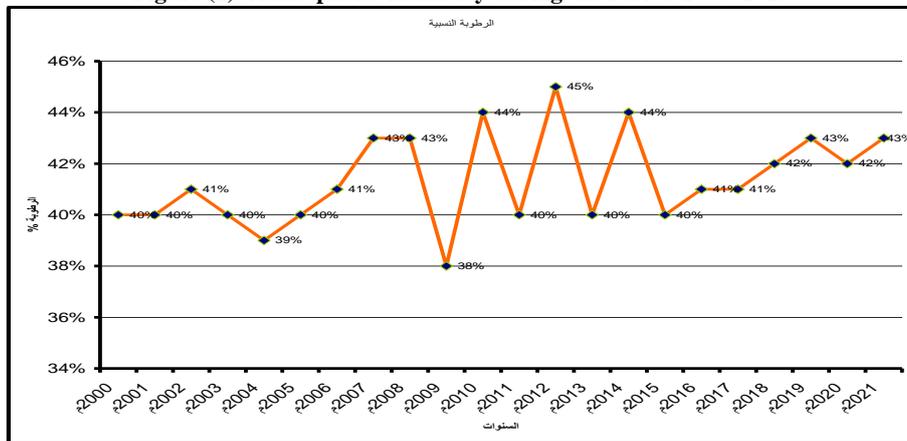
3. Wind: Winds play a fundamental role in vegetation and directly influence the processes of evaporation and transpiration. Wind patterns in the study area vary according to the seasons. During winter, the region

is affected by low-pressure systems moving across the Mediterranean Sea, bringing cold air masses, and occasionally by high-pressure areas over Europe. As a result, dry and cold northerly winds prevail from mid-October to April, with speeds ranging between 5–30 knots per second. These winds are dry and active (Abdelrahim, 2017).

4. Evaporation and Humidity: Relative humidity in the study area varies seasonally. It reaches its highest values during the rainy season, peaking in July and September at around 60%, and in August reaching approximately 68%. During winter months (December, January, February), relative humidity is lower. The lowest humidity occurs in March due to high temperatures and the prevalence of dry northern winds. The annual mean relative humidity reached its highest level of about 55% in 2003, coinciding with rainfall of approximately 404.6 mm, and the lowest level was 29% during a year when rainfall was 285.9 mm (Meteorological Station, El-Obeid, 2016).

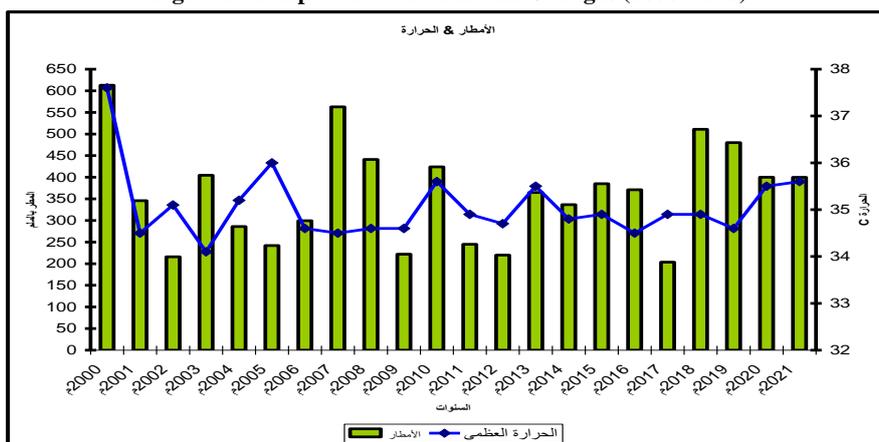
5. Rainfall: Rainfall is the most influential climatic factor affecting agricultural production in the study area. The rainy season begins when the Sudanese monsoon reaches the southwestern edges of the region in February. The monsoon gradually moves northward, reaching the study area by May or June and peaking in August. Afterward, the monsoon retreats southward in September and leaves the region by October. Consequently, the study area experiences dry conditions in December, January, February, and April. Rainfall is highly variable both temporally and spatially, especially in years with low annual totals. The average annual rainfall for the study area, calculated over the previous thirty years, is approximately 318.8 mm (Omar Babiker, 2016)

