PAP/RAC of UNEP/MAP

Candidate Common Indicator 25
“Land cover change”
for Libya

Contents

1. Introduction

This report elaborates calculation process of the upgraded Candidate Common Indicator on Land cover change (CCI 25) for Libya, under the Integrated Monitoring and Assessment Program (IMAP) of the UNEP/MAP Ecosystem Approach (EcAp) initiative (hereinafter LCC indicator 25) as approved by the EcAp Coordination Group meeting held in September 2019. The GEF MedProgramme project provides an opportunity to test this indicator and the following chapters describe results on the area.

The Mediterranean Sea Programme: Enhancing Environmental Security (MedProgramme) addresses major present and future threats to environmental sustainability and climate related impacts. The seven child projects funded by the Global Environment Facility (GEF) over the 2021-2025 period aim to kick start the implementation of priority actions to reduce the major transboundary environmental stresses affecting the Mediterranean Sea and its coastal areas, while strengthening climate resilience and water security and improving the health and livelihoods of coastal populations. This task was developed under the MedProgramme child project 2.1 Mediterranean Coastal Zones: Water Security, Climate Resilience and Habitat Protection, Activity 1.1.1. Development of the materials for the consultations in support of Integrated Coastal Zone Management (ICZM) Protocol ratification/implementation.

The LCC indicator 25 aims to support implementation of the ICZM Protocol, particularly related to the balanced allocation of uses, preserving open coastal space, securing setback zone, avoiding urban sprawl by limiting linear extension of urban development including transport infrastructure along the coast and securing ecosystem health. These objectives are among the most important ones of the ICZM Protocol. Being a Candidate Common Indicator, the land cover indicator is still in a testing phase. Thus, the initial methodology developed in 2017 is reviewed and updated including more extensive use of elevation data to adapt this indicator to be used for identification of low-lying coastal zones that are under complex risks caused by coastal flooding, erosion and salinization. The analytical units are upgraded with low elevation coastal zone and new indicator's parameters are introduced. The reporting units are expanded with altitude zones and thus the new reporting units combine coastal strips with altitude zones in the coastal area.

The following sections of the report include description of the identified and used open data sources for the calculation of the LCC indicator 25, process of calculation and the results and finally discussion and conclusions with special emphasis on achievement of the good state of the environment (GES) in the coastal zone of Libya.

2. Project area

The Libyan coast is the longest coast of an African country overlooking the Mediterranean Sea, with a length around 2139.30 km (Coastline data extracted from openstreetmap (OSM) data). Although OSM data is not official and crowd-sourced, OSM coastline data is very reliable and up-to-date. OSM coastline data is downloaded from https://osmdata.openstreetmap.de/data/coastlines.html, project area includes the coastal zone of Libya (10 kilometres inland) of 17414 km2, covering the territory of all cities and villages in coast, the total area of the Administrative units of Libyan coast with the total area of 454901.0 km2from the area of Libya, which is 1613011.9 km2 long (Figure: 1 &2)

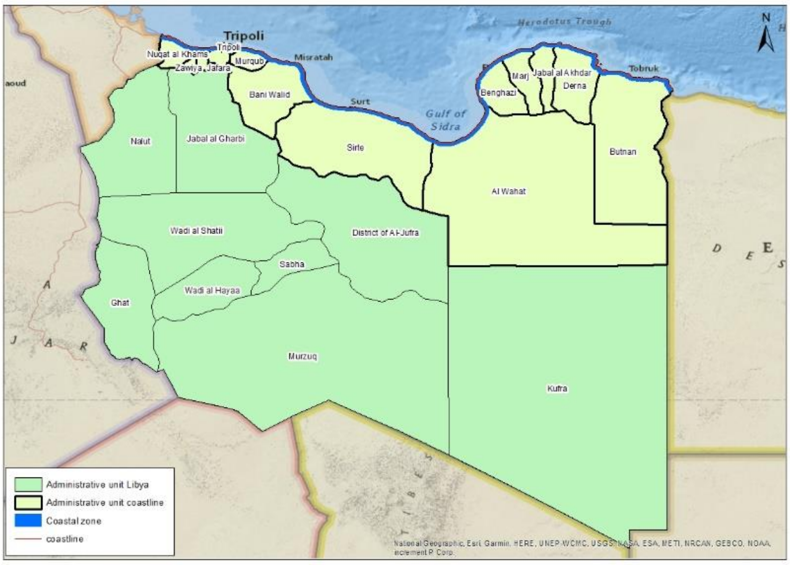


Figure 1. Project area - Administrative units in Libya

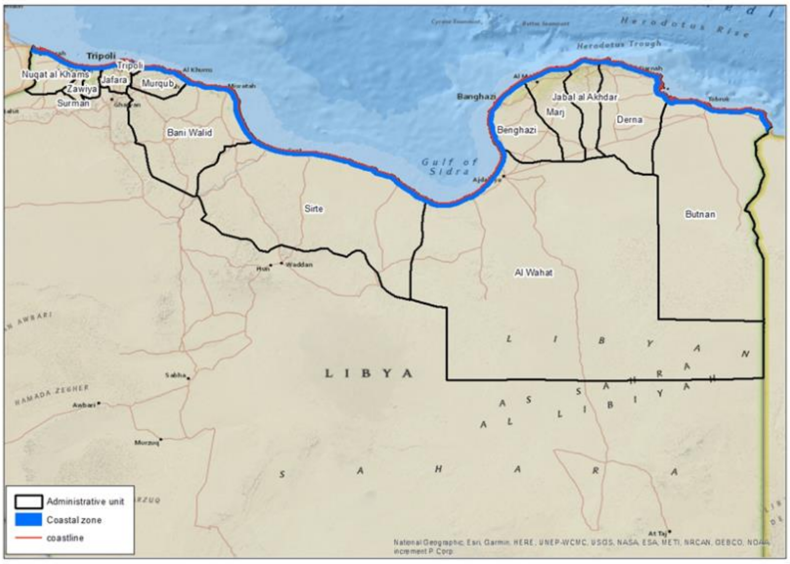


Figure 2. Project area - Administrative unit of coastal zone

It includes the natural coast, the Coast of Farwa Island, and some small islands off the coast, in addition to the industrial coast, such as ports, breakwaters, etc.

The municipality of Sirte has the longest coast on the sea, with a length of 358 km and a percentage of 16% of the total. It is followed by the municipality of Butnan, with a length of 328 km and a percentage of 15% of the total. The smallest length on the coast is the municipality of Surman, with a length of 7.29 km and a percentage of 0.34% of the total. As for the municipality of the capital city of Tripoli (Figure 3), its coastline is 4% of the coastline, with a coast length of 86 km.

Table No. (1) Shows the length of the sea coast in each coastal municipality and its percentage of the Libyan sea coast.

Administrative unit	Length Km	% in Coastline
Libya Coastline	2139.3	100
Nuqat al Khams	150.96	7.06
Surman	7.29	0.34
Zawiya	27.65	1.29
Jafara	24.39	1.14
Tripoli	86.77	4.06
Murqub	115.27	5.39
Bani Walid	217.59	10.17
Sirte	358.27	16.75
Al Wahat	208.25	9.73
Benghazi	196.85	9.2
Marj	92.95	4.34
Jabal al Akhdar	78.66	3.68
Derna	246.12	11.5
Butnan	328.3	15.35

Table. 1 length of the sea coast and its percentage

The Libyan coastal region includes many cities with a dense population and multiple commercial activities. Divided into fourteen municipalities from the far west are the cities of Nuqat al Khams - Surman - Zawiya - Jafara - Tripoli - Murqub- Bani Walid - Sirte - Al-Wahat - Benghazi - Marj - Jabal al Akhdar - Derna – Butnan and many villages surrounding them, the total area of the Administrative unit of Libyan coast 454901.01 km^2, and they count for about 28.2% of the total area of Libya, which is 1613011.9 km^2.

