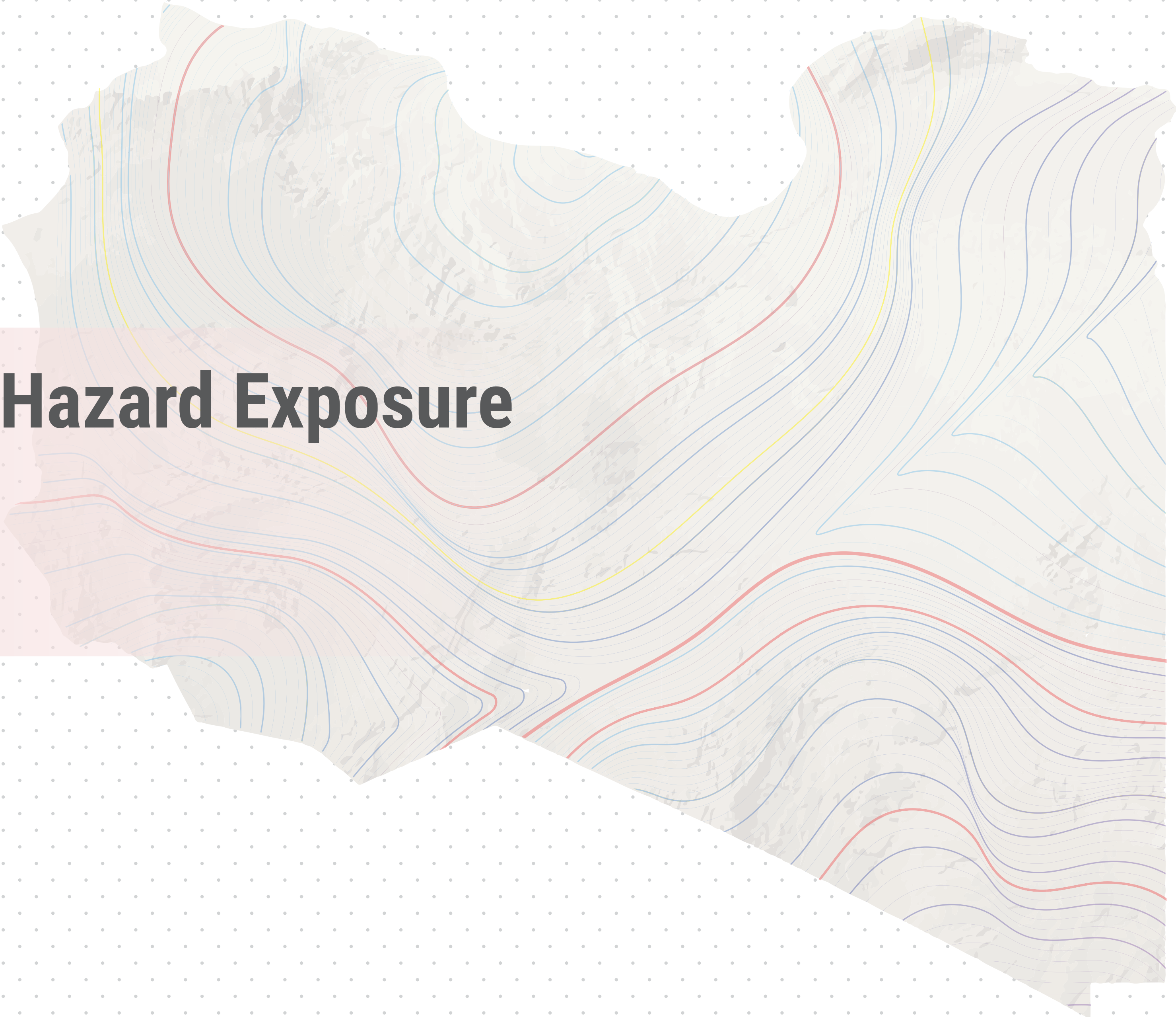
Climate-Related Hazard Exposure Assessment

June 2024 | LIBYA



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Climate-Related Hazard Exposure Assessment - Eastern Region of Libya

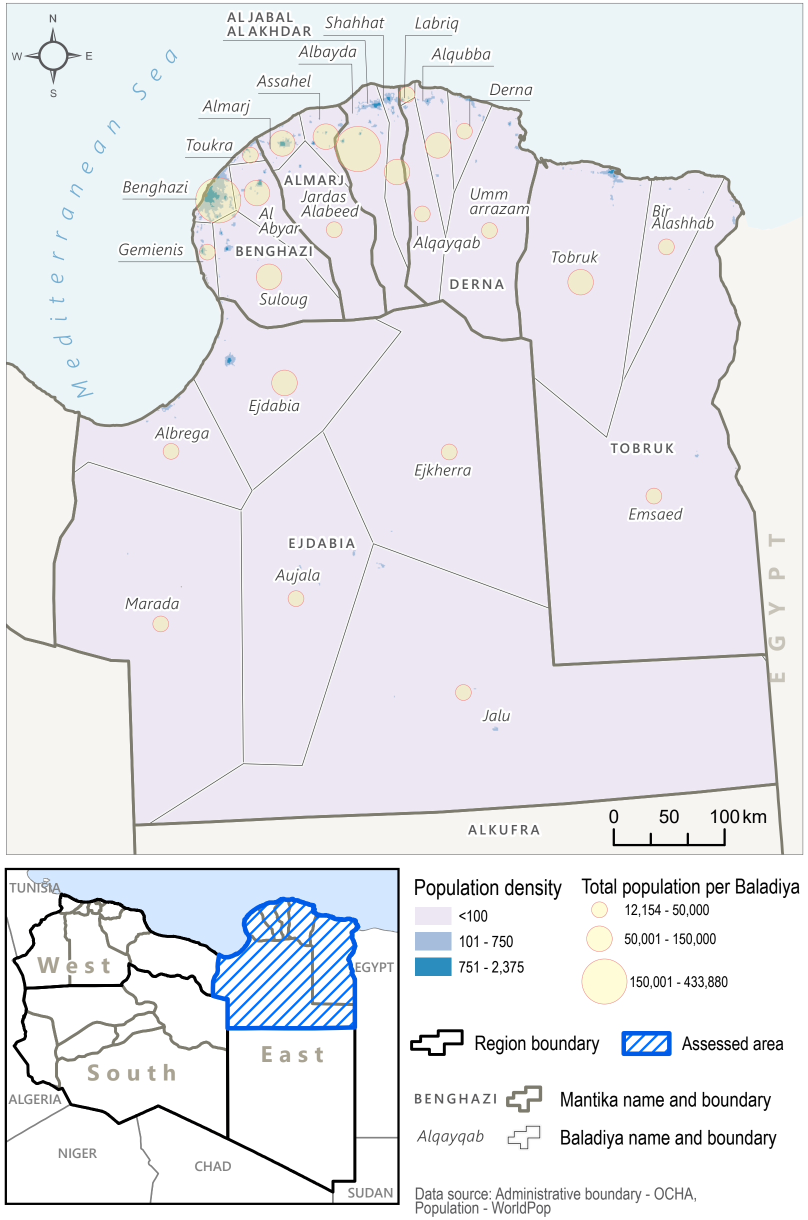
June | Libya
Context & Rationale

When tropical-like cyclone Daniel struck the north-eastern coastal area of Libya, its impact was profound, affecting 15 municipalities in the region. This medicane was not only marked as the deadliest cyclone to hit Africa in recorded history but also stood as the deadliest storm globally in the last decade. The rarity of such medicane occurrence in the Mediterranean, coupled with the influence of climate change, which is predicted to increase the frequency of such events, highlights the urgency to examine the climate-related hazards affecting the devastated areas and the adjacent territories. Human-induced climate change is expected to amplify the formation of tropical-like cyclones and similar storms in the Mediterranean, leading to the onset of extreme rainfall events. Therefore, it is crucial to conduct an analysis of the climate-related hazards affecting the eastern region of Libya. The analysis is based on identifying the susceptibility of the area to various hazards, including extreme heat waves, droughts, and floods. Additionally, the analysis is assessing the extent of exposure of the assessed area to the impacts of these events, particularly focusing on their effects on the local population, livelihood zones and to some extent the critical infrastructure. Overall, the assessment aims to facilitate informed decision-making and targeted action to mitigate disaster risks and strengthen the resilience of affected population and infrastructure. By providing detailed insights into hazard exposure, the assessment aims to enable policymakers and stakeholders to prioritize resources effectively, implement tailored intervention strategies, and enhance preparedness and response measures.

Key Messages

- Projected climate changes suggest **a significant rise in annual mean temperatures, particularly in the warmest and driest quarters,** increasing the likelihood of drought and more intense heat waves. The slight decrease in annual precipitation further heightens drought risks. These trends emphasize the necessity for proactive water management and heatwave response strategies.
- The eastern region of Libya, particularly in areas like **Benghazi, Tobruk,** and **Ejdabia**, has experienced a significant increase in extreme heat wave events. Over the past decade, **Benghazi mantika had 78% of recorded days with temperatures higher than the historical mean**, indicating a significant warming trend which can lead to more frequent and intense heat waves.
- **Benghazi is considered a highly exposed mantika to drought,** with an elevated Land Surface Temperature Index (LST) and high population density, which may lead to severe water stress and, consequently, drought.
- **Northern coastal areas, particularly urban regions with poor drainage infrastructure, are highly susceptible to flash floods.** Intense rainfall events, combined with inadequate drainage, lead to significant infrastructure damage and displacement of communities.

Coverage Map



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1. CLIMATE CHANGE PROJECTION

Map 1. Projected temperature (A) and precipitation (B) changes from the baseline (1970-2000) to the near future (2041-2060)

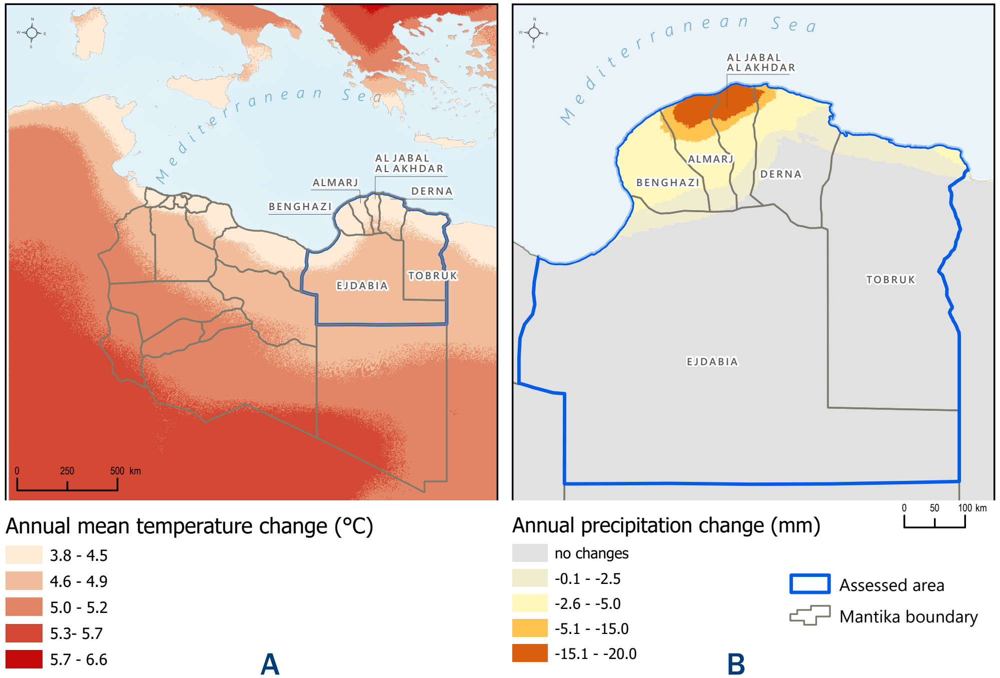


Figure 1. Projected changes in bioclimatic variables

A. Eastern Libya, between 1970-2000 and 2041-2060

B. Northern Mantika of Derna, Benghazi, Amarj, and Al Jabal Alakhdar between 1970-2000 and 2041-2060

+3.6°c Annual mean temperature increase

-1 mm Decrease in annual precipitation

-9 mm Annual precipitation

+4.5°c Change in mean temperature in warmest and driest quarter

-0.8 mm Decrease in precipitation in warmest quarter

-8 mm Precipitation of coldest quarter

+3.0°c Increase in minimum temperature in coldest quarter

-0.9 mm Decrease in precipitation of coldest quarter

-7 mm Precipitation of wettest quarter

To analyse the climate change impact in the study region, a number of bioclimatic variables from WorldClim[1] were analysed to estimate projected temperature and precipitation changes from the baseline (1970-2000) to the near future (2041-2060) in 5 mantika, according to UKESM1-0-LL model ssp3-7.0 scenario.[1]

Overall, the data indicates a trend of increasing temperatures and slight changes in precipitation patterns.