Figure (2): Atmospheric Humidity during the Period 2000–2020



Source: Authors' work based on data from the Meteorological Station, El-Obeid, 2021

Figure 3: Temperature and Rainfall Changes (2000–2020)



Source: The researchers' work, based on the meteorological data of Al-Obeid, 2021

Vegetation:

Wicken (1991) classified the vegetation in the study area as falling within the semi-arid plant zone, dominated by scattered trees of the *Acacia* genus, which are capable of adapting to climatic changes, particularly low and fluctuating rainfall and harsh environmental conditions. Al-Hafyan (1995) indicates

that these trees and shrubs are mostly found in sandy areas and around valleys and seasonal watercourses, forming a vegetation cover that plays an important role in soil protection and desertification prevention. The most prominent plant species recorded in the area include the following:

Table 1: Major Trees and Shrubs in the Study Area

Scientific Name	Local Name
Acacia Arabica	Al-Sant
Acacia Tortilis	Al-Sial
Acacia Seyal	Al-Talah
Adansonia digitata	Al-Tibeldi
Ziziphus mucronata	Al-Nabq and Al-Sidr
Acacia Nobica	Al-La'ut
Acacia Mellifera	Al-Katr
Balanites aegyptiaca	Al-Haljij or Al-Laloub
Albizzia sericocephala	Al-Arad
Azadirachta indica	Al-Neem
Posciasang Lensis	Al-Mukhayt or Al-Karsan
Calotropis Procera	Al-Ashr
Leptadeniapy rotechnica	Al-Markh
Grewia tonax	Al-Qadim

Source: Fieldwork, 2020

Based on field observations conducted by the researchers in Al-Ain Forest, it was found that trees play a pivotal role in maintaining the local ecological balance. *Azadirachta indica* (Neem) trees contribute to climate moderation and air quality improvement, in addition to protecting the soil from erosion. The researchers observed a significant decline in the density of dominant trees such as *Acacia seyal*, *Ziziphus* (Sidr), and other *Acacia* species in recent years, which aligns with previous studies on the impact of recurrent droughts and climate change on vegetation in the area (Ahmed et al., 2025; Lu et al., 2025). The researchers also noted that this decline in dominant trees has weakened traditional pastoral and agricultural activities, pushing many residents toward urban centers in search of alternative livelihoods, directly reflecting the impact of climate change on population mobility and urban growth, in agreement with the observations of Young et al. (2009). Moreover, shrubs such as *Prosopis* (Al-Karsan), *Calotropis procera* (Al-Ashr), *Leptadenia pyrotechnica* (Al-Markh), and *Grewia tenax* (Al-Qadim) have begun to play a supportive role in the local ecosystem by maintaining soil fertility and providing forage resources for animals, highlighting the need for forest and tree protection strategies to cope with climate change pressures and enhance food and environmental security in the region (Young et al., 2013). As for the dominant grasses in the study area, they are numerous and diverse despite the climatic changes affecting the region. The most important of these can be listed as follows:

Table 2: Major Dominant Grasses in the Study Area

Scientific Name	Local Name
Dactyloctenium aegyptium	Abu Saabi
Stipogrostis Inosa	Samima
Panicum turgidum	Al-Tamam
Cenchrus biflorus	Al-Hasaknit
Eragrostis termula	Al-Banu
Sesamum alatum	Simsim Al-Jamal
Echinochloa colona	Al-Dafra
Aristida mutabilis	Al-Dambalab
Cymbopogon proximus	Al-Muhraib
Corchorus olitorius ¹	Al-Mulukhiyah
Vigna sunhum	Al-Tuwaiqat
Cassia acutifolia ¹	Al-Sanmaka
Blepharis persica	Al-Baqil
Aristida spp.	Al-Qaw