The total area from 0 to 10 km, is about 17414 km^2, where of the area within the coastal strip 0 - 300 m is 584.18 km^2 (3.35 %), within the coastal strip 300 - 1000 m is 1267.16 km^2 (7.27%), while the rest (15563.19 km^2, or 89.36 %) is located in Area 1 - 10 km from the coast.

Figure 3. City of Tripoli Capital of Libya

The largest area of the coastal zone 0 - 300 meters is located within Sirte Municipality (104.14 Km^2) (Figure. 4), while the shortest there are (6.69 km^2) in Surman. The largest area of the coastal zone 300 - 1000 meters is located within Sirte Municipality (237.71 km^2) and the largest area of coast zone 1-10 km^2 is in Sirte Municipality (3042.13 km^2). (See table 2) (Figure 5. Coastal zone areas)

Figure 4. Sirte The largest area of the coastal zone

Administrative unit	Reporting units areas in km^2				
	0-300 m	300 - 1000 m	1 km - 10 km	Total	Share (%)
Libya	584.18	1267.16	15563.19	17414.53	100
Tripoli	19.00	39.29	441.63	499.92	2.84
Zawiya	6.69	15.16	177.56	199.41	1.14
Surman	1.97	4.26	63.17	69.40	0.41
Nuqat al Khams	37.47	74.02	933.28	1044.76	6.00
Jafara	7.35	16.72	240.16	264.24	1.54
Murqub	29.52	64.67	800.20	894.38	5.14
Bani Walid	60.38	136.41	1709.54	1906.33	10.98
Sirte	104.14	237.71	3042.13	3383.99	19.55
Al Wahat	61.52	142.19	1874.44	2078.14	12.04
Benghazi	56.11	123.96	1508.51	1688.59	9.69
Marj	26.31	59.42	751.51	837.24	4.83
Jabal al Akhdar	20.90	43.83	527.15	591.88	3.39
Derna	65.49	136.34	1543.79	1745.62	9.92
Butnan	87.32	173.18	1950.11	2210.62	12.53

Table 2 . Coastal zone areas (0 m - 10 km) in km^2 per NUTS3 level administrative units

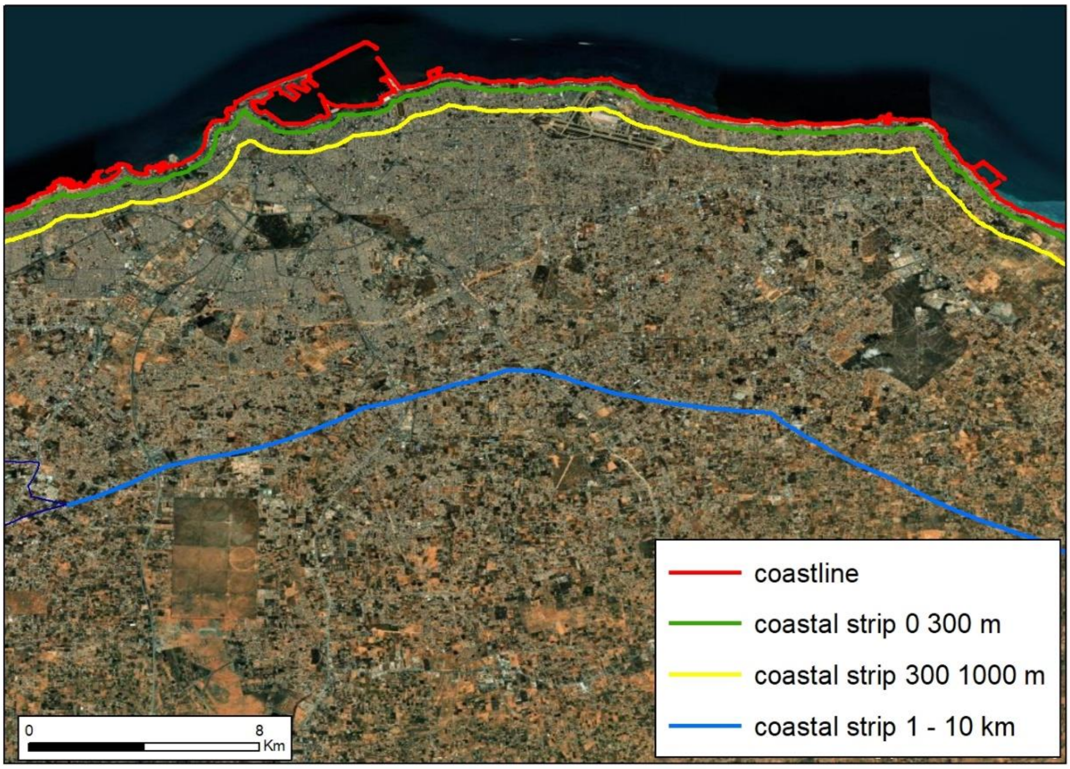


Figure 5 . Coastal strip & Coastal zone areas

2.1. Natural-geographic features

Libya is located in the southern Mediterranean Sea and the total landmass area is about 1759.540 km^2. The terrain in Libya is characterized by a gradual rise of the land, starting from north to south, reaching the highest mountain peak in the country (Pico Biti), where it reaches a height of 2,267 meters above sea level (it is located within the Tibesti Mountains in southern Libya) and the lowest point: Sabkha. Ghazil (-47 meters) below sea level (the lake is located southeast of Brega on the coast), and the terrain of Libya is arid, ranging from flat to undulating plains in addition to depressions and marshes (See Figure 3). The desert areas occupy the largest part of Libya's area (up to 90%), as it extends between the northern highlands and the Gulf of Sirte in the northern part of the Northern Highlands range: Al-Jabal Al-Gharbi, Al-Jabal Al-Akhdar. There are chains of mountains along the coast: Butnan Plateau and Al-Dafna; Plateaus: Hamada Al-Hamra Plateau; Northern Lowlands: Al-Jaghbub Depression, Awjala, Jalo, and Ajkhara Depression, and Marada Depression; Basins: Ubari Basin, Murzuq Basin, Kufra Basin, coastal plains, including the Al-Jafara Plain in the west, the Sirte Plains is in the center, the Benghazi Plain and the North Jabal Al-Akhdar Plain in the east, the surface formations, Al-Sarir, the Great Sand Sea, and Al-Hamada Al-Hamra.