Temperatures are projected to increase, particularly in the driest and warmest month and quarters. The mean temperature of the warmest quarter will increase by 4.5°C, from 27.6°C to 32.1°C. The max temperature of the warmest month is expected to increase significantly from 34.5°C to 39.2°C, a difference of 4.7°C.

The annual precipitation shows a slight decrease from 53.88 mm to 52.9 mm, a reduction of 1.0 mm. Precipitation of the driest quarter, precipitation of the warmest quarter, and precipitation of the driest month remain unchanged at 0.1 mm, 0.2 mm, and 0 mm, respectively.

The northern parts of the assessment area, located along the coast, are projected to experience a smaller increase in temperature but a larger decrease in precipitation. Specifically, the Al Jabal Alakhdar and Almarj regions are expected to witness significant reductions in precipitation, ranging from -15 mm to -20 mm (map 1). A 5% loss in precipitation in northern mantika of Derna, Almarj, Benghazi and Al Jabal Alakhdar could impact water availability, agriculture, and overall socio-economic stability.

The significant increase in both annual mean temperature and the temperatures of the warmest and driest quarters indicates a higher likelihood of drought conditions. These higher temperatures can lead to more frequent and intense heatwave conditions.. The annual precipitation is projected to decrease slightly, which could exacerbate drought conditions by providing less overall rainfall.

The projected increase in temperature seasonality (variations during the year) can contribute to the occurrence of extreme heat events.

The precipitation of the driest month and driest quarter is projected to remain unchanged, suggesting that already dry periods might not see any relief from increased rainfall, further contributing to drought conditions and heat waves.

The precipitation seasonality remains almost the same, indicating that the variability of precipitation is not expected to change much, which means that extreme changes in precipitation patterns (which can cause flooding) are not likely to increase significantly.

1 The UKESM1-0-LL model is developed by Hadley Centre, as a part of Coupled Model Intercomparison Project (CLIP6) with a good performance in simulating climate over the Mediterranean and North African region. The middle-of-the-road shared socioeconomic pathways scenario (SSPs3-7.0 was selected for the analysis.

1. CLIMATE CHANGE PROJECTIONS

Figure 2: Variability and Trends of Average Means surface Air Temperature Across Decades, 1951-2020, Benghazi

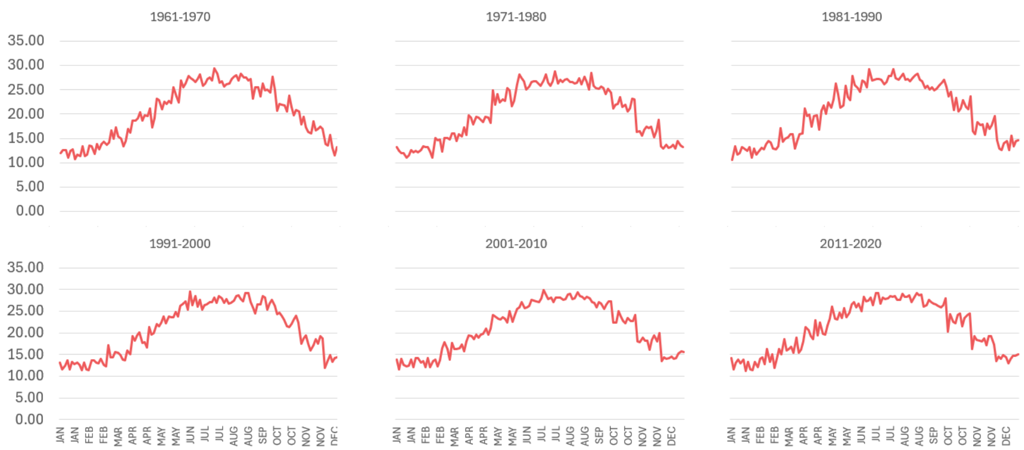
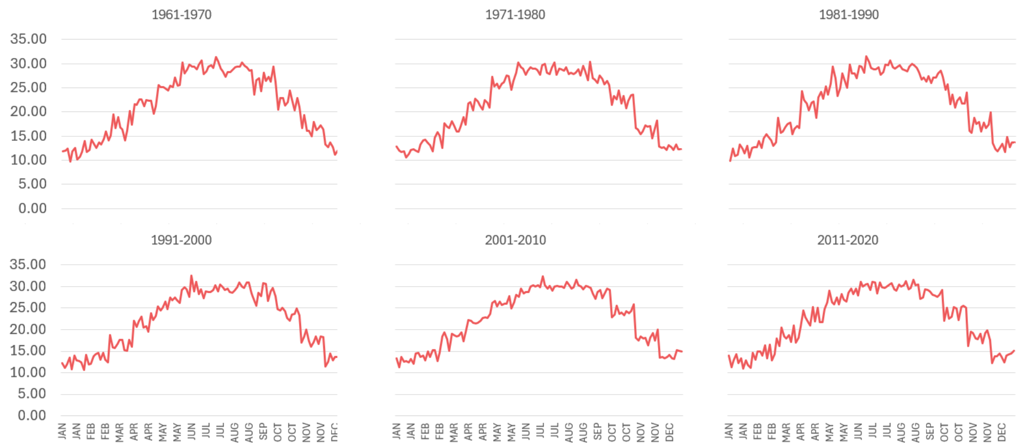


Figure 3: Variability and Trends of Average Means surface Air Temperature Across Decades, 1951-2020, Ejdabia



Variability and trends of average means surface air temperature across decades 1950-2020

In the eastern regions of Libya, there appears to be an upward trend in surface air temperatures. This trend is particularly evident in recent decades, with temperatures generally increasing from the 1950s to the 2010s[2].

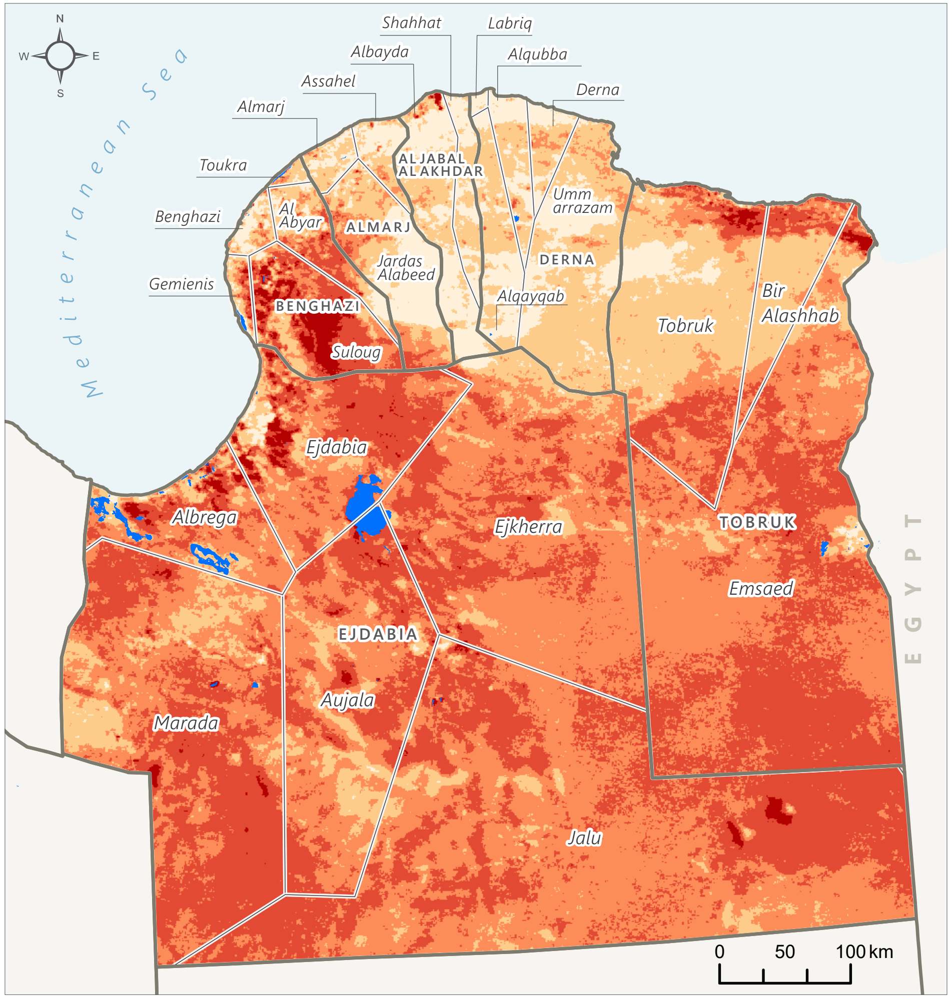
According to the analysis of historical climate records, in Benghazi temperatures appear to have generally increased over the decades. The upward trend in temperatures from earlier decades (1951-1960, 1961-1970) to recent decades (2011-2020) is indicating a consistent warming trend in the mantika over the past 70 years. **(See figure 2)**[3] During winter months (December-February) recorded temperature has increased when comparing earlier decades (e.g.,1981-1990 and 1991-2000) to more recent period (2011-2020). This indicates a slight warming trend during the winter season.

The same trend could be observed in Ejdabia, **(see figure 3)**[4]. Through examining the variability of the mean surface air temperatures across the decades, there is a notable shift in temperature patterns. For instance, during the winter months (December-February), there is a noticeable increase in temperatures, particularly in February during the 2001-2010, with a further temperature rise, especially in January and February during the 2011-2020 period. Concerning the summer months, and during the same periods (2001-2010 and 2011-2020), there is a consistent rise in temperatures, with notable highs in June and July.

The increase in average mean surface air temperature can have a significant impact on various aspects of an area or region. For instance, a rise in average temperatures is likely to lead to more frequent and intense heat waves, which can have severe health impacts, especially in urban areas where the heat island effect[a] can exacerbate the temperature[5].

2. HAZARD - EXTREME HEAT WAVES

Map 2.1: Percentage of Days over the last decade (2013-2023) with temperatures higher than historical mean (2000-2012), eastern region of Libya



Heat wave susceptibility

- very low (0-12%)
- low (12.1-16%)
- medium (16.1-18%)
- high (18.1-22%)
- very high (22.1-78%)

BENGHAZI — Mantika name and boundary

Alqayqab — Baladiya name and boundary

Water body

Data source: Land Surface Temperature - MOD11A1 from Google Earth Engine, Administrative boundary - OCHA, Water body - OpenStreetMap contributors

Hazard Description

Extreme heat events are defined as periods of excessively high temperatures that are significantly above the normal averages for a region. A heatwave is a marked unusual period of hot weather over a region[6].

Susceptibility

The susceptibility analysis compared daily mean land surface temperature (LST) recorded during the hottest months (June-August) over the last decade (2013-2023) to historical baseline. The historical baseline was created by averaging the daily satellite-driven LST recorded over the time line of 2000-2012, and adding the standard deviation (stdv) for the same period.

Looking at the susceptibility of the area of interest to extreme heat waves **(see map 2.1)**, the mantika (admin 2) Tobruk, Benghazi, and Ejdabia appears to be more prone to experience extreme heat waves than other areas. The baladiya (admin 3) that are relatively more susceptible to heat waves across the north-east of Libya are the coastal baladiya of Alberge and Ejdabia in Ejdabia mantika, the entire mantika of Benghazi, and northern part of Tobruk baladiya, Bir Alshahab and Emsaed in Toburk mantika. Multiple hotspots can be observed with "cooler" spots corresponding directly to the presence of mountains in the Al Jabal Alakhdar and Al-Marj mantika.

Data on the average percentage of day throughout the observed period 2013-2023 (out of total number of days during the year) where temperature exceeded historical mean shows that northern of Toburk, Benghazi, and Ejdabia mantika (admin 2) are ranked high on the scale, with Benghazi mantika having 78% of recorded days over the last decade with temperature higher than the historical mean.

Heat waves have significant impacts on the eastern Mediterranean region, including the coastline of eastern Libya, which could be observed in Tobruk, Benghazi, Ejdabia. This indicates that both atmospheric and oceanic conditions are warming significantly, which can lead to more frequent and intense heat waves.[7].

The projections for extreme heat waves in Libya, including the eastern region of the country, indicate that the country is likely to experience high heat conditions due to climate change. According to Climate Change Knowledge Portal, extreme events such as heat waves are expected to occur more frequently as temperatures rise globally[8].

Additionally, the Think Hazard report classifies the extreme heat hazard in Libya as high, suggesting that heat stress due to prolonged exposure to extreme heat is expected to occur at least once in the next five years[9].