Source: Fieldwork, 2020

Field observations indicate that climate changes, particularly recurrent droughts, have led to a decline in high-forage-value plant species such as *Al-Qaw* (*Aristida mutabilis*) and *Al-Hantout* (*Ipomoea cardiose*) in the study area, while the spread of unpalatable plants for livestock, such as *Al-Drisa* (*Tribulus terrestris*) and *Al-Dafra* (*Echinochloa pyramidalis*), has increased. Interviews with some residents who migrated from rural areas surrounding Al-Obeid revealed that these shifts in vegetation have weakened

traditional pastoral and agricultural activities, prompting increasing numbers of people to move to the city in search of alternative livelihoods. This has contributed to urban expansion in Al-Obeid, reflecting the clear impact of climate change on population mobility and the growth of urban centers in the region (Rahma, 2022).

These findings are consistent with other studies on the impact of climate change on vegetation and human activities in Sudan, including:

*A study in southern Port Sudan reported a decline in vegetation due to rising temperatures and decreasing rainfall, affecting the sustainability of plant and grazing resources (Abdelgadir et al., 2019).

*A study on changes in natural vegetation in eastern Sudan showed a decrease from 26.1% in 1979 to 9.4% in 2007, due to the combined effects of climate change and human activity on natural resources (Mahgoub, 2012).

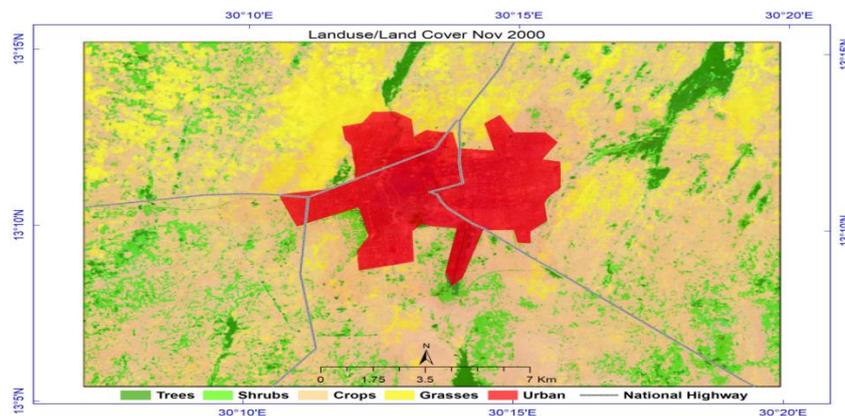
*Multiple studies confirmed that water scarcity and crop failure drive people to migrate from rural to urban areas, increasing pressure on urban infrastructure and services (FAO, 2015; IOM, 2019).

Thus, it is evident that climate change is a major factor in reducing grazing and agricultural resources and exacerbating rural-to-urban migration in Sudan, affecting the economic and social fabric of cities like Al-Obeid. This highlights the need for comprehensive adaptive policies to ensure the sustainability of natural resources and support alternative livelihoods for affected populations.

Urban Expansion of Al-Obeid City as a Result of Population Mobility

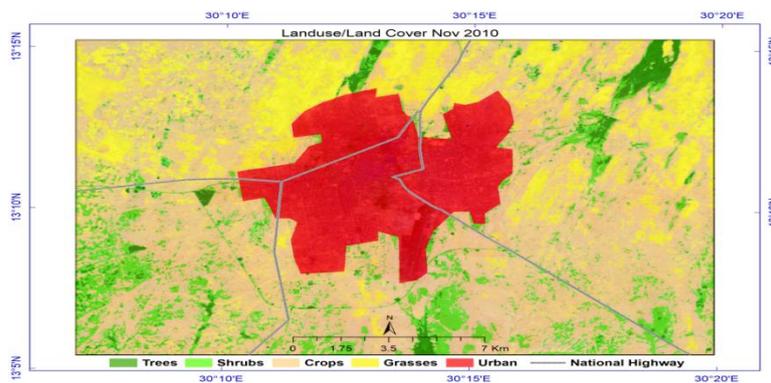
Al-Obeid City has experienced a clear expansion due to natural population growth, coupled with significant migration from surrounding rural areas. This urban growth is evident when comparing the city's size over different periods using aerial images from the years 2000, 2010, and 2020.