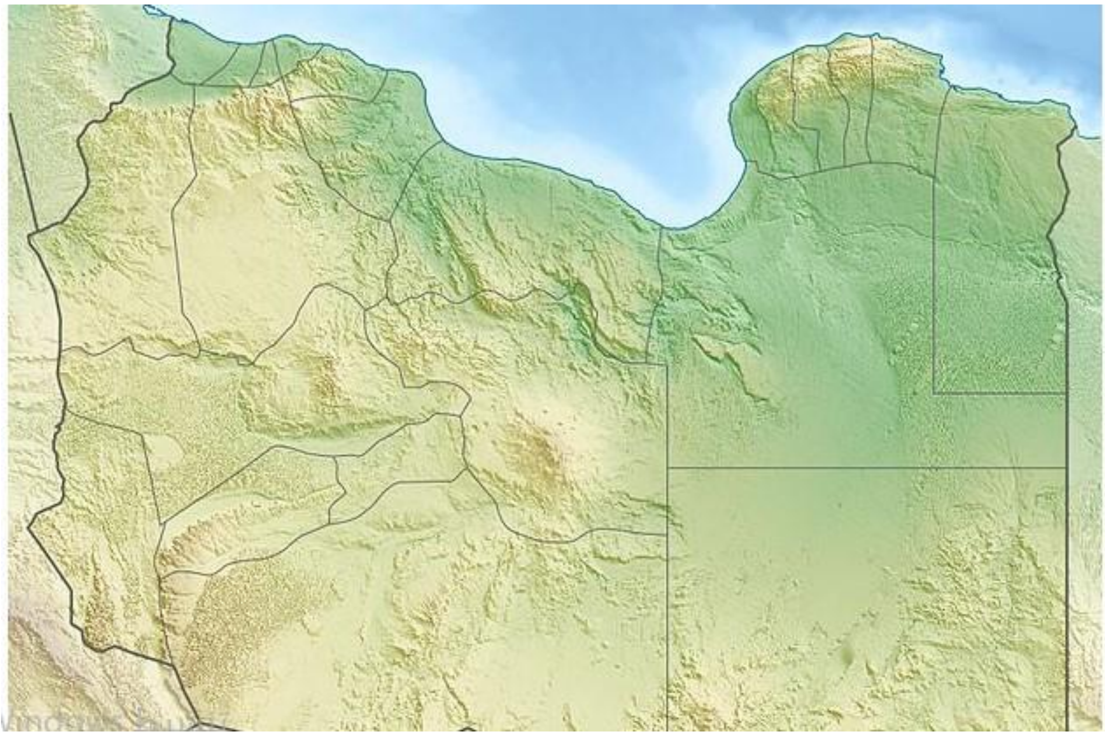


Figure 6. Libya relief location map.jpg (Wikimedia Commons)

There are different coastal terrains, the most common being the pristine coasts. From Zuwara (Nuqat al Khams) in the west to Sabratha in the east, a group of sandy beaches stand out, on the island of Farwa. Its area is 13 square hectares, and it contains scattered palm trees.

The coast to the east of Tripoli, to the coast of Garabulli, is spread over vast distances of sandy beaches, sometimes interspersed with rocky plateaus. There is a backdrop of scattered forests in the areas of Ghanima. Bsis island, a rectangular rock, is on an elevation of 10 meters above sea level and is 600 square metres large. There are also Nuqiza, Al-Quwaya, Naima, Bzliten, and the beaches of Al-Dafniyah and Al-Arar

The coast Gulf of Sirte includes the sand dunes of Shatt Bouirat Al-Hassoun, Bouzahia, Al-Thalateen, Sultan, and Al-Ouija, to Brega, Bishr, Shatt Al-Bedin, and Al-Habri island Its area is about 5 hectares, 8 meters above sea level, and it is rich in bird nesting and surrounded by small islands. Al-Bardaa Island (Joca) is 1800 square meters, its height is 2 meters, and in the middle of the island is a small island called Al-Lutiya, where the sea views blend with scenes of the pre-desert area

On the east of the country and along the Benghazi Plain, there are many sprawling beaches with varied terrain, including Driana, Toukra, and Boutraba. The coasts of the (Jebel Akhdar region) are full of the most beautiful landscapes with rocky beaches and biodiversity interspersed with expanses of sand, forests, and its depths rich in marine life. Si Al-Hamri area is the highest area in the Green Mountain (Jebel Akhdar) 830 meters above sea level. The most important beaches are Ras Al-Hilal Beach, Al-Athroun, Al-Haniya, the beaches of Jurjar Amma, Al-Hamamah, Wadi Al-Hamsa Beach and Wadi Al-Khabta. Derna city is located in a low-lying coastal area bordered to the south by Jebel Akhdar hills. The city divides the valley of Wadi Derna in two. It is adjacent to a mountainous plateau in the shape of an arc, about 300 km long, and its average height ranges from 400 to 600 metres. This plateau descends, passing the city of Derna, towards the Mediterranean Sea, amidst a rugged, rocky nature, covered with a layer of sand. The main beaches are Ras Amer Beach and Ras Al-Tin Beach in the Gulf of Bamba, with their depths full of diverse marine life (Figure 4).

In the far east of the country municipality of Butnan, the views of the plateaus and highlands, intersected by a network of valleys, dominate the coast, and are the most pure and isolated from noise. The most famous beaches are Ras Bayad Beach, Umm Chaouch Beach, Marsa Lak Beach, Umm Rukba, Al-Bardi, Kampot Beach, Gabes Beach, Rabie, Ras Azaz, Ramla Beach, Al-Aqila, and Janzour. In the Far East, against the coast of Ain El Ghazala, there is a small island called (Seal Island).

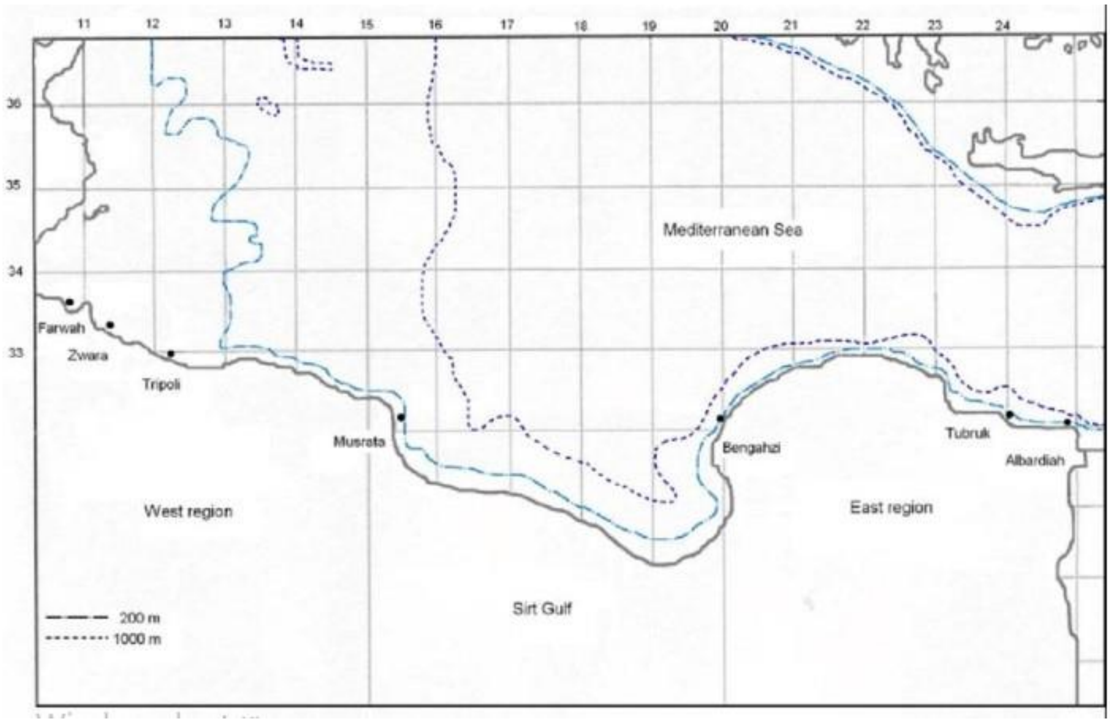


Figure 7: Natural-geographic features of Libyan coast (Source: Simeoni et al., 1997)

The Mediterranean climate is the prevailing climate along the coastal strip, which mainly includes the mountainous highlands in the east and west of the country.

Desert climate: It includes the majority of the country's area south of the northern regions (the semi-desert climate also falls under it, which represents a transitional zone between the Mediterranean Sea and the Sahara).

Rainfall: Concentrated mainly in the north of the country, winter season falls between September and May. It is concentrated in the months from October to March. It is not constant and fluctuates from year to year. Rainfall may be delayed until November or December, or it may stop in March or April as it happened during the 2020-2021 rainy season. The total rainfall recorded at Shahat station reached 626 mm, while the lowest level recorded in Al-Jaghbub was 3 mm. As for the coastal areas of Jabal Akhdar, the rates exceeded by 120-150%. For example, in Al-Bayda the cumulative amount was 602, and in Shahat 626 mm.