2. HAZARD - EXTREME HEAT WAVES

EXPOSURE

Exposure is the situation where people, critical infrastructure, and other tangible human assets are located in hazard-prone areas[10]. To estimate exposure to heat waves, the population density indicator was employed, as heat waves can have severe health impacts, particularly on the elderly and individuals with heart conditions. This indicator provided valuable insights into the potential impact of heat waves on the affected population.

Exposure Index

The Exposure to Heat Waves Index reveals nuanced patterns across baladiya. For instance, Benghazi and Suloug (admin 3) exhibit the highest exposure to heat waves. While Benghazi is a highly populated urban baladiya, indicating that the population residing there is extremely vulnerable to the impacts of heat waves with a high susceptibility index, Suloug emerges with the highest susceptibility index and a relatively high population density. Similarly, Tobruk and Al Abyar (admin 3) demonstrate considerable exposure indices classified as lower, despite moderately high susceptibility indices.

Benghazi mantika (admin 2) has the highest hazard exposure to severe impacts from extreme heat waves due to the combination of high population density and high temperatures.

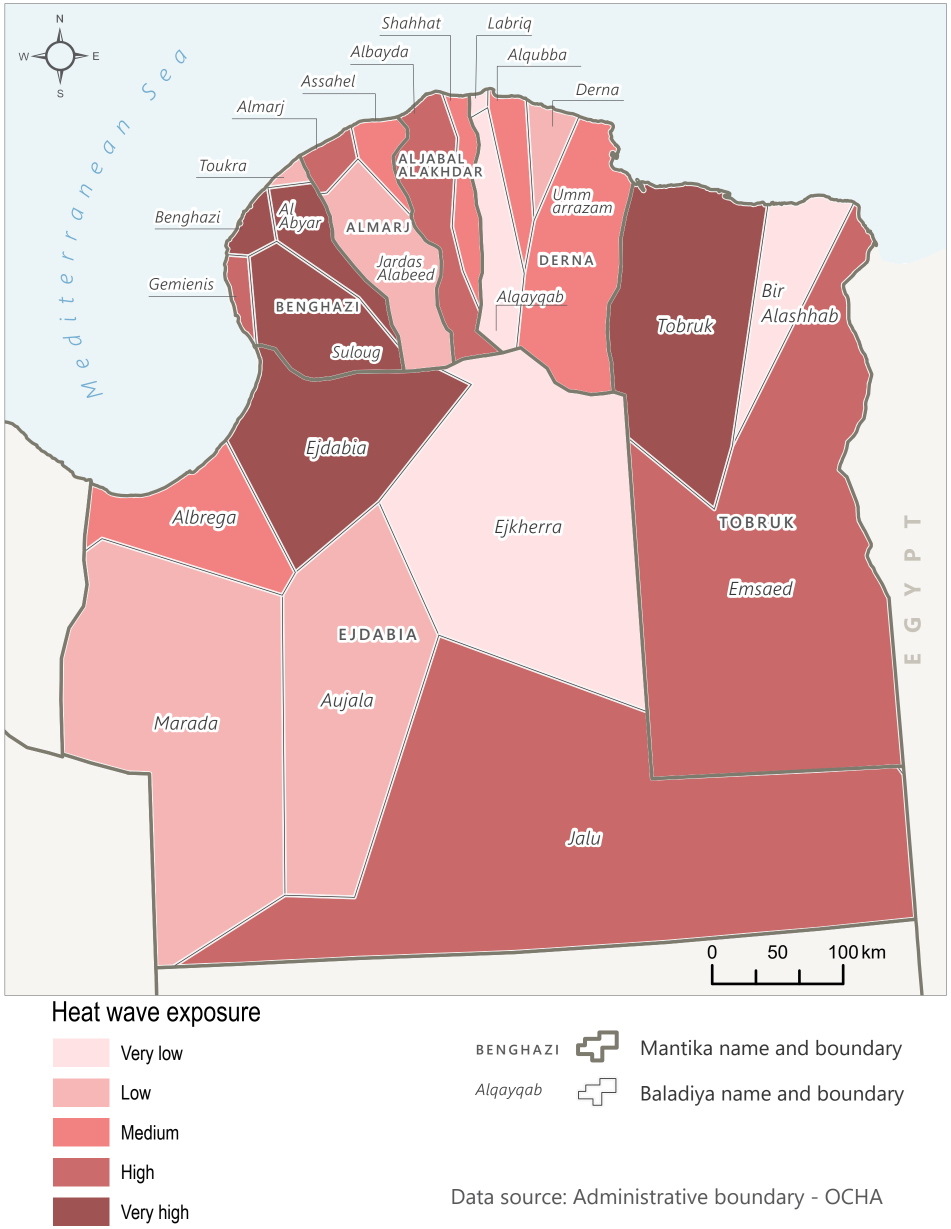
Hazard Impact

Exposure to extreme heat waves poses significant challenges to the assessed area with various consequences for environment, health, and livelihoods. Several baladiya (admin 3) are experiencing high exposure to extreme heat waves which is visible on **map 2.2**. For instance, in Benghazi baladiya, which is a part of the Akhdar Plateau, is the second most populated city in the country and it is considered as an important service and transportation hub[11].

Such urban cities are susceptible to the Urban Heat Island (UHI) effect which refers to the phenomenon where urban areas experience higher temperatures than their surrounding rural areas[12]. This is due to the concentration of buildings, roads, and other infrastructure that absorb and re-emit the sun's heat more than natural landscapes like forests and water bodies. This can lead to higher energy consumption, increased air pollution and greenhouse gas emissions, heat-related illness and mortality, and impaired water quality[13].

Moreover, concerns arise regarding electricity consumption and power disruptions during the hottest months (June-August). High temperatures drive up the demand for cooling, potentially straining the power system and leading to blackouts or system

Map 2.2: Heat Exposure



2. HAZARD - EXTREME HEAT WAVES

damage. While the exact causes of power cuts remain unclear, findings from the Libyan Population MSNA 2022 indicate widespread experiences of such disruptions, particularly in Benghazi, where households endured an average of 5.6 hours of power cuts daily during the data collection period between July and October.

In general, prolonged exposure to high temperatures puts stress on the human body, exacerbating existing health conditions. Certain groups are particularly vulnerable to heat-related health impacts, including the elderly, infants, pregnant women, and internally displaced people (IDPs), especially in the baladiya such as Benghazi which hosts around 6869 IDP households [14] making it the second largest settlement in the country[15]. Additionally, extreme heat waves often contributes to droughts, which could pose challenges on the agricultural sector and livelihoods as this extreme weather event could lead to reduced crop yields and increased irrigation demands.

Mitigation[54 55]

- According to a study on heat resilience in urban environment conducted by J. Parihar and S. Birman, it was reported that prioritizing urban planning strategies that promote heat resilience is important. Strategies could include compact urban form, mixed land use, and green space integration. Urban greening initiatives, such as tree planting, green corridors, and green infrastructure networks, mitigate heat stress, improve air quality, and enhance urban liveability.
- The same report highlighted that creating a meteorological monitoring networks to track temperature patterns and forecast heatwave events in advance is crucial. Early warning systems issue alerts and advisories to public, health authorities, and emergency responders, triggering heat health action plans and preventive measures.
- According to J. Parihar and S. Birman, developing climate-responsive adaptation policies is crucial. Prioritizing climate-resilient infrastructure investments, including heat-resilient transportation systems, energy-efficient buildings, and sustainable water supply and sanitation infrastructure. Climate-proofing measures consider projected temperature increases and extreme heat events, ensuring infrastructure resilience and adaptation to future climate risks.
- According to World Health Organization's Public Health Advice on Preventing Health Effects of Heat, community and vulnerable groups should be informed during heat-waves.

3. HAZARD - DROUGHT

Hazard Description

A drought is a period of abnormally dry weather characterized by a prolonged deficiency of precipitation below a certain threshold over a large area and a period longer than a month.[16]

Drought is a weather-related natural hazard, which can affect large areas for months or years, severely affecting economic growth, notably food production. Droughts affect millions of people each year, and susceptibility to drought is likely to rise as populations grow, the environment degrades, development demands mount, and climate change takes hold. North Africa, including Libya, is expected to be severely affected in future projections.[17] As part of the Mediterranean the North African region, inherently Libya, has a long and varied history of drought and is projected to witness recurrent events of droughts.

There are different types of droughts; the two main droughts impacting Libya are hydrological droughts and meteorological drought. In general meteorological drought can lead to hydrological drought affecting surface water bodies. Typically, hydrological drought is when a low water supply becomes evident in the water system, for instance, groundwater. Whereas, meteorological drought is when a dry weather patterns dominate an area, usually, it manifests in low precipitation rates.

The country has been experiencing a wave of droughts since 2021 with projections of severe drought due to the low rates of precipitation and the rise in temperatures due to global warming and climate change[18].

Libya is facing critical water stress[b] with the country ranking 17 on the top 33 water-stressed countries by 2040.[19] Additionally Libya ranks 6 on the National Water Stress Rankings under the Extremely High Baseline Water Stress. It also ranked ***"extremely high"*** under the Business-as-usual climate change scenario.[20] These projections suggest water stress will threaten national water security and economic growth. The main source of freshwater in Libya originates mainly from groundwater aquifers (unrenewable source of water), which accounts for more than 97% of the water usage in the country.

Water scarcity[c] is classified as high level hazard for the whole of Libya, with droughts expected to occur every 5 years.[21] Libya is relying to some extent on renewable water, as the country has a total of 105 cubic meter per capita annually. This is considered as the lowest in the MENA region and it is lower than global levels.

3. HAZARD - DROUGHT

Precipitation

Figure 4: Annual total precipitation in the assessed area

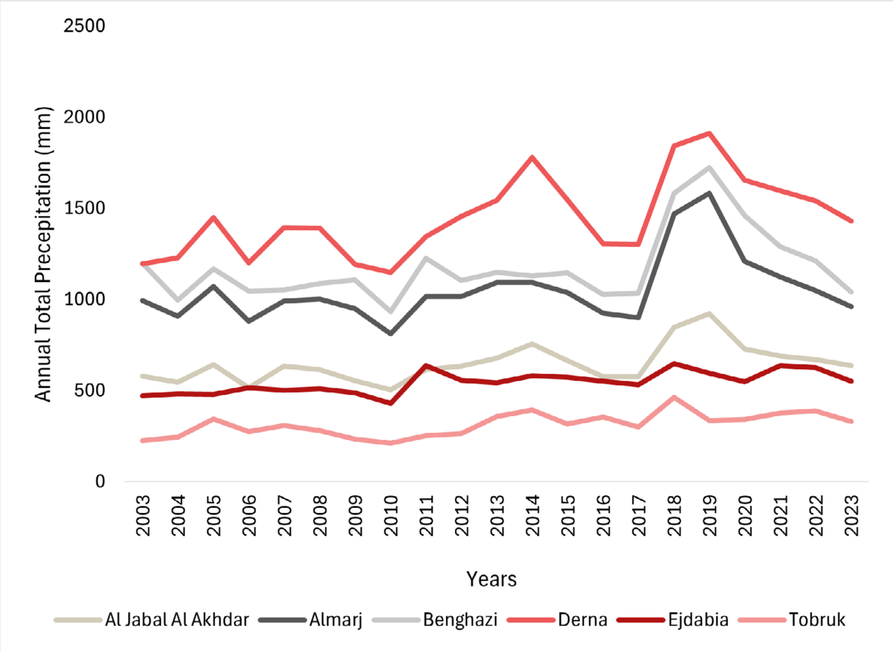


Figure 4 on annual total precipitation in millimetres recorded throughout the last 20 years (2003-2023) in the 6 mantika in Northeast Libya, reveals significant variability.

The observed declines in rainfall in the years 2016-2017 and 2021-2023 could be associated with climatic phenomena such as El Niño events, which significantly impact weather patterns globally, including rainfall. For instance, Al Jabal Alakhdar saw a drop from 663 mm in 2015 to 577 mm in 2016, and a slight further decrease to 575 mm in 2017. Almarj experienced a decrease from 1038 mm in 2015 to 925 mm in 2016, and then to 900 mm in 2017. Derna reduced from 1546 mm in 2015 to 1305 mm in 2016, remaining stable at 1303 mm in 2017. Ejdabia dropped from 573 mm in 2015 to 550 mm in 2016, and a further decrease to 532 mm in 2017. Tobruk decreased from 316 mm in 2015 to 356 mm in 2016, then down to 300 mm in 2017.