Figure 4: Administrative Boundaries of Al-Obeid City in 2000



Source: Agricultural Research Station, Al-Obeid, 2020.

Figure 5: Administrative Boundaries of Al-Obeid City in 2010

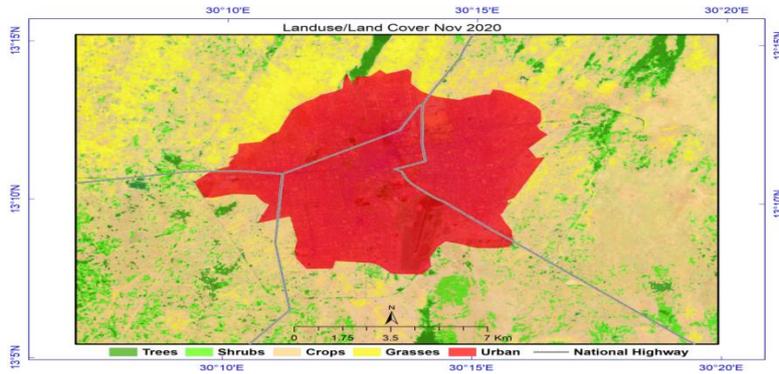


Source: Agricultural Research Station, Al-Obeid, 2020

Figure 5 shows an aerial image depicting the boundaries of Al-Obeid City in 2010. The image reflects the urban expansion that occurred during the first decade of the 21st century compared to 2000, with increased urban area coverage and changes in population density distribution. At the same time, vegetation analysis indicates a noticeable decline in the density of trees and shrubs, with clear fragmentation of vegetation, particularly in areas experiencing rapid urban growth. This highlights the relationship between urban growth, population mobility, and vegetation loss, and allows for comparison

with previous (2000) and subsequent (2020) images to assess environmental and spatial changes in the city.

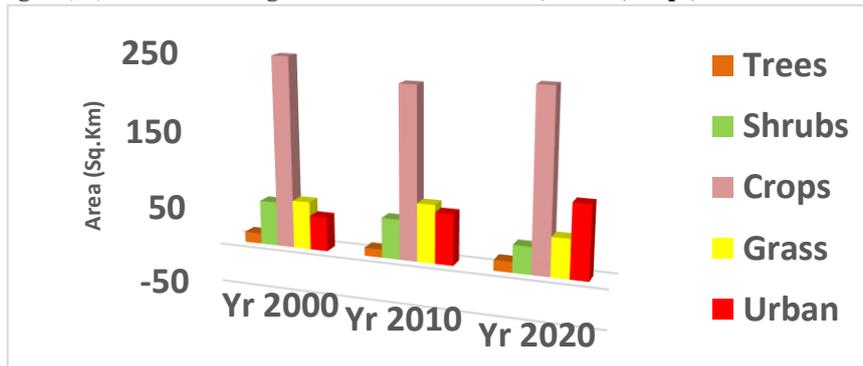
Figure 6: Administrative Boundaries of Al-Obeid City in 2020



Source: Agricultural Research Station, Al-Obeid, 2020.

Figure 6 shows the vegetation cover of Al-Obeid City in 2020. Compared to the aerial image of 2000, the city expanded noticeably, accompanied by a decline in tree and shrub density. When compared with the 2020 image, a larger urban sprawl becomes evident, while vegetation cover continued to shrink and fragment. This emphasizes the relationship between urban expansion, population mobility, and vegetation loss over the two decades

Figure(7) shows the changes in the size of tree cover, shrubs, crops, and urban centers



Source: Agricultural Research Station, Al-Obeid, 2020.