2.2. Socio-economic features

The population of Libya in 2013 was estimated at about 6 million people, with a growth rate of 4.85% annually. The recent data from the World Bank estimated the population in 2022 at 6,821,341 people, with a growth of 1.1% annually. The average life expectancy in Libya in years is approximately the same as other countries (72,15 years in 2023) with a similar gross domestic product per capita, and the average life expectancy in this group of countries ranges from 3% to 9% above the global average.

Most of Libya's population is concentrated along Mediterranean coast, especially in the major cities and around the oil fields. The population density in the Tripoli and Benghazi regions is estimated at between 11 and 500 people per square kilometre.

In 2022, the GDP was estimated at approximately 45.75 billion US dollars, the GDP per capita was 1.716.1. The same year, the GDP growth has been -1.2, and the annual consumer price inflation was 4.5. In 2013, it was estimated that agriculture represented 2% of GDP, industry represented 58.3%, and services represented 39.7%.

Oil exports constitute more than 95% of Libya's hard currency revenues. Since the discovery of oil in the 1950s, this economic activity has expanded rapidly while the relative importance of agriculture has decline.

The agricultural sector ranks second in importance in the Libyan GDP, immediately after oil. However, agricultural production is rather weak as national grain production covers only 8% of national needs, forcing Libya to import the rest. On the other hand, the production of vegetables and fruits is sufficient to cover national needs. Agriculture has consistently been given one of the highest priorities by the government to promote economic growth.

The weakness of the agricultural sector is due to the amount of arable land, which is small in Libya (about 5% of the land). Municipalities represent an important proportion of the total irrigated land in Libya, along with other coastal areas, especially around the capital, Tripoli. Irrigated agriculture has become crucial in generating a large portion of agricultural production in Libya.

Agricultural practices in the area of these municipalities constitute a mixture of traditional and advanced methods that are adapted to environmental conditions and available expertise.

Libya has great tourism potential, with a coastline of more than 2000 kilometres, five UNESCO World Heritage Sites (three located on the coast), and mountain and desert tourism. A growing diving industry is developing as the country becomes increasingly able to host tourism.

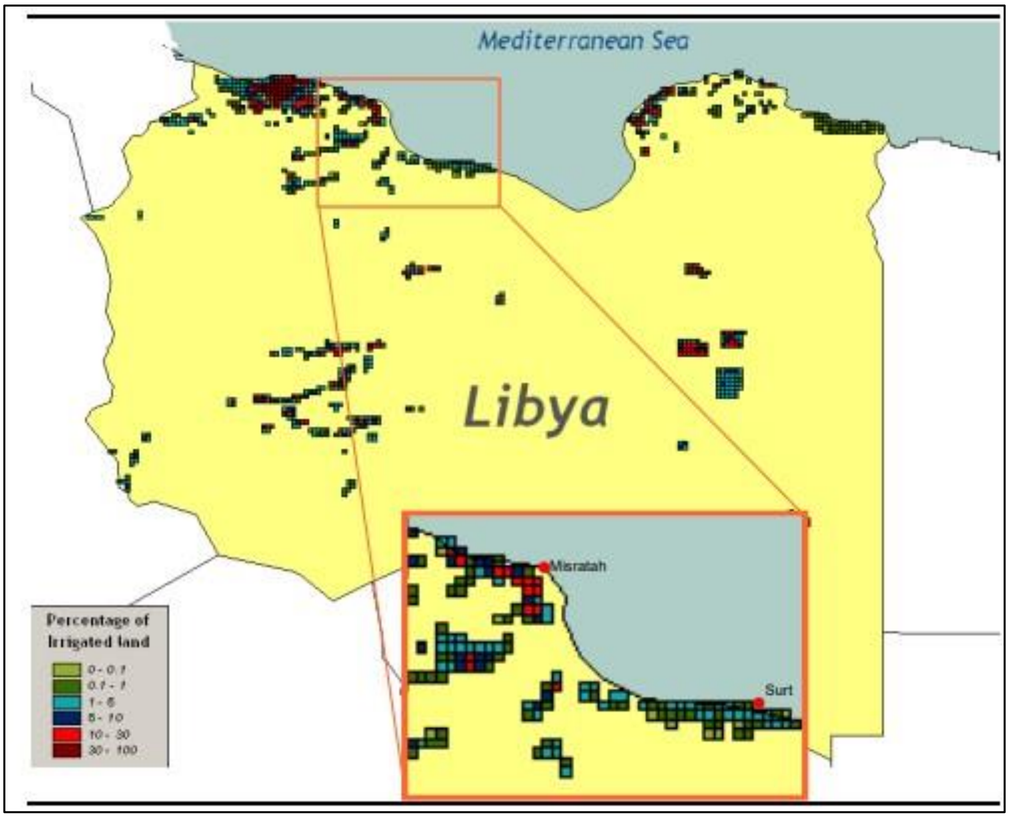


Figure 8: Percentage of Irrigated land

Despite the length of the Libyan coast, Libya's marine fishing resources remain largely unexploited, local waters produce abundant supplies of tuna and sardines in addition to many other species.

2.3. Main pressures and threats to the coastal environment

About 95 % of Libya's land area consists of desert. The coastal regions, low mountains and scattered oases in the desert are among the most densely populated areas of the country, suffering from the highest levels of land degradation and the least protection of their ecosystems and biodiversity habitats. Desertification is one of the most pressing environmental threats, posing the risk of further loss of already limited arable land, which could impact food security. Desertification is due to a combination of factors, including high rates of urbanization and overexploitation of water resources and decayed natural vegetation.

Libya is considered one of the countries in the world that suffers from water scarcity, and water scarcity is considered one of the biggest emerging threats facing Libya. The country needs to ensure equitable access to water for domestic and economic purposes of all kinds. Modern agricultural methods should be followed that reduce the excessive use of water resources and other environmentally harmful agricultural practices that contribute to soil erosion and desertification, which further affects the productive sectors and food security.

The Man-Made River Project provides about 60% of Libya's fresh water needs (Figure 6), and the sources of this water are non-renewable groundwater aquifers that cannot be recharged by rain. Rising temperatures and lower rainfall lead to increased irrigation needs, increased pressure on water resources and increased risk of drought. The lack of awareness and rationalization of optimal water use and conservation and Seawater intrusion into coastal aquifers, contribute to the exacerbation of the water crisis.

There are no rivers in Libya. The country has 0.8 cubic kilometres of renewable water resources, 87% of which is used in agricultural activity and 4% for industrial purposes It comes through valleys and dams.