From 2021 to 2023, Al Jabal Alakhdar saw a decrease from 728 mm in 2020 to 689 mm in 2021, further to 670 mm in 2022, and 636 mm in 2023. Almarj reduced from 1210 mm in 2020 to 1122 mm in 2021, then to 1048 mm in 2022, and finally to 960 mm in 2023. Benghazi decreased from 1459 mm in 2020 to 1289 mm in 2021, further to 1212 mm in 2022, and to 1041 mm in 2023. Derna dropped from 1653 mm in 2020 to 1595 mm in 2021, then to 1541 mm in 2022, and 1429 mm in 2023. Ejdabia dropped from 624 mm in 2022, and to 552 mm in 2023. Tobruk reduced from 342 mm in 2020 to 376 mm in 2021, then to 389 mm in 2022, and to 329 mm in 2023.

The decline from 2021 could be linked with the start of an El Niño event, which generally brings drier conditions to the regions in question. Monitoring these patterns and integrating forecasts into early warning systems could help mitigate the impacts on water resources and agriculture.

Consecutive Dry Days

Figure 5 represents the annual maximum number of consecutive dry days across the six mantika in the northeast Libya from 2003 to 2020.

Ejdabia consistently exhibits high values for the maximum number of consecutive dry days throughout the assessed period. The figures range from 247 days in 2017 to 331 days in 2004. The values tend to stay above 250 days most years, highlighting a generally arid climate with prolonged dry spells.

Similar to Ejdabia, Tobruk shows high number of dry days, with the highest number observed in 2004 with 291 days and the lowest was 221 days in 2017. The consistently high values with less variability compared to other regions indicate that prolonged dry periods are more common in the manitka.

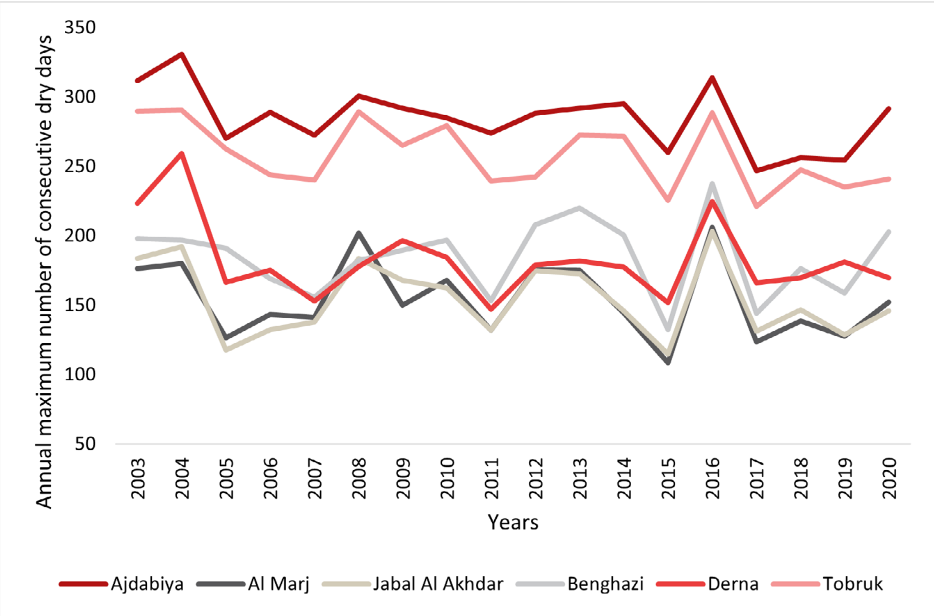
Jabal Al Akhadar and Almarj have similar pattern as both mantika have moderate values and noticeable fluctuations, suggesting intermittent wet periods. For Al Jabal Alakhdar, the highest was 203 days in 2016, and the lowest was 115 days in 2015. While, Almarj mantiak witnessed its highest dry days in 2016 with 206 days and its lowest in 2015 with 108 days.

Benghazi experiences moderately high dry days with some significant peaks. The maximum value was 238 days in 2016, and the minimum was 132 days in 2015. This mantika, like Almarj and Al Jabal Alakhdar, shows considerable annual variability and some years with relatively fewer dry days.

Derna's data also indicates moderate to high values with fluctuations. The maximum days were 259 in 2004, while the minimum was 147 days in 2011. There is significant variability, with alternating years of higher and lower values, pointing to a fluctuating balance between dry and wet periods.

3. HAZARD - DROUGHT

Figure 5: Annual maximum number of consecutive dry days[22]



Overall, Ejdabiaand Toburk face more prolonged dry spells, indicating more arid conditions. In contrast, Almarj, Al Jabal Alakhdar, Benghazi, and Derna have more moderate values with significant annual fluctuation, suggesting these regions experience more varied climatic conditions. Most mantika exhibit year-to-year variability, with 2016 being particularly dry year for many mantika, while 2015 to be a wetter year for multiple mantika.

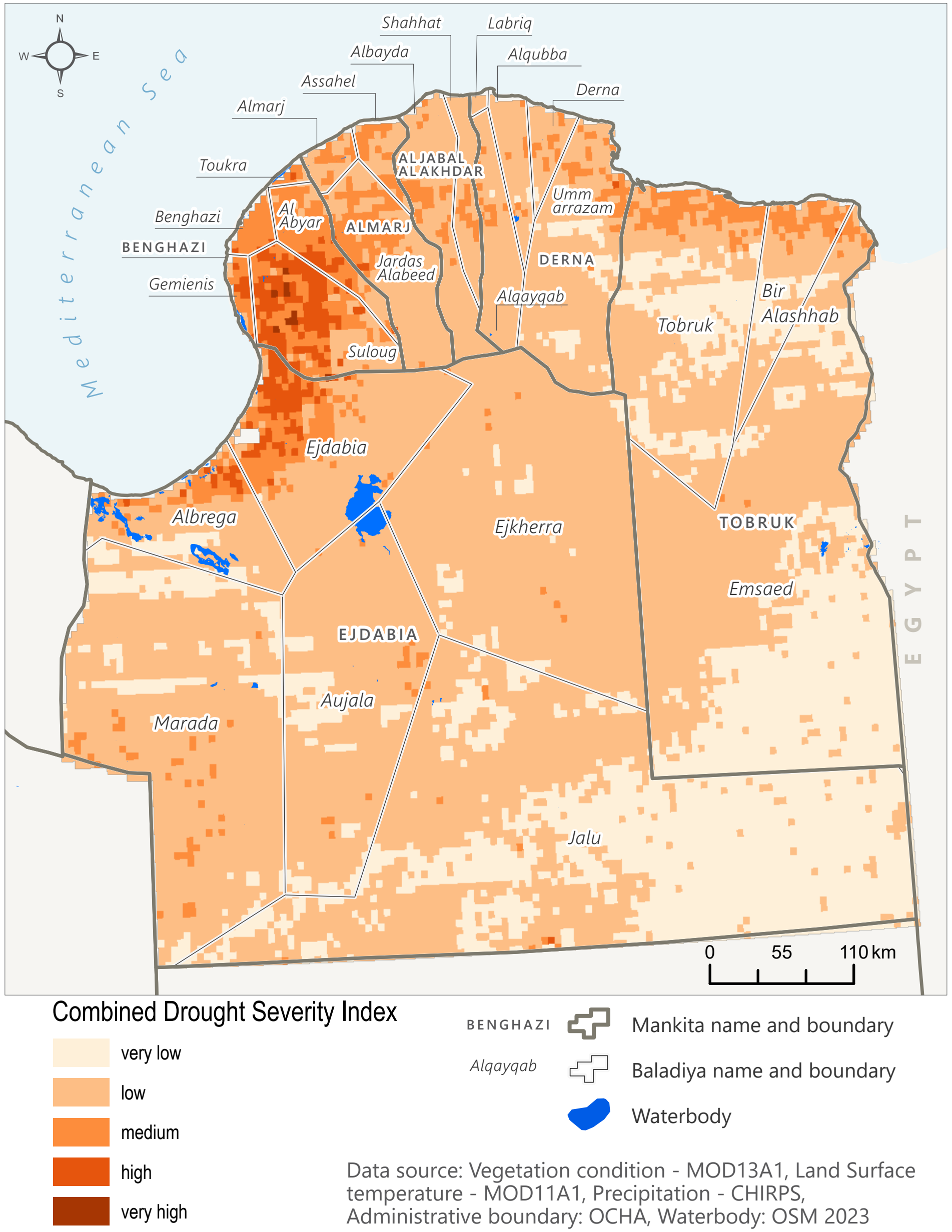
Northeast Libya experiences considerable variability in maximum number of consecutive dry days. This variability has impactions for vegetation condition and health in these mantika.

Combined Drought Severity Index

The highest drought severity index values are observed in Suloug (Benghazi), followed by Gemienis (Benghazi), Benghazi (Benghazi), Al Abyar (Benghazi), and Toukra (Benghazi). These baladiya exhibit significant drought conditions. The lowest exposure was recorded in Jalu (Ejdabia), Emsaed (Tobruk), Tobruk (Tobruk), Marada (Ejdabia), and Aujala (Ejdabia), indicating relatively milder conditions.

Examining the distribution of drought severity by mantika, Benghazi shows high variability. Ejdabia exhibits a broad range, indicating diverse conditions. Derna has moderate exposure while Almarj shows consistent severity. Al Jabal Alakhdar shows

Map 3.1: Combined drought severity index



Data source: Vegetation condition - MOD13A1, Land Surface temperature - MOD11A1, Precipitation - CHIRPS, Administrative boundary: OCHA, Waterbody: OSM 2023

3. HAZARD - DROUGHT

milder conditions. Baladiya in the mantika of Benghazi, particularly Suloug, Gemienis, and Benghazi city, are experiencing the most severe drought conditions. Ejdabia and Tobruk show generally lower drought severity indices, with some baladiyas like Jalu and Emsaed having the least severe conditions.

Exposure of Agricultural Lands to Drought

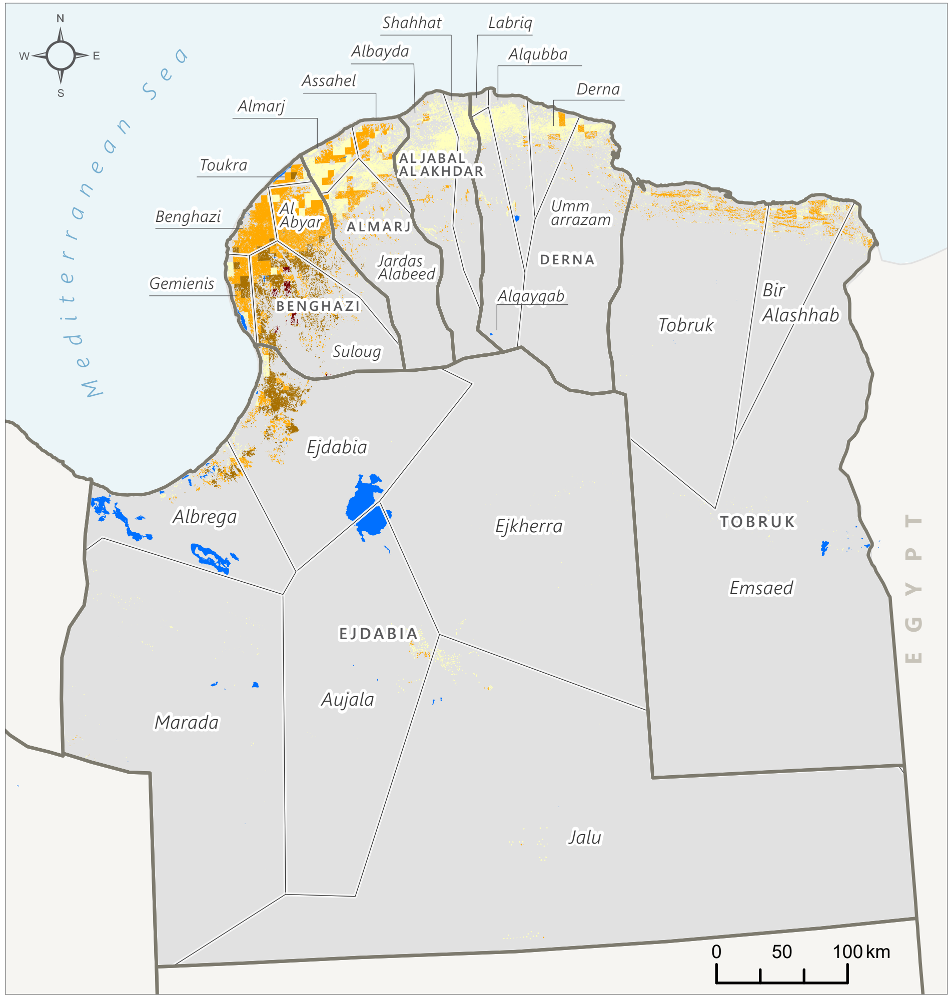
High exposure areas include areas like Suloug (admin 3) with the highest exposure, followed by Al Abayar (admin 3), then Ejdabia (admin 3). Moderate exposure values could be observed in Almarj (admin 3) and Tobruk (admin 3). Areas with low exposure are mainly Ejkherra (admin 3) and Labriq (admin 3) with a very low exposure.