Figure (7) illustrates the changes in land use components in El-Obeid and its surroundings. It shows a decline in tree and shrub cover, accompanied by an expansion of agricultural crop areas and urban centers. This reflects the impact of human activities and population growth on natural resources, indicating a reduction of natural vegetation in favor of agricultural and urban development. Aerial images of Al-Obeid City for the years 2000 (Figure 4), 2010 (Figure 5), and 2020 (Figure 6) illustrate the clear urban expansion that has occurred due to natural population growth and significant migration from surrounding rural areas. Climatic data indicate that Al-Obeid is located in a semi-arid region characterized by high temperatures, fluctuating annual rainfall, and increased evaporation rates, which have led to ecological imbalance and a decline in vegetation cover, particularly in high-forage-value species, alongside the emergence of low-value vegetation. Comparing the aerial images shows that these climatic changes are clearly reflected in the spatial reality: in 2000, vegetation was widely distributed while urban areas were limited; by 2010, vegetation cover had declined and become fragmented, coinciding with drought waves and decreased agricultural and pastoral production, prompting migration toward the city. By 2020, the urban landscape clearly dominated, with built-up areas expanding at the expense of farmland and pastures, leaving only limited natural vegetation pockets such as Al-Ain Forest. Figure 7 vividly documents these changes, illustrating the relationship between vegetation loss and urban expansion. These findings indicate that climatic factors—particularly temperature, rainfall, and evaporation—have directly contributed to population movement toward Al-Obeid, as evidenced by the spatial changes captured in maps and aerial images. This supports the research hypothesis of a causal relationship between climate changes, demographic shifts, and urban expansion in the region,



highlighting the need for sustainable development policies to protect vegetation, mitigate the environmental impacts of urban growth, and support alternative livelihoods for affected populations.

Conclusion:

Climate change is one of the most pressing challenges facing developing countries, particularly Sudan, which is the second-largest country in Africa by area. Its implications are not limited to negatively affecting the most important ecosystems but also extend directly to the livelihoods of millions of farmers and herders scattered across thousands of villages, stretching from the desert regions in the north to the forested areas in the south. In the study area, climate change is no longer merely an environmental issue associated with rainfall variability and rising temperatures; rather, it has become a genuine obstacle to sustainable development efforts within fragile local communities that are already suffering from rising heat stress, recurring droughts, and dwindling natural resources. Therefore, addressing this challenge requires concerted efforts at both national and international levels, including the provision of financial support, technical assistance, and development programs, to enhance the resilience of local populations and protect their ecosystems from further degradation. Based on these findings, the study reached the following key results and recommendations:

Findings

1. Decline in biomass: Tree cover decreased and became fragmented during the period (2000–2020), negatively impacting plant diversity.
2. Fluctuation in agricultural production: Agricultural crops experienced significant variations in productivity due to rainfall variability and rising temperatures.
3. Increase in population mobility: Environmental degradation and pressure on natural resources drove rural populations toward urban centers.
4. Urban growth expansion: Built-up areas in Al-Obeid expanded in response to the influx of migrants from rural areas.
5. Emergence of low-value plant species: Recurrent droughts led to the spread of grasses and plant species with limited value for grazing and agriculture.

Recommendations

1. Strengthen the role of governmental institutions and voluntary organizations in mitigating the impacts of climate change on rural communities.
2. Promote the cultivation of drought-resilient crops to reduce forced migration toward cities.
3. Manage urban expansion through sustainable urban planning policies that address growing population needs.
4. Protect natural vegetation cover through afforestation projects and the maintenance of existing forests.
5. Enhance community-based adaptation programs for farmers and herders through training, capacity-building, and technical support.

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