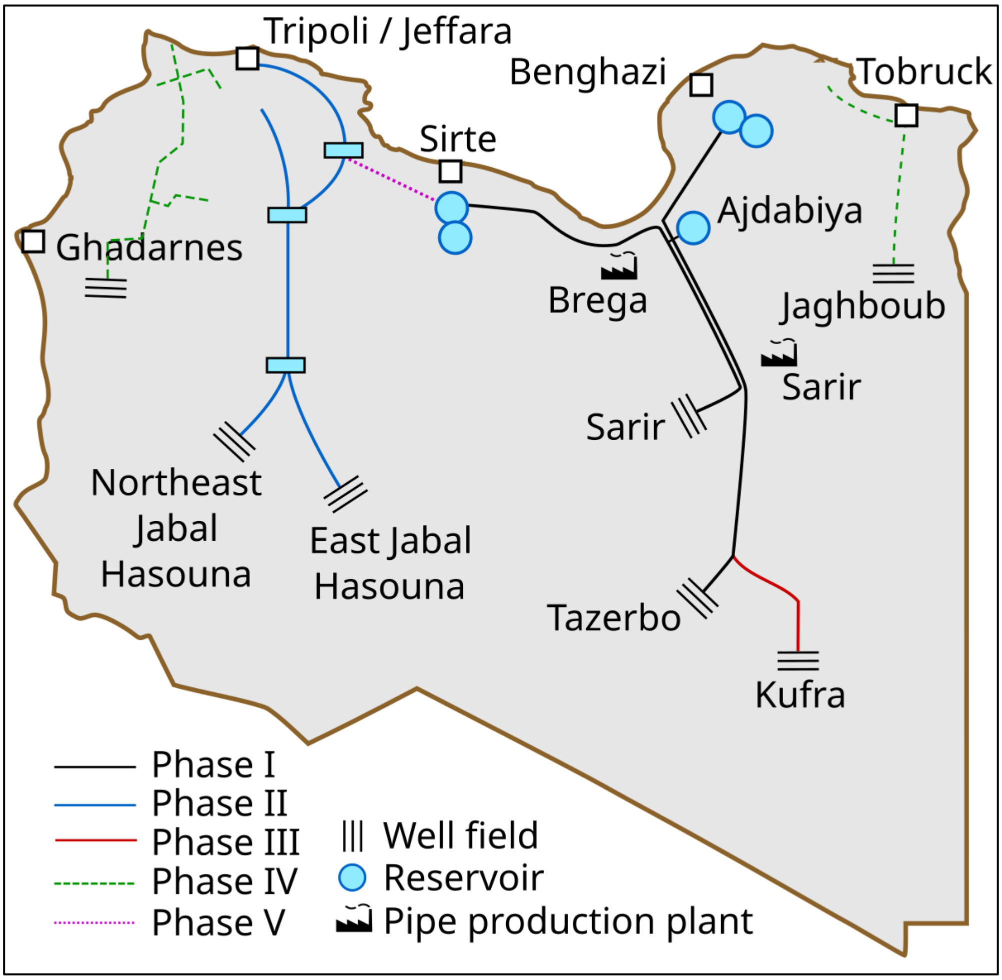
Another important environmental issue in Libya is seawater pollution. The combined effect of sewage, petroleum products and industrial waste threatens the coast of Libya and the Mediterranean Sea in general.

Municipal wastewater treatment is managed by the General Water and Sewerage Company, which falls under the jurisdiction of the Ministry of Housing and Government Utilities. There are approximately 200 wastewater treatment plants across the country, but only a few are operational.

Libyan cities produce approximately 0.6 million tons of solid waste annually. Greater Tripoli produces approximately 2,737 tons of waste daily, containing up to 24% of materials that could have been recycled. Although a large amount of waste is collected by people who make a living selling these recyclable materials, this sector lacks a legal framework to manage it.

The largest operational wastewater treatment plants are located in Sirte, Tripoli and Misrata, with a design capacity of 21,000, 110,000 and 24,000 cubic meters per day, respectively. Furthermore, the majority of remaining wastewater facilities are small and medium-sized plants with a design capacity of approximately 370 to 6,700 cubic meters per day. Therefore, 145,800 cubic meters per day or 11 percent of the wastewater is actually treated, and the rest is released into an artificial lake or into the sea. In fact, non-functioning wastewater treatment plants in Tripoli leak more than 1,275,000 cubic meters of untreated water into the sea every day.

Endangered species: at year 2001, 11 mammal species and two bird species were at risk. Also, about 41 species of plants are threatened with extinction. Endangered species in Libya include the Mediterranean seal, the cheetah, and the Bhopal-horned gazelle (the hartebeest and the slender desert oryx).



Fuger;9- Great Man Made River

Source: Great Man-Made River Water Investment Authority

3. Common Indicator 25 “Land cover change”

The key determinants of CCI 25 are defined through document UNEP/MAP WG.549/5 The Guiding Factsheet for the Candidate CI 25 "Land cover change" [10]. The following determinants are listed and described below.

Ecological Objective

The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved

Relevant GES definition

- Linear coastal development minimised, with perpendicular development being in balance with integrity and diversity of coastal ecosystems and landscapes.
- Mixed land-use structure achieved in predominantly man- made coastal landscapes

Related Operational Objective

Integrity and diversity of coastal ecosystems, landscapes and their geomorphology are preserved.

Proposed Target

Proposed targets should be considered as general recommendations to be adapted to regional / local specificities and knowledge.

- No further construction within the setback zone and low-laying terrain prone to coastal flooding.
- Change of coastal land use structure, dominance of urban land use reversed.
- Keep, and increase where needed, landscape diversity.

Rationale

Identifying and understanding the processes of land cover change (i.e. how land cover has been changed by humans and the processes that result in landscape transformation) is especially relevant for critical and vulnerable areas such as coastal zones, where several competitive uses are pressing. In this context urbanization, or land take, is the most dramatic change given the (almost) irreversibility of the process. The associated impacts could be listed as follows:

•Habitat loss with the associated impact on related ecosystem functions like C sequestration, regulation of water cycle, or biomass production.

Indicator definitions

Land use/land cover change is the change of purpose to which land is profited by humans (e.g., protected areas, forestry for timber products, plantations, row-crop agriculture, pastures, or human settlements). Different parameters can be considered for evaluation of indicator on land use/land cover change. The combined analysis of these parameters entails an inventory of the urbanization pressures on coastal ecosystems. In practice the parameters can identify: (i) where pressures are higher (by amount of change and by pace of the process); (ii) spatial trends (along the coast and landwards, in low-laying terrain prone to coastal flooding); and (iii) areas for priority action. However, responsible (local) institutions are necessary to correctly interpret these processes and to understand the drivers behind them.

3.1. Methodology

The current methodology for LCC indicator 25 is defined within UNEP/MAP WG.549/5 the Guiding Factsheet for the Candidate CI 25 "Land cover change" [10]. The existing methodology resulted from the upgrade of the initial methodology, whereby several essential determinants were taken into account.

Data compilation

In the context that new data sources are emerging on the monthly basis it should be stressed that the same data source should be used for land cover/land use data for change detection (difference of land cover between two reference years). It is because different data sources have different quality and classification schemas and that could result with misleading data about the change.

Special consideration should be given to land cover/land use classification schemas and their mappings to the LCC indicator 25 classes. For example, in case that Land Cover Classification System (LCCS) developed by United Nations (UN) is used by the used data source, urban green areas are considered as vegetation, while dump and construction sites as bare land. The LCC indicator 25 defines aforementioned land cover as built-up. Additionally, LCCS classification does not differentiate between managed and natural grassland, but LCC indicator 25 considers managed grass land as agricultural and natural grassland as forest and semi-natural land. Thus, it is necessary to provide table with the mappings of used classification schema to the LCC indicator 25 classes and stress that while interpreting the results. In this report, a proposal is elaborated to adopt LCC indicator 25 classes to UN-LCCS classification system. As most of the global land cover maps are using UN-LCCS, the above described mappings of classification systems will not be necessary.

For the construction of the reporting units (that are combination of coastal strips/zone and administrative units) and for the Low Elevation Zone, it is recommended that the same coastline is used as baseline. The GIS layers representing reporting units and LECZ could be fixed to certain reference year. That will provide the same analytical units for evaluating the change. Also, not many changes in administrative units and terrain elevation

Data processing

In the context of today computer power and software efficiency, the GIS analysis could be performed over vector and raster data and there is no need to convert all data to raster. Reporting units and protected areas data could remain as vector data representing correctly discrete nature of that geographic features. Land use / land cover is mostly raster data and could remain in that data model. Various "zonal statists" functions could be performed combining vector and raster data to retrieve LCC indicator parameters.

Data confidence and uncertainties

The uncertainties in the LCC indicator 25 parameters are introduced by input data and by the calculation steps. To correctly interpret and to understand limitations of the results, the calculated LCC indicator 25 parameters, it is necessary to perform uncertainty assessment, hereinafter validation. Validation should provide information about reliability of LCC indicator 25 parameters that measure land cover changes in coastal areas, and most important the reliability of calculated land take in the monitoring period (increase of built-up areas).