Agricultural lands in Benghazi mantika (admin 2) seem to be highly exposed to drought with the highest values being observed in the areas. In a study[23] conducted to assess drought occurrence in Benghazi between 1990 and 2020, it was reported that drought incidents did occur during the assessed period. Though, the incidents were not prevalent as regular conditions, the findings highlighted the significance of such incidents. Drought occurrences was found to have significant impact on crop yield and quality in Benghazi, especially, affecting the wheat yields.

Exposure

Population density plays a crucial role in vulnerability to drought. Benghazi, with the highest population, faces greater challenges due to a large population relying on limited water resources. High population density leads to increased demand for water resources, intensifying competition during droughts. Areas with lower population density, such as Umm Arrazam, may face comparatively lower stress during drought events.
Agriculture Lands Hazard Exposure Index highlights areas prone to agricultural losses during droughts. Benghazi, Suloug, and Al Abyar exhibit high exposure, suggesting significant risks to agricultural productivity. Droughts can lead to crop failures, livestock losses, and economic hardships in agricultural-dependent regions. Conversely, Derna, Labriq, Ejdabia, and Emsaed show very low exposure, indicating lower vulnerability of agricultural lands.
Areas with consistently high values across multiple indicators are more exposed to droughts. Benghazi emerges as the most exposed baladiya, characterized by extreme Standard Precipitation Index (SPI), high Land Surface Temperature (LST), dense population, and significant agriculture land exposure. Similarly, Suloug and Al Abyar also exhibit high exposure to drought, driven by similar factors.
In terms of mantika (amdin 2), Benghazi stands out with high exposure, likely due to its association with Benghazi baladiya (admin 3), which has the highest exposure among baladiya.
However, areas with low exposure to drought, such as Derna, Labriq, Ejdabia, and Emsaed, benefit from factors like moderate SPI, lower LST, sparse population, and minimal agriculture land exposure.

Map 3.2: Agriculture lands drought exposure



Agriculture land exposure to drought
- low drought
- moderate drought
- high drought
- very high drought
- Non-agricultural land

BENGHAZI Mantika name and boundary
Alqayqab Baladiya name and boundary
Water body

Data source: Vegetation condition - MOD13A1, Land Surface Temperature - MOD11A1, Precipitation - CHIRPS, Administrative boundary - OCHA, Water body - Water body - OpenStreetMap contributors

3. HAZARD - DROUGHT

Hazard Impact

Eastern Libya, particularly regions like Benghazi and Al Jabal Alakhdar, faces significant challenges due to drought, compounded by issues such as dust and sandstorms. These environmental stresses critically affect livelihoods in these areas, which are heavily reliant on agriculture and pastoral activities.[24]

Drought leads to a significant reduction in water availability, severely affecting both domestic water supply and agricultural irrigation in Benghazi. The GMMRP, which replaced the Benina and Sidi Mansour groundwater well fields, supplies most of the domestic water demand. However, areas such as Bu Atnai and Hay al-Salaam depend on private wells, which suffer from aquifer pollution due to proximity to untreated wastewater disposal sites.[25] Illegal connections for agricultural use further strain the water supply system, and poor network maintenance leads to high levels of leakages. Additionally, sea water intrusion into well fields exacerbates the scarcity.

Lack of water for irrigation results in widespread crop failures, impacting food security and local economies. As expressed by a participant in a Benghazi Focus Group Discussion (FGD), climatic factors such as desertification and water scarcity have severely damaged crops like olives and grapes, causing significant price increases. For instance, the price of olive oil has doubled from 7 to 14 Libyan dinars within a year.[26] The primary crops grown in these regions, including wheat and barley, face similar threats, further straining the agricultural sector.

According to Libyan Population MSNA data (2022), 1% of the assessed households in Benghazi reported their involvement in crop production, and in livestock production, respectively. While in Derna, 6% of the assessed households reported involvement in crop production and 7% in livestock production. When asked about whether they have experienced reduction of agricultural activities; 3% in Benghazi did reduce their activities while 13% of the households reported the same thing.

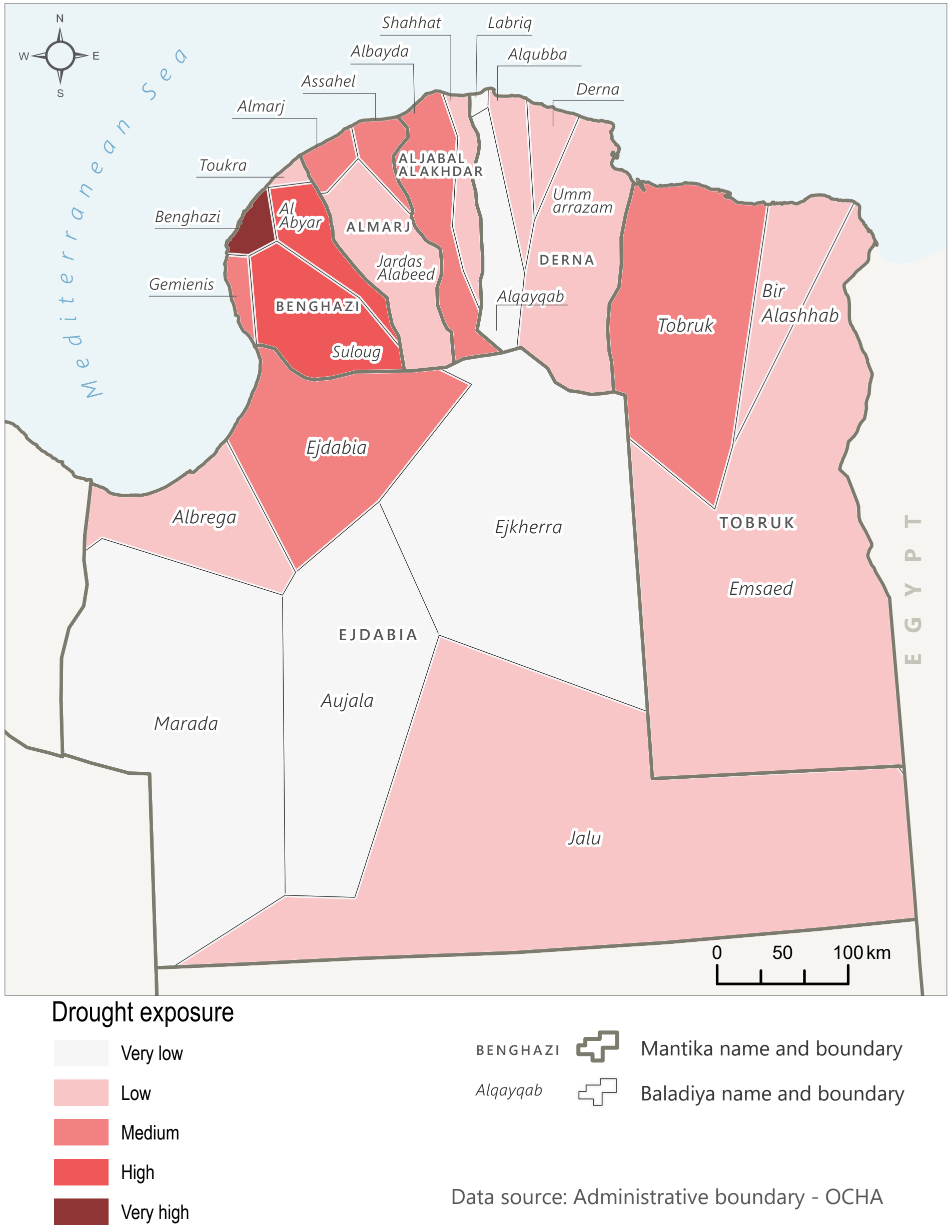
When asked about the main reasons behind the reduction, households in Benghazi reported bad harvests as the main reason, while 35% of the households in Derna reported the same.

Livestock health, economic losses, and health risks

Drought impacts grazing lands, leading to insufficient forage for livestock. This results in malnutrition and dehydration among animals, affecting their health and productivity. Livestock production, comprising cattle, sheep, goats, and poultry, has declined since 2014 due to the remoteness of grazing lands, high transportation costs, and poor security conditions in Benghazi.[27]

The agricultural sector's decline due to reduced crop yields and livestock health leads

Map 3.3: Drought Exposure



Data source: Administrative boundary - OCHA to significant economic losses. Benghazi’s economy, heavily reliant on agriculture, suffers from decreased productivity, affecting both individual livelihoods and the broader economic stability of the region.

Social displacement, environmental degradation, and conflict/tensions

Drought-induced hardships can lead to migration from rural areas to urban centres in search of better living conditions. This migration places additional strain on urban infrastructure and services, potentially leading to overcrowding and increased demand for resources in cities like Benghazi.

Drought stresses ecosystems, causing soil erosion, deforestation, and loss of biodiversity. As vegetation struggles to survive, the risk of desertification increases, further degrading the environment and reducing the land’s capacity to support agriculture and livestock.

Competition for scarce resources such as water, food, and pasture can lead to conflicts among communities. These social tensions can undermine stability and security in the region, as people vie for limited resources to sustain their livelihoods

Mitigation[52] [53]

- According to the UN convention to combat desertification, it is important to implement Integrated Water Resources Management (IWRM) principles to manage water resources sustainably, considering water availability, quality, and demand to mitigate drought risk.
- According to the same convention and in regard with nature-based solution for drought resilience, it is crucial to enforce land use planning regulations that promote sustainable agriculture practices, soil conservation, and water retention to reduce drought risk.
- According to a study on drought early warning conducted by the National Integrated Drought Information System, it was highlighted that develop and implement effective Early Warning Systems (EWS) for droughts to provide timely information to communities and authorities, enabling proactive measures to mitigate drought impacts.
- According to the same report, it is important to implement Nature-Based Solutions (NBS) such as soil conservation, water harvesting, and drought-resistant crop cultivation to enhance water retention, reduce soil erosion, and mitigate drought risk.

4. HAZARD - FLOOD

Hazard Description

According to United Nation Disaster Risk Reduction (UNDRR), flooding is an overflowing of water onto land that is normally dry.

There are different categories of floods, namely, coastal floods, flash floods and, fluvial flood. Coastal flooding often occurs when storm surges and strong winds align with high tides.[28] Flash floods are a type of flood of short duration with a relatively high peak discharge in which the time interval between the observable causative event and the flood is less than four to six hours.[29] Fluvial flooding is considered as a sudden, however, brief increase in the water level from a stream or water body, reaching a peak before receding at a slower pace.[30]

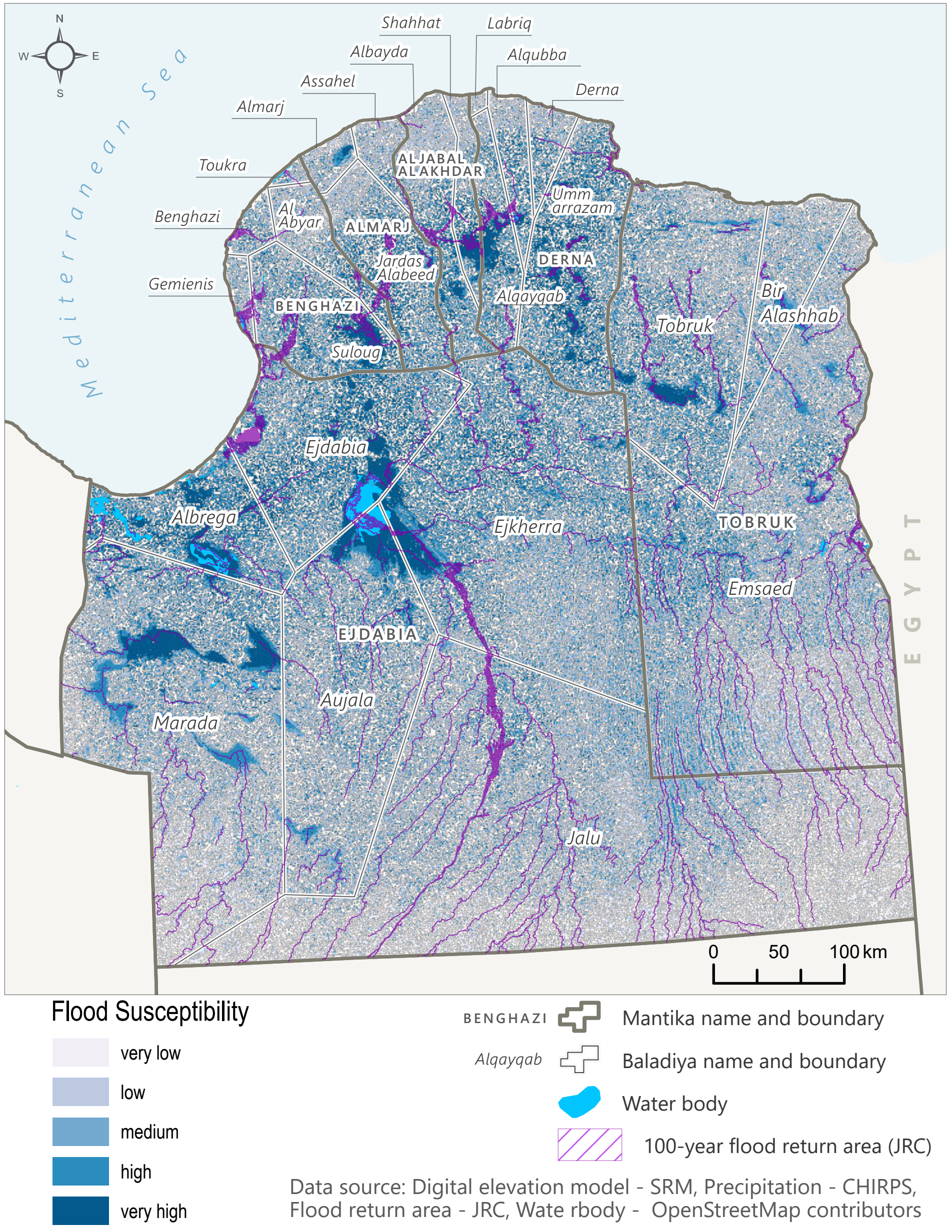
Floods are affecting more people than any other hazards, as worldwide almost 200 million31 live in coastal areas considered at risk of flooding. Flooding typically occurs when heavy or continuous rain surpasses the ability of the soil to absorb water and the capacity of rivers, streams, and coastal areas to manage the flow. Floods can be caused by thunderstorms, tornadoes, tropical cyclones, monsoons, melting snow, and dam failures.[32]