The input data validation includes studying of the reports provided by the data producers and an analysis of data fitting for LCC indicator 25. Furthermore, the comparison with the data of higher quality could be done by visual inspection on the selected locations, significant for the monitoring of land cover change. The visual inspection is proved as an essential part of any validation able to identify uncertainties which could not be detected by the quantitative methods. Aerial photos from the reference year could be used as higher quality data.

The uncertainties introduced by the calculation steps have sources in GIS overlaying of data with various spatial quality and in definitions of geographic features mapped. For LCC indicator 25 parameter, overlaying of land use/land cover data with spatial resolution of 100 m over the narrowest coastal strip of 300 m width could introduce uncertainties. Regarding uncertainties introduced by the definition of geographic features, the coastline is a key geographic feature for LCC indicator 25 calculation. Coastline is a reference line for construction of coastal strips, it represents border between sea and land in land use/land cover data and it should correspond to line of 0 meters above the sea level in elevation data. As sea water level varies, the coastline as geographic feature depends on intended use and its horizontal position and shape varies in data sets. Thus, the comparison between coastlines incorporated in main data sets should be performed: reporting units, land use/land cover data and elevation data.

Spatial scope guidance and monitoring station

Data are to be expected within the temporal scope of monitoring. Today, available open-source land use / land cover data satisfies that requirement, and enable more detailed mapping and change detection. Two suggested data sources, Copernicus Global Land Cover and ESA WorldCover Project Land cover, have spatial resolution of 100 m and 10 m and thus the new proposed minimum mapping unit (MMU) is the: 100 x 100 m (area of 1 ha).

The ESA WorldCover Project data is not yet available for two or more years and minimum unit for change detection is not declared. But, ESA WorldCover Project data has very fine spatial resolution of 10 m (1/100 of 1 ha) and because of that one can suppose that change of 1 ha could be detected, so MMU for change detection is: 100 x 100 m (area of 1 ha), and it corresponds to MMU. The current CCI 25 Guidance factsheet defines that **temporal scale** for monitoring is 5 years.

3.2. Data

Main preparation steps that have been prerequisite for calculation of CCI 25 included defining the area of interest (AOI), downloading required data, creating coastal strips and reporting units and preparing LC/LU and elevation data and data on protected areas for CCI25 calculation.

3.2.1. Data acquisition and preparation

To calculate parameters for the LCC indicator 25 according to the Guidance Factsheet for the Candidate Common Indicator on Land cover change 25, the following data were required:

- land use / land cover (LU/LC) data;
- coastline data;
- administrative units data;
- elevation data;
- data on protected areas.

When analyzing available datasets, the main aim was to ensure that data are open and freely available, and also easily accessible and stored in well-known digital formats.

3.2.1.1. Land use/land cover data

For the purpose of CCI 25 calculation ESA WorldCover land use / land cover dataset for year 2021 was selected. This dataset is produced from Sentinel-1 and Sentinel-2 images, and from auxiliary data such as Copernicus DEM, OpenStreetMap, Global Surface Water Explorer, Global Human Settlement Layer, and others [5]. Data was

available in raster format (Cloud Optimized GeoTIFF) with spatial resolution of 10 m, georeferenced in WGS84 (EPSG:4326) coordinate system [5].
ESA WorldCover Classification is made with gradient boosting decision tree algorithm (CatBoost) to produce final LU/LC map with 11 classes from LCCS:

- Tree cover (areas dominated by trees, with a cover of 10 % or more, plantation trees (e.g. oil palm, olive trees) are also included);
- Shrubland (areas dominated by natural shrubs, with a cover of 10% or more);
- Grassland (areas dominated by natural herbaceous plants, with a cover of 10 % or more);
- Cropland (areas with annual cropland that is harvested at least once within the 12 months);
- Built-up (buildings, roads, and other man-made structures, urban parks are not included in this class);
- Bare / sparse vegetation (soil, sand, or rock that is never more than 10 % vegetated throughout the year);
- Snow and ice (persistent snow and ice cover);
- Permanent water bodies (areas covered for more than 9 months during the year with water bodies);
- Herbaceous wetland (areas dominated by natural herbaceous vegetation, with a cover of 10 % or more and is regularly flooded by water);
- Mangroves (salt-tolerant trees and other plants which thrive in intertidal zones);
- Moss and lichen.

Accuracy assessment showed that overall accuracy of the ESA WorldCover is around 74 %, with tree cover, cropland, water bodies, snow/ice, and bare/sparse vegetation classes being classified more accurately, and shrubs, herbaceous wetlands, and moss/lichen classes classified with lower accuracy.

Finally, ESA World Cover classes were reclassified into five basic classes defined by CCI 25 Guidance Factsheet, which is represented in table below (Tab 2.).

Table 3. Reclassification scheme – CCI 25 and ESA World Cover classes

CCI 25 LU/LC classes	ESA World Cover classes
Artificial surfaces (also referred as **built-up areas**)	**50 Urban/Built-up** Land covered by buildings and other man-made structures. Urban green (parks, sport facilities) is not included in this class. Waste dump deposits and extraction sites are considered as bare.
Agricultural	**40 Cultivated and managed vegetation/agriculture (cropland)** Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Greenhouses are considered as built-up.
Forest and semi-natural areas	**10 Forest** Closed (tree canopy >70 %) / open forests (tree canopy 15-70%), evergreen/deciduous, needle/broad leaf, mixed. **20 Shrubs** These are woody perennial plants with persistent and woody stems and without any defined main stem being less than 5 m tall. The shrub foliage can be either evergreen or deciduous. **30 Herbaceous vegetation/grasslands** Plants without persistent stem or shoots above ground and lacking definite firm structure. Tree and shrub cover is less than 10 %. Irrespective of different human and/or animal activities, such as: grazing, selective fire management etc. It may also contain uncultivated cropland areas (without harvest/ bare soil period) in the reference

	year. **60 Bare / sparse vegetation** Lands with exposed soil, sand, or rocks and never has more than 10 % vegetated cover during any time of the year. **70 Snow and Ice** Lands under snow or ice cover throughout the year. **100 Moss and lichen** Moss and lichen
Wetlands	**90 Herbaceous wetland** Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in either salt, brackish, or fresh water. 95 Mangroves
Water bodies	**80 Permanent water bodies** Lakes, reservoirs, and rivers. Can be either fresh or salt-water bodies. **200 Open sea** Oceans, seas. Can be either fresh or salt-water bodies.

3.2.1.2. Coastline

Official coastline data is proposed to be used for CCI25 calculation, but often official data are not available, they are not dense enough or they are outdated. For this purpose, coastline data was extracted from the OpenStreetMap (OSM) data. Although OSM data are not official and are crowdsourced, OSM coastline data are highly reliable and up-to-date. OSM coastline data are downloaded from https://osmdata.openstreetmap.de/data/coastlines.html

3.2.1.3. Elevation data

For the purpose of creating LECZ layer data Copernicus DEM was used. Copernicus DEM is a digital surface model (DSM) that was produced from WorldDEM (Airbus) which was produced from TanDEM-X radar satellite mission (DLR & Airbus). In Copernicus DEM, water bodies have been flattened, all sea areas have been lowered/raised to elevation of 0 m, first strip of land pixels next to sea with negative elevation was "raised" to 0,5 m, piers and peninsulas have been taken into account if they are wider than 40 m. If for some pixels WorldDEM is lacking data, values have been added from other DEM-s: Aster, SRTM 90, SRTM30, SRTM30plus GMTED2010, AW3D30, and TerraSAR-X DEM. COP-DEM is produced in three resolutions: 10 m (only EEA39 countries, not publicly available), 30 m (global, freely available), and 90 m (global, freely available). For this purpose, global 30 m DEM dataset was used.

Reported absolute vertical accuracy is less than 4 m (90 % LE), relative vertical accuracy for slopes up to 20 % is less than 2 m, for slopes greater than 20 % is less than 4 m, and absolute horizontal accuracy is less than 6 m (90 %).

Data for producing WorldDEM, and consequently Copernicus DEM were gathered between 2010 and 2015. Copernicus DEM is delivered in raster GeoTIFF format as 1°x1°tiles. Pixel values (heights) are stored in DTED (16-bit integer), DGED (32-bit floating-point number) or INSPIRE format.

3.2.1.4. Administrative units

The CCI25 indicator guidance factsheet suggests using NUTS 3 (Nomenclature of territorial units for statistics, level 3 - population from 150 000 to 800 000) or equivalent administrative units for aggregating LC/LU data (i.e. creating coastal strips). Furthermore, it is suggested to use national official data on administrative units if they are available. If national official data are not available or are not suitable, then NUTS administrative units data can be used.

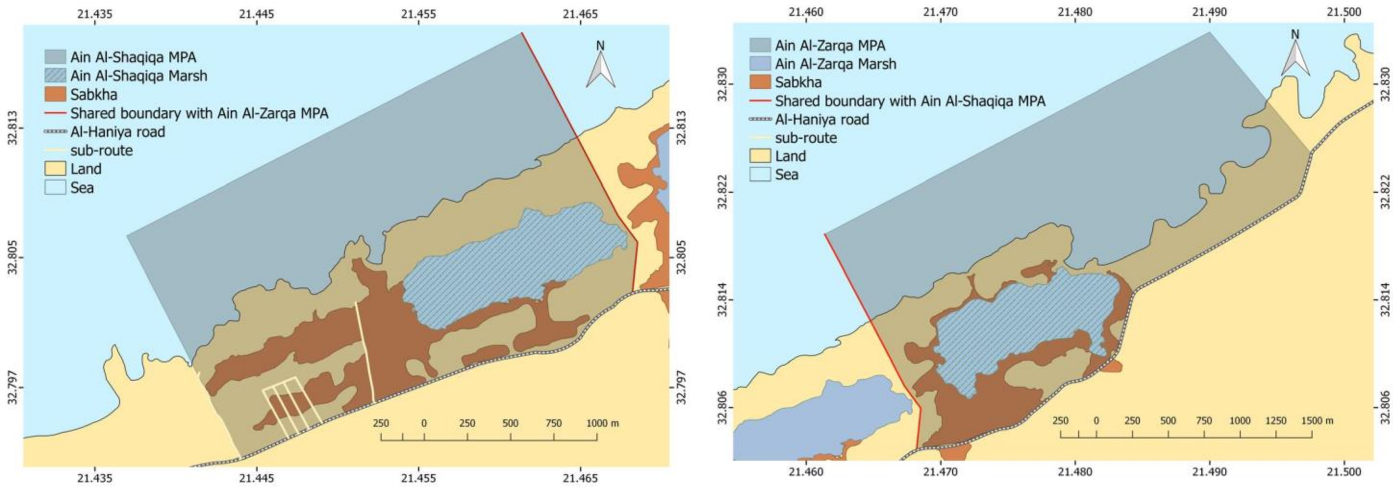
For this purpose administrative data were extracted from the OSM, for two reasons: NUTS administrative units are defined only for the EU countries (and some other European countries outside the EU), and because of coastline data are extracted from OSM, potential problems with data incompatibility, are avoided.

OSM administrative units data are downloaded from https://osm-boundaries.com/Map.

3.2.1.5. Protected area

Locations and boundaries of terrestrial and marine protected areas are obtained from the World Database on Protected Areas (WDPA) available for non-commercial use on Protected Planet websites (https://www.protectedplanet.net). WDPA is a UN Environment Programme (UNEP) and International Union on Conservation of Nature (IUCN) project, it is being created in collaboration with governments, non-governmental organizations, academic institutions, and industry representatives. World Database on Protected Areas is being updated every month.

However, the information in this database regarding Libyan protected areas is in the form of points, which cannot be used in calculating the areas required in the report. Therefore, the Ministry of Agriculture was consulted to obtain the required information, as shown (Figure:10 Ain Al-Shaqiqa and Ain Al- Zarga MPA), (Table No. 4) shows the coastal Protected Areas for which a decision was issued and their areas.



Fuger.10 - Ain Al-Shaqiqa and Ain Al- Zarga MPA Explanatory map

NAME	DESIG	DESIG TYPE	Arae Km^2	STATUS	Year
Wadi El kouf	Protected and National Park	National	320	Designated	1978
El Nagaza	National Park	National	4000	Designated	1992
Ain Elshakika	Wetland of International Importance	International	0.33	Designated	2000
Ain Elzarga	Wetland of International Importance	International	0.5	Designated	2000

Table 4. Protected areas at municipality level at coastal zone

3.2.2. Data pre-processing

Data pre-processing included data clipping and/or merging to the pilot project area extent, transformation to the selected reference coordinate system, creation of costal strips, creation of reporting units by overlaying costal strips with administrative units, conversion of vector data to raster data, aligning raster data, attribute data harmonization and area calculation, land use/cover classes reclassification to CI25 classes and some other technical steps such as dissolving geometry or creation of spatial indices for faster data processing. Data pre-processing was done via open QGIS software, formats used were Shape (SHP), GeoPackage (GPKG) and TIFF files.
One of the key pre-processing steps for successful calculation of indicator parameters was creation of coastal strips and reporting units. Reporting units are coastal zones as defined by country and three coastal strips: the first strip 0 m to 300 m, the second strip 300 m to 1 km, and the third strip 1 km to 10 km from coastline. Coastal zones and coastal strips are split with administrative units of NUTS3 level and hence the CI25 parameters are calculated for units that combine coastal zones, coastal strips and administrative units, herein after reporting units. Intersecting administrative units with created coastal strips (0 – 100 m, 300 – 1000 m, 1 – 10 km), reporting units were created. Created reporting units that were used for aggregating LC/LU and elevation

data, and data on protected areas.
Proposal for upgraded LCC indicator 25 includes Low Elevation Coastal Zone (LECZ) as additional analytical unit. LECZ is an area within the coastal zone prone to coastal flooding, erosion and salinization. Based on the defined elevation threshold value of 5 m above sea level, the land area contiguous to the coast below the threshold is constructed. The indicators on km^2 and % of land use/cover are analyzed for the LECZ within each coastal strip/zone.
When all input data were prepared (transformed to common coordinate system, converted to raster data if needed, and all raster data are resampled to the same resolution and spatially aligned) indicator parameters were calculated with different functions that are commonly present in GIS tools (raster calculator, zonal statistics, zonal histograms, etc.).
Various aggregation and functions were performed over table data resulting from the GIS analysis. Table data were converted to excel files and all the processing is done via Excel software such as pivot tables and charts visualizing the results.

3.3. Calculation of indicator parameters

LCC indicator 25 evaluates the processes of land use/land cover changes in coastal areas by quantifying them with indicator parameters for reporting units.

For the **first monitoring**, the calculated indicator units represent the base line from which changes will be calculated. First monitoring **indicator units** are the following:

1. km^2 of built-up area in coastal zone;
2. % of built-up area in coastal zone;
3. % of other land cover classes in coastal zone;
4. % of built-up area within coastal strips of different width compared to wider coastal units;
5. % of other land cover classes within coastal strips of different width compared to wider coastal units;
6. km^2 of protected areas within coastal strips of different width.