In September 2023, catastrophic flooding struck eastern Libya, caused by heavy rains generated by Storm Daniel, a strong and rare Mediterranean cyclone. The medicane was reported to be the deadliest cyclone to hit Africa in recorded history but also stood as the deadliest storm globally in the last decade.[3334] In Derna, rainfall exceeded 100mm in just 3 days, where the average monthly rainfall in the whole of September is under 1.5mm.[35] The storm also led to the collapse of two dams located upstream from the baladiya of Derna, resulting in a widespread destruction of residential areas, sweeping away entire neighbourhoods[36], and causing significant damage in multiple coastal town in the east, for instance, Albayda, Al Jabal Alakhdar, Almarj, and Shahhat[37]. The likelihood of similar events occurring in the area is considered high, as global temperatures continue to rise. The warming trend of sea surface temperatures due to climate change is becoming more intense in the Mediterranean.

Flood Susceptibility

The flood susceptibility analysis incorporates a diverse array of influencing parameters as model input factors, including topographical, physical, and hydrological attributes of the region. These parameters comprise elevation, slope, the Topographic Wetness Index (TWI), Rainfall Intensity (calculated as the average of maximum annual rainfall over the past 30 years), Rainfall Duration (determined by the average duration of consecutive days with rainfall per year over the past 30 years), proximity to drainage systems (including primary and secondary streambeds), land cover, and soil type.

Map 4.1: Flood Susceptibility



Data source: Digital elevation model - SRM, Precipitation - CHIRPS, Flood return area - JRC, Wate rbody - OpenStreetMap contributors

4. HAZARD - FLOOD

These key variables are essential in determining the areas that are more susceptible to flooding. For instance, land cover provides information on the type of vegetation or infrastructure in the area, which can affect the capacity of the ground to absorb water. Soil texture and degree of wetness influence runoff potential and the magnitude of inundation, thereby impacting flood susceptibility. Elevation data helps identify low-lying areas where water may accumulate during floods, while slope data is crucial for understanding how water drains during intense rainfall events, affecting flood risk. Additionally, assessing rainfall intensity and duration is vital for evaluating the impact of precipitation on flood susceptibility. The Topographic Wetness Index (TWI), derived from elevation data, aids in understanding the wetness of the terrain and its relation to flood risk.

The flood susceptibility map illustrates varying degrees of flood risk across different regions, highlighting areas that are more prone to flooding. Areas with very high flood susceptibility are marked in the darkest shade, indicating the highest risk. Significant areas within this category include parts of Benghazi, Ejdabia, and various coastal zones. These regions are more prone to experiencing severe flooding.

Areas marked with high flood susceptibility are indicated in a slightly lighter shade and include regions such as Derna, Alqubba, and additional coastal areas. These regions also face a considerable risk of flooding, necessitating robust flood management measures.

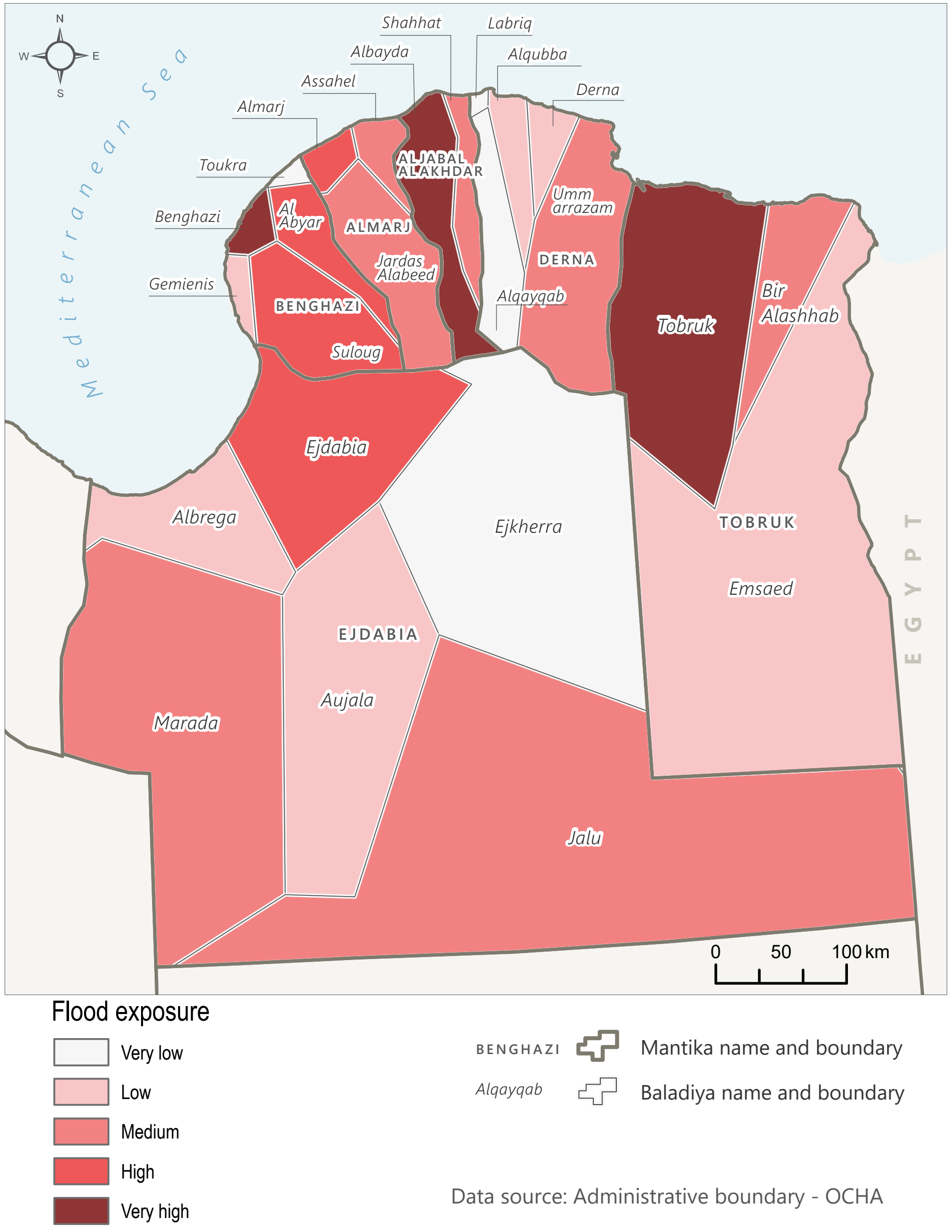
Medium flood susceptibility zones cover a substantial portion of the map and are represented in a mid-tone shade. This category includes parts of Al Jabal Alakhdar and Almarj. While these areas face a moderate risk of flooding, they still require significant attention. Low to very low flood susceptibility regions are shaded the lightest on the map. These areas, including the inland parts of Tobruk, have minimal flood risk.

The map also highlights the 100-year flood return area developed by Joint Research Centre (JRC), denoting zones likely to experience significant flooding events once in a hundred years. These areas often overlap with regions of high to very high flood susceptibility.

Through the observation of the map reveals that coastal regions and areas with lower elevation are more prone to flooding. It emphasizes the necessity of effective flood management strategies in high-risk zones to mitigate potential damage and enhance community resilience.

Flood Exposure

Map 4.2 : Flood Exposure



Data source: Administrative boundary - OCHA

4. HAZARD - FLOOD

Exposure

The flood susceptibility and hazard exposure analysis for various mantika (admin 2) in eastern Libya provides critical insights into their vulnerability to flooding, considering population, roads, and residential buildings.

Regions with very high flood susceptibility include Jalu in Ejdabia, which has the highest flood susceptibility index and a moderate hazard exposure index. Emsaed in Tobruk also shows very high flood susceptibility with an index and a lower hazard exposure index, suggesting a high susceptibility but relatively less exposure to population and infrastructure. Marada in Ejdabia has a high flood susceptibility index and a higher hazard exposure index, indicating considerable flood exposure.

Regions with moderate to high flood susceptibility include Ejkherra in Ejdabia, which has a high flood susceptibility index but the lowest hazard exposure index among high-exposure areas, suggesting limited population and hazard exposure. Aujala in Ejdabia shows moderate flood susceptibility with an index and a moderate hazard exposure index, indicating a balanced but notable flood risk. Tobruk, with a flood susceptibility index and a relatively high hazard exposure index, shows significant risk to population and infrastructure despite moderate susceptibility.

Low to moderate flood susceptibility regions include Ejdabia in Ejdabia, with a flood susceptibility index and a considerable hazard exposure index, highlighting significant risk. Umm Arrazam in Derna has a flood susceptibility index and a moderate hazard exposure index, indicating a balanced but notable flood risk.

Regions with low flood susceptibility, such as Suloug in Benghazi, have a low flood susceptibility index but a relatively high hazard exposure index, suggesting significant exposure despite low susceptibility. Jardas Alabeed in Almarj, with a low flood susceptibility index and a moderate hazard exposure index, indicates some risk to population and infrastructure. Bir Alashhab in Tobruk, with a low flood susceptibility index and a moderate hazard exposure index, presents a manageable risk. Albayda in Al Jabal Alakhdar shows low flood susceptibility with an index but a high hazard exposure index, indicating a significant threat to population and infrastructure despite lower susceptibility. Albrayga in Ejdabia has moderate flood susceptibility with an index and low hazard exposure, suggesting a manageable risk. Alqubba in Derna, with a low flood susceptibility index and low exposure, indicates minimal flood expsure.

In summary, the flood susceptibility and hazard exposure indices highlight regions like Jalu and Emsaed as having the areas with the most flood exposure. On the other hand, areas like Suloug and Alqubba, despite low susceptibility, face varying levels of exposure. Effective flood management strategies must consider both susceptibility and exposure to mitigate potential impacts on population, infrastructure, and overall region resilience.

The immediate impact of the Derna's flooding on the northeast of Libya

The city of Derna has experienced several flooding incidents in the past, leading to the construction of two earth dams along the Wadi Derna river valley. These dams were intended to control soil erosion and flooding.[38] However, due to maintenance neglect since 2002, the dams failed during the unprecedented storm Daniel on the 11th of September 2023, resulting in widespread destruction, loss of life, and displacement of population. Derna has a dry climate and rarely experiences heavy rainfall like that which occurred during the storm, when a recorded 414 millimetres of rain fell in just one day, according to Libya's National Meteorological Centre.

In arid areas, rainwater usually remains on the surface instead of seeping into the ground, often resulting in rapid flash floods.[39] Additionally, Derna is situated on an alluvial fan, a landscape created at the base of mountain ranges by loose sediment carried by rivers and streams. These areas are prone to extremely hazardous flooding. When heavy rainfall occurs, floods on alluvial fans can hit suddenly, move rapidly, and carry significant sediment and debris, causing extensive destruction.[40]

According to the Multi-Thematic Rapid Needs Assessment conducted in September 2023 (MTRNA)[41], the population of the affected area have faced challenges in the aftermath of the flooding, particularly in terms of shelter, health, access to basic services.

Displaced individuals were reported in 92% of assessed muhallas, primarily staying with relatives or in collective shelters, facing challenges such as insufficient shelters, privacy, and space. Shelter and health were the most frequently highlighted priority needs, with specific issues including a lack of medicine, medical equipment, and barriers to accessing health facilities. In 60% of assessed muhallas, key informants indicated that unaccompanied and separated children were particularly in need of assistance.

Severe to very severe building damage was reported in 28% of assessed muhallas, with flooding affecting almost half of the muhallas. The highest levels of damage were reported in Derna, Albayda, Shahat-Sousa, Um Arrezam, and Labrik. Healthcare infrastructure faced significant challenges, including interruptions to health services, damage to health facilities, and impacts on medical staff.

Environmental risks in affected muhallas included the use of contaminated water sources, an increase in stagnant bodies of water, and exposure to dead animal bodies. While the assessment did not specifically mention the impact on agricultural land, it noted environmental risks such as soil contamination from waste affecting agricultural lands or crops.

4. HAZARD - FLOOD

Reported most pressing concerns related to disaster-generated waste as observed by key informants (multiple options allowed), MTRNA (September, 2023)

72% Contamination of water bodies from waste	46% No waste concerns
63% Improper disposal leading to health risk	43% Affecting agricultural lands or crops
58% Soil contamination from waste	42% Odor or aesthetic impact

Mitigation[51]

- According to UNESCO's best practices on flood and drought risk management, it is important to implement and enhance early warning systems are crucial for mitigating the impacts of flash floods and drought. Early warning systems help in monitoring natural phenomena, analysing data, and providing timely alerts to at-risk communities.
- The same report highlighted that Developing infrastructure that is resilient to disasters is vital for reducing the impacts of flash floods and drought. This involves setting up infrastructure facilities, managing major resources wisely, and enhancing the efficiency of infrastructure facilities through digital asset management systems.
- According to UNESCO, investing in disaster risk reduction is essential for supporting sustainable development strategies. This includes allocating financial resources for mitigation efforts and incorporating disaster risk reduction procedures into development assistance programs across different sectors.

Conclusion

The analysis of the susceptibility and exposure of the eastern region of Libya to extreme heat waves, drought, and flood hazards has revealed significant vulnerabilities that need urgent attention.

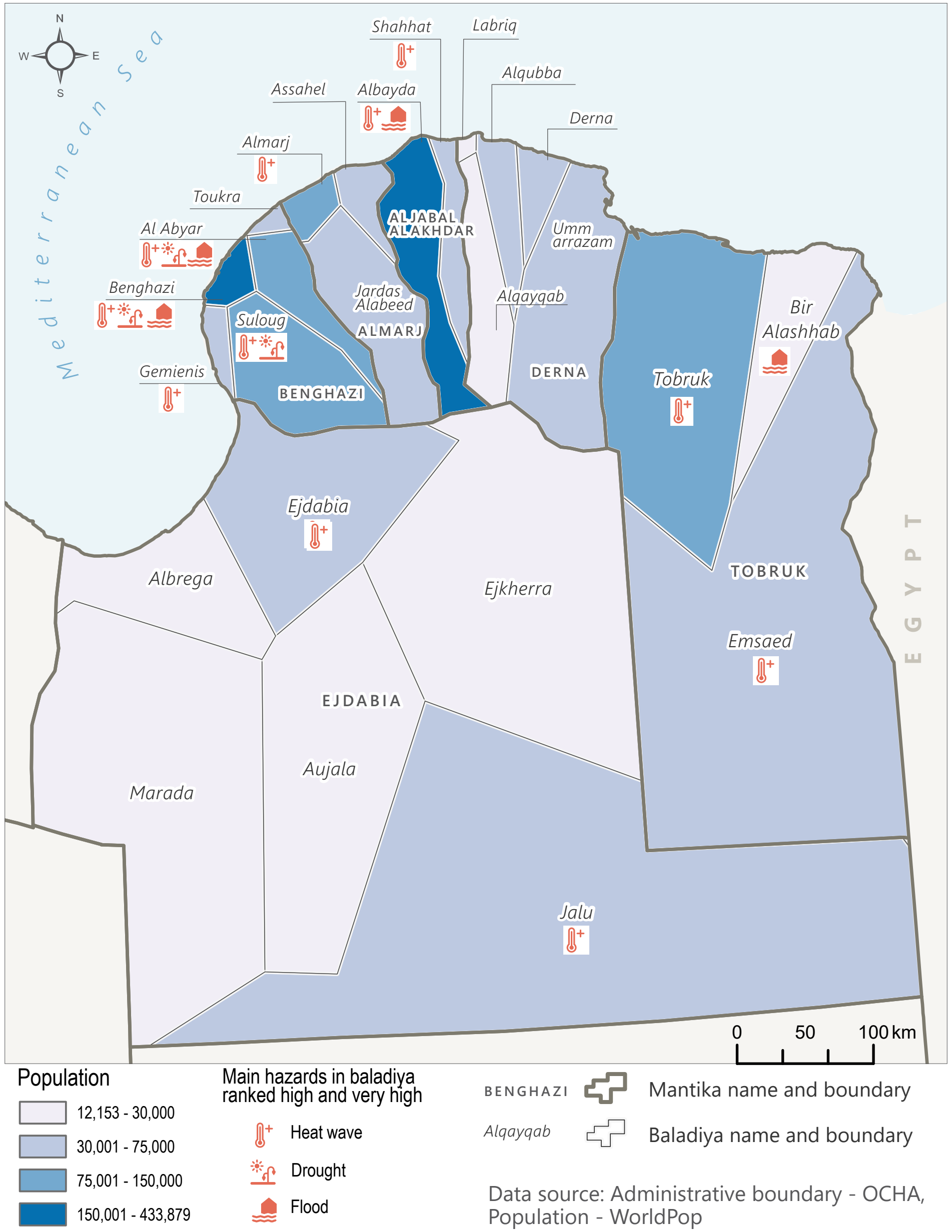
The region, particularly the mantika of Tobruk, Benghazi, and Ejdabia, is highly susceptible to extreme heat waves. The coastal baladiya of Alberge and Ejdabia in Ejdabia mantika, the entire mantika of Benghazi, and the northern part of Tobruk baladiya are among the most vulnerable. Data from 2013 to 2023 shows that these areas have experienced a significant increase in days with temperatures exceeding historical averages. The exposure to heat waves is exacerbated by high population density, especially in urban centres like Benghazi, which also suffer from the Urban Heat Island effect. This increases energy consumption, pollution, and heat-related health issues. Effective mitigation strategies such as urban greening, improved meteorological monitoring, and climate-responsive infrastructure are critical to reduce the adverse impacts of extreme heat waves.

Drought poses a severe threat to the region due to its prolonged periods of low precipitation, impacting water availability and agricultural productivity. The North African region, including Libya, is expected to experience recurrent drought events. Both hydrological and meteorological droughts significantly impact surface and groundwater supplies. The analysis indicates that drought susceptibility is high, affecting not only the environment but also the economic stability of the area. Implementing efficient water management practices and drought-resistant agricultural techniques are vital to mitigate the effects of droughts.

Flooding remains a significant hazard, particularly affecting low-lying coastal areas and regions with inadequate drainage systems. Increased rainfall variability and intensity due to climate change contribute to the heightened risk of floods. Urban areas, with their impermeable surfaces, are especially prone to flash floods, which can cause substantial property damage and loss of life. Enhancing flood risk management through improved infrastructure, early warning systems, and community preparedness is essential to protect vulnerable populations.

5. MULTI-HAZARD EXPOSURE

Map 5: Multi-Hazard Exposure



The Multi-hazard Exposure Map highlights baladiya ranked as high or very high for specific hazards, represented by their respective symbols. The areas facing very high exposure to hazards include Benghazi, Derna, Ejdabia, Almarj, and Al Jabal Alakhdar. Benghazi shows high population density and is marked with high exposure to heat waves, drought, and flood risks. Derna is another significant mantika with high hazard exposure, particularly to floods and heat waves. Ejdabia faces considerable exposure from multiple hazards, while Almarj is known for high exposure to droughts and heat waves. Al Jabal Alakhdar, including areas like Shahhat and Alqubba, is highly exposed to multiple hazards.

Specifically, areas like Benghazi, Derna, and parts of Al Jabal Alakhdar are particularly prone to extreme temperatures. Ejdabia, Almarj, and parts of Al Jabal Alakhdar show significant drought exposure. Coastal areas, including Benghazi and Derna, along with some inland regions, are at high exposure of flooding. The map indicates that densely populated urban areas and regions with specific geographical features, such as coastal proximity or elevation changes face the highest exposure to natural hazards. These insights are crucial for targeted disaster preparedness and mitigation efforts in eastern Libya.

Methodology Overview

The Climate-related Hazard Exposure Assessment primarily utilized quantitative secondary data from IMPACT, other humanitarian and development actors, and geospatial data for hazard and exposure analysis. Geospatial analysis, including remote sensing and GIS, determined the geographic distribution and characteristics of main hazards, contributing to hazard-exposure index calculations.

REACH performed regional geospatial analysis for droughts, extreme heat, and flooding across the mantikas of Benghazi, Derna, Ejdabia, Al Jabal Alakhdar, Almarj, and Tobruk, aggregating data to the baladiya level.

The narrative integrated secondary data from various sources and included insights on mitigation measures. The assessment used admin 3 (baladiya) as the unit of measurement, aggregated to admin 2 (mantika) level.

Limitation

Vulnerability indicators are crucial for understanding risk, such as the susceptibility of communities to flooding due to poor infrastructure, drought due to reliance on rain-fed agriculture, and heat waves due to lack of access to cooling facilities. However, this assessment relied solely on available open data, primarily based on remote sensing. Information about community vulnerability to these hazards was limited and not integrated into the assessment. Field observations and ground validations of remote sensing results were not conducted, though the satellite image processing followed well-established practices, particularly those developed by UN-Spider. Several survey results were used to triangulate key findings from remote sensing, including the Multi-Sector Needs Assessment conducted in 2022 and the Derna Multi-Thematic Rapid Needs Assessment conducted in September, 2023.

Definitions

Critical infrastructure: The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society.[42]

Exposure: the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.[43]

Hazards: a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.[44]

Risk: the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.[45]

Mitigation: The lessening or minimizing of the adverse impacts of a hazardous event. The adverse impact of hazards, in particular natural hazards, often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness. It should be noted that, in climate change policy, "mitigation" is defined differently, and is the term used for the reduction of greenhouse gas emissions that are the source of climate change.[46]

Water Stress: water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers) and quality (eutrophication, organic matter pollution, saline intrusion).[47]

Water Scarcity: water scarcity refers to the volumetric abundance, or lack thereof, of water supply. This typically calculated as a ratio of human water consumption to available water supply in a given area. Water scarcity is a physical, objective reality that can be measured consistently across regions and over time.[48]

Urban Heat Islands effect: The urban heat island effect is a phenomenon whereby cities experience higher air temperatures than the surrounding countryside.[49] Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies.[50]

ABOUT REACH

REACH Initiative facilitates the development of information tools and products that enhance the capacity of aid actors to make evidence-based decisions in emergency, recovery and development contexts. The methodologies used by REACH include primary data collection and in-depth analysis, and all activities are conducted through inter-agency aid coordination mechanisms. REACH is a joint initiative of IMPACT Initiatives, ACTED and the United Nations Institute for Training and Research - Operational Satellite Applications Programme (UNITAR-UNOSAT).

5. ANNEX

Table 1: Heat exposure index per baladiya

Mantika	Baladiya	Susceptibility index	Population index	Exposure Index	Range
Ejdabia	Aujala	0.80	0.02	0.02	Low
Ejdabia	Marada	0.84	0.02	0.01	Low
Benghazi	Gemienis	0.65	0.08	0.05	High
Benghazi	**Benghazi**	**0.24**	**1.00**	**0.24**	**Very High**
Benghazi	Toukra	0.39	0.05	0.02	Low
Al-Marj	Assahel	0.23	0.11	0.03	Medium
Derna	Alqubba	0.24	0.09	0.02	Medium
Derna	Labriq	0.00	0.00	0.00	Very low
Derna	Derna	0.31	0.06	0.02	Low
Tubruk	Bir Alashhab	0.61	0.01	0.01	Very low
Tubruk	Emsaed	0.83	0.06	0.05	High
Tubruk	**Tobruk**	**0.56**	**0.22**	**0.12**	**Very High**
Derna	Umm Arrazam	0.30	0.07	0.02	Medium
Ejdabia	Ejkherra	0.79	0.00	0.00	Very low
Jabal Al-Akhdar	Shahhat	0.21	0.14	0.03	High
Derna	Alqayqab	0.21	0.01	0.00	Very low
Al-Marj	Almarj	0.26	0.23	0.06	High
Benghazi	**Al Abyar**	**0.58**	**0.21**	**0.12**	**Very High**
Benghazi	**Suloug**	**1.00**	**0.23**	**0.23**	**Very High**
Ejdabia	**Ejdabia**	**0.85**	**0.15**	**0.12**	**Very High**
Ejdabia	Albrega	0.77	0.03	0.02	Medium
Ejdabia	Jalu	0.84	0.09	0.07	High
Al-Marj	Jardas Alabeed	0.31	0.07	0.02	Low
Jabal Al-Akhdar	Albayda	0.19	0.37	0.07	High

Table 2: Flood exposure index per baladiya

Mantika	Baladiya	Flood Susceptibility index	Flood Exposure Index	Range
Benghazi	**Al Abyar**	**0.06**	**0.012006596**	**High**
Al Jabal Alakhdar	**Albayda**	**0.11**	**0.016613638**	**Very High**
Ejdabia	Albrayga	0.21	0.004835784	Moderate
Almarj	Almarj	0.02	0.009457975	Moderate
Derna	Alqayqab	0.09	0.00302048	Moderate
Derna	Alqubba	0.05	0.004481306	Moderate
Almarj	Assahel	0.03	0.007509196	Moderate
Ejdabia	Aujala	0.43	0.004575682	Moderate
Benghazi	**Benghazi**	**0.02**	**0.017012203**	**Very High**
Tobruk	**Bir Alashhab**	**0.11**	**0.006649885**	**High**
Derna	Derna	0.03	0.004367357	Moderate
Ejdabia	Ejdabia	0.34	0.010239448	Moderate
Ejdabia	Ejkherra	0.70	0.001785308	Low
Tobruk	Emsaed	0.91	0.005381512	Moderate
Benghazi	Gemienis	0.01	0.003999721	Low
Ejdabia	Jalu	1.00	0.006259782	Moderate
Almarj	Jardas Alabeed	0.14	0.006220314	Moderate
Derna	Labriq	0.00	0.000896023	Very Low
Ejdabia	Marada	0.65	0.00705828	Moderate
Al Jabal Alakhdar	Shahhat	0.05	0.006695107	Moderate
Benghazi	**Suloug**	**0.15**	**0.011419249**	**High**
Tobruk	**Tobruk**	**0.37**	**0.014649536**	**Very High**
Benghazi	Toukra	0.01	0.002612622	Low
Derna	Umm Arrazam	0.24	0.006223895	Moderate

Table 3: Drought exposure index per baladiya

Mantika	Baladiya	SPI Index	LST Index	Population Index	Agriculture Land Hazard exposure	Exposure Index	Range
Benghazi	**Al Abyar**	**0.86**	**0.96**	**0.21**	**0.56**	**0.35**	**High**
Al Jabal Alakhdar	Albayda	0.66	0.92	0.37	0.03	0.16	Moderate
Ejdabia	Albrega	0.44	0.95	0.03	0.07	0.04	Low
Almarj	Almarj	0.91	0.91	0.23	0.12	0.16	Moderate
Derna	Alqayqab	0.51	0.94	0.01	0.00	0.01	Very Low
Derna	Alqubba	0.53	0.92	0.09	0.01	0.04	Low
Almarj	Assahel	0.88	0.91	0.11	0.12	0.10	Moderate
Ejdabia	Aujala	0.49	0.97	0.02	0.00	0.01	Very Low
Benghazi	**Benghazi**	**1.00**	**0.92**	**1.00**	**0.32**	**0.64**	**Very High**
Tobruk	Bir Alashhab	0.40	0.92	0.01	0.11	0.04	Low
Derna	Derna	0.57	0.91	0.06	0.03	0.03	Low
Ejdabia	Ejdabia	0.60	0.95	0.15	0.40	0.21	Moderate
Ejdabia	Ejkherra	0.48	0.95	0.00	0.00	0.00	Very Low
Tobruk	Emsaed	0.33	0.95	0.06	0.02	0.02	Very Low
Benghazi	Gemienis	0.74	0.96	0.08	0.23	0.13	Moderate
Ejdabia	Jalu	0.32	1.00	0.09	0.00	0.03	Low
Almarj	Jardas Alabeed	0.71	0.95	0.07	0.13	0.08	Moderate
Derna	Labriq	0.79	0.80	0.00	0.00	0.00	Very Low
Ejdabia	Marada	0.52	0.96	0.02	0.00	0.01	Very Low
Al Jabal Alakhdar	Shahhat	0.58	0.95	0.14	0.01	0.06	Moderate
Benghazi	**Suloug**	**0.87**	**0.98**	**0.23**	**0.72**	**0.44**	**High**
Tobruk	Tobruk	0.36	0.93	0.22	0.11	0.10	Moderate
Benghazi	Toukra	0.90	0.89	0.05	0.07	0.05	Low
Derna	Umm Arrazam	0.42	0.93	0.07	0.04	0.04	Low

Hazard Exposure calculation

	Hazard indicators	Exposure indicators
Heat wave	***Heat wave susceptibility index*** *was calculated as the percentage of days over the last decade (2023 - 2013) with land surface temperature higher than historical mean supplement by standard deviation (2000 - 2012), as detected from MODIS Land Surface Temperature and Emissivity Daily Global dataset - MOD11A1*	***Population density*** *Data source: WorldPop*
Drought	***Standardized Precipitation Index (SPI)*** *reflecting the precipitation anomalies during 2023 compared to long-term observations based on CHIRPS datasets* ***Land Surface Temperature (LST)*** *- averaged during 10-year period (2014 to 2023) as detected from MODIS Land Surface Temperature and Emissivity Daily Global dataset - MOD11A1* ***Combined Drought severity index*** *run for agricultural, croplands, and forests and calculated by equally weighting the long-term Vegetation Condition Index (VCI) spanning from 2003 to 2023, the Vegetation Health Index (VHI) during the drought period in 2023, and the 12-month Standardized Precipitation Index (SPI) of 2023.*	***Population density*** *Data source: WorldPop* ***Agriculture land area*** *in high and very high drought susceptibility zone* *Data source: Proba-V Land Cover* *Final exposure index was calculated by equally weighting of population density and drought affected agriculture area*
Flood	***Flood susceptibility index*** *calculated as a combination of different influencing parameters as input factors of the model, such as topographical, physical, and hydrological characteristics of the region:* *- Topographic Wetness Index (30%) extracted from SRTM 30m* *- Precipitation duration (8%) and intensity (7%)* *- Distance from primary channels (15%) and other channels (10%)* *- Vegetation Cover (10%)* *- Soil Drainage (10%)* *- Elevation (5%)* *- Slope Angle (5%)* *For more details please see: [Flood susceptibility methodology,](#) Impact Initiatives, 2019*	***Population density*** *Data source: WorldPop* **Road network density** *Data source: Open Street Map contributors* ***Building density*** *Data source: Microsoft building footprint* *Final exposure index was calculated by weighting of population density (75%), major road density (10%), minor road density (5%), building density (10%)*

Endnotes

1 WorldClim, https://worldclim.org/data/cmip6/cmip6climate.html
2 Wolrd Bank, (assessed 2024), Libya - Climatology, Climate Change Knowledge Portal
3 World Bank, (assessed 2024), Libya - Climatology, Climate Change Knowledge Portal
4 World Bank, (assessed 2024), Libya - Climatology, Climate Change Knowledge Portal
5 Rebecca Lindsey and Luann Dahlman, reviewed by Jessica Bluden, Climate Change: Global Temperature, January 18, 2024
6 UNDRR, Sendai Framework Terminology on Disaster Risk Reduction, WMO, 2020
7 Hassan boelkhair, Bayoumy Mohamed, Mostafa Morsy, and Hazem Nagy, Co-Occurrence of Atmospheric and Oceanic Heat waves in the Eastern Mediterranean over the Last Four Decades, Academic paper, 30 March 2023.
8 World Bank, climate Change Knowledge Portal, Libya - Profile
9 Think Hazard - Libya Profile
10 UNGA, 2016
11 REACH, WFP, Libyan Ministry of Environment, CLEAR - Consolidated Livelihood Exercise for Analyzing Resilience
12 United States Environmental Protection Agency - Heat Island Effect
13 United States Environmental Protection Agency - Heat Island Effect
14 DTM Libya Round 45, IDPs and Returnees Dataset
15 UNHCR, Libya - Internally Displaced Persons in Libya, 2020
16 Sendai Framework terminology on Disaster Risk Reduction, WMO, 2020.
17 Global Assessment Report on Disaster Risk Reduction (GAR), Special Report on Drought, 2021
18 PL. PRENSA LATINA, Severe Drought in Libya Due to Climate Change, September 2022
19 World Resources Institute, 17 Countries, Home to One-Quarter of the World's Population, Face Extremely High Water Stress, August2019
20 World Resources Institute, Ranking the World's Most Water Stressed Countries in 2040, August 2015
21 UNICEF Libya, Water Scarcity and Climate Change – an analysis on WASH enabling environment in Libya, September 2022
22 Wolrd Bank, (assessed 2024), Libya - Climatology, Climate Change Knowledge Portal
23 Hanan Ali Alrteimei, Zulfa Hanan Ash'aari, Farrah Melissa Muharam, Nurulhuda Khairudin, Monitoring Rainfall Variability to assess Drought Occurrence Using SPI and Aridity Between 1990 and 2020 in Benghazi and
24 REACH, WFP, CLEAR - Consolidated Livelihood Exercise for Analyzing Resilience, October 2022
25 REACH, WFP, CLEAR - Consolidated Livelihood Exercise for Analyzing Resilience, October 2022
26 REACH, WFP, CLEAR - Consolidated Livelihood Exercise for Analyzing Resilience, October 2022
27 REACH, WFP, CLEAR - Consolidated Livelihood Exercise for Analyzing Resilience, October 2022
28 UNDRR, Knowledge Base, Hazards - Flood
29 UNDRR, Knowledge Base, Hazards - Flood
30 UNDRR, Knowledge Base, Hazards - Flood
31 UNDRR, Knowledge Base, Hazards - Flood
32 UNDRR, Knowledge Base, Hazards - Flood
33 Yale Climate Connections, the Libya floods: a climate and infrastructure catastrophe, September 13th, 2023. Accessed on December 11th, 2023
34 Reliefweb, Tropical Storm Daniel – September 2023 Disaster Description. Accessed on December 11th, 2023
35 REACH, Northeast Libya flood Susceptibility and Exposure, Derna Flood Impact, 26 October 2023
36 AP, Flooding in Libya leaves 2,000 people feared dead and more missing after storm collapsed dams, 12 September 2023
37 REACH, Libya 2023 floods: Emergency Situation Overview Albayda, 15 September 2023
38 Abu-Aziza, Fatma B; Yacoub M El-Barasi; Rebeh O Rahil, Flora, Vegetation and Human Activities of Wadi Derna-El-Jabal Flora, Vegetation and Human Activities of Wadi Derna-El-Jabal El-Akhadar-Libya, January 2018
39 Nature, Jie Yin, Yao Gao, Ruishan Chen, Dapendg Yu, Robert Wilby, Nigel Wright, Youn Ge, Jeremy Bricker, Huili Gon, and Mingfu Guan, Flash Floods: Why are more of them devastating the world's direst regions?, March 2023
40 The New York Times, Why floods can be so deadly, so fast, September 2023
41 UNDAC, REACH, Northeastern Libya Floods - Multi-Thematic Rapid Needs Assessment (MTRNA), September 2023
42 United Nation Office for Disaster Risk Reduction (UNDRR)
43 United Nations General Assembly Resolution A/71/644, (UNGA, 2016).
44 United Nations General Assembly Resolution A/71/644, (UNGA, 2016).
45 United Nations General Assembly Resolution A/71/644, (UNGA, 2016).
46 United Nation Office for Disaster Risk Reduction (UNDRR)
47 European Environment Agency, Glossary Definitions, Water Stress
48 Pacific Institute, Defining Water Scarcity, Water Stress, and Water Risk,
49 MIT, Climate Portal, Urban Heat Island
50 US Environment Protection Agency, Heat Island Effect
51 UNSECO, Best Practices on Flood and Drought Risk Management, 2023
52 UN Convention to Combat Desertification, International Drought Resilience Alliance, The Nature Conservancy, Nature-based Solution for Drought Resilience
53 National Integrated Drought Information System, Why Drought Early Warning?
54 Parihar, J, Birman, S, Heat Resilience in Urban Environments: Strategies for Sustainable City Climate Management, 2024
55 World Health Organization, Public Heath Advice on Preventing Health Effects of Heat, January 2011