Additional seven parameters are defined for the first monitoring:

7. km^2 of LECZ;
8. km^2 of built-up area within LECZ;
9. % of built-up area within LECZ;

10. % of built-up area within LECZ compared to coastal administrative unit;

11. % of other land cover classes within LECZ;

12. % of other land cover classes within LECZ compared to coastal administrative unit

For the **second monitoring**[1], in addition to the indicator units defined for the first monitoring, the following units are to be calculated:

1. % of increase of built-up area, or land take;
2. % of change of other land cover classes;
3. % of change of protected areas.

By introduction of LECZ, additional three parameters are defined for the second monitoring:

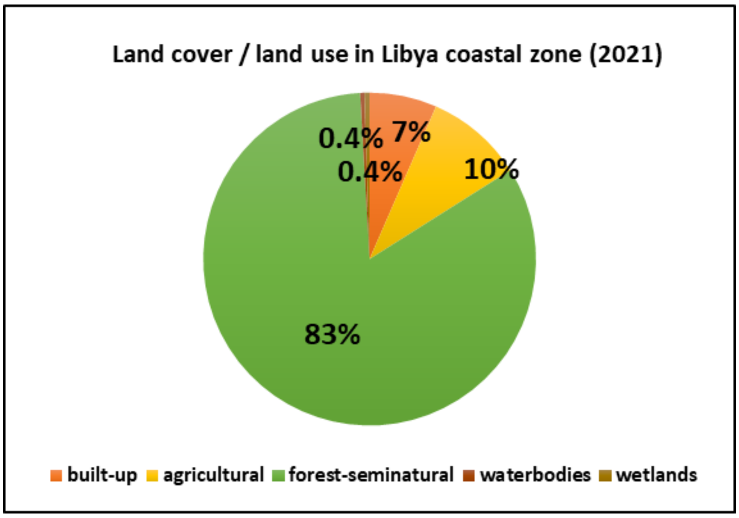
4. % of increase of built-up area, or land take within LECZ;
5. % of change of other land cover classes within LECZ;

Aggregate views on the calculated CI25 parameters are presented in the following paragraphs

[1] Since at the time the report was made, calculations were made only on the basis of data from ESA World Cover 2021, second monitoring was not carried out.

3.3.1. First monitoring (2021)

According to the available ESA World Cover data, the year 2021 was chosen for the first year of monitoring. In year 2021, the most represented category of land use in Libya was forest and semi-natural land (83%), then agricultural land (10 %), wetlands (0.4 %), water bodies (0,4 %) and finally built-up areas (7 %) (Figure. 11).



Figur:11 . Land use / land cover in Libya coastal zones base on ESA World Cover data, 2021

Considering the data at the municipality level (Table. 5), the largest areas of **built-up** were located in municipality of Tripoli, at 248.50 km^2, at a rate of 21.83 % (The percentage is the value of class in the Administrative unit in relation to the value of the same class in Libya. For example, the built-up in the Tripoli municipality is 248.5 km^2 and the built-up in Libya is 1138.16 km^2 . The percentage of construction in Tripoli is 21.8 %.) followed Bani Walid 222.95 km^2 at a rate of 19.59 % then Benghazi 137.29 km^2 at a rate of 12.06% from a total area.

The largest areas of **agricultural** areas were located in Municipality of Butnan 335.59 km^2 then Benghazi 206.51 km^2 and Marj 219.44 km^2,

The largest share of agricultural areas in the total area were also recorded in Butnan (20.27%) then Benghazi (18.52%) and Marj (13.26) from the total area.

The largest areas of forest and **semi-natural land** were recorded in Municipality of Sirte 3169.39 km^2 followed by Al-Wahat 2036.88 km^2 then Butnan 1824.29 km^2,

The largest share of forest and semi-natural areas in the total area were recorded in Municipality of Sirte (21.91%) followed by Al-Wahat (14.08%) then Butnan (12.61%).

2021		built-up	agricultural	forest-seminatural	waterbodies	wetlands
Libya	Area in km 2	1138.16	1655.23	14462.95	72.58	85.61
	% in coastal zone	6.54	9.50	83.05	0.42	0.49
Tripoli	Area in km 2	248.50	56.85	193.58	0.86	0.12
	% in coastal zone	21.83	3.43	1.34	1.19	0.14
Jafara	Area in km 2	93.72	52.26	117.96	0.29	0.01
	% in coastal zone	8.23	3.16	0.82	0.40	0.01
Zawiya	Area in km 2	78.61	30.17	90.32	0.30	0.00
	% in coastal zone	6.91	1.82	0.62	0.41	0.00
Surman	Area in km 2	25.80	4.30	39.22	0.07	0.02
	% in coastal zone	2.27	0.26	0.27	0.09	0.02
Nuqat al Khams	Area in km 2	101.69	27.84	889.32	5.95	19.97
	% in coastal zone	8.93	1.68	6.15	8.19	23.33
Murqub	Area in km 2	90.54	165.00	637.72	1.10	0.03
	% in coastal zone	7.96	9.97	4.41	1.51	0.03
Bani Walid	Area in km 2	222.95	153.22	1487.78	8.66	33.72
	% in coastal zone	19.59	9.26	10.29	11.94	39.39
Sirte	Area in km 2	42.93	148.42	3169.39	20.22	3.03
	% in coastal zone	3.77	8.97	21.91	27.86	3.54
Al Wahat	Area in km 2	14.65	11.44	2036.88	12.99	2.18
	% in coastal zone	1.29	0.69	14.08	17.90	2.55
Benghazi	Area in km 2	137.29	306.51	1214.43	15.12	15.25
	% in coastal zone	12.06	18.52	8.40	20.83	17.82
Marj	Area in km 2	3.46	219.44	613.14	1.14	0.06
	% in coastal zone	0.30	13.26	4.24	1.56	0.07
Jabal al Akhdar	Area in km 2	6.75	33.24	549.95	0.92	1.02
	% in coastal zone	0.59	2.01	3.80	1.26	1.20
Derna	Area in km 2	25.01	110.94	1598.98	3.17	7.52
	% in coastal zone	2.20	6.70	11.06	4.36	8.79
	Area in km 2	46.26	335.59	1824.29	1.80	2.67
Butnan	% in coastal zone	4.06	20.27	12.61	2.49	3.12

Table 5. Areas of CI 25 land use classes in the coastal zones and their percentage, year 2021

The largest areas of **water bodies** (dam) were located in Municipality of Sirte 20.22 km^2 followed by Benghazi 15.12 km^2 then Al-Wahat 12.99 km^2, the largest share of water bodies in the total area were recorded in Sirte (27.86% %) and followed by Benghazi (20.83%) then Al-Wahat (17.90%).

The largest areas of **wetlands** were located in Municipality of Bani Walid 33.72 km^2, followed by Nuqat al Khams 19.97 km^2 then Benghazi 15.25 km^2 then The largest share of wetlands in the total area were also recorded in Bani Walid (39.39%) followed by Nuqat al Khams (23.23%) then Benghazi (17.82%).

3.3.1.1. Built-up area in coastal zone

The total area of built-up area in the coastal zone (1) of Libya is 1138.16 km^2, which represents 6.54 % of built-up area in the coastal zone (2) (Tab. 5). About 1/2 of built-up area in Libya coastal zone is located within two coastal municipality Tripoli and Bani Walid and the remaining third in the other coastal municipalities.

The most built-up areas in the narrowest coastal zone (0 - 300 meters) was located in Municipality of Tripoli (9.1km^2), followed by Bani Walid (5.1 km^2) and Benghazi (4.1km^2). Share of built-up areas in the narrowest coastal zone in the total coastal zone (Table 6) in 2021 was 3.9 %. It is interesting to point out that the largest share of built-up areas in the narrowest coastal zone was recorded in municipality of Derna (14.0 %), followed by Al Wahat (12.3 %) and Jabal al Akhdar (10.8%) (Figure 12). The most built-up areas in the coastal zone 300 m – 1 km was also located in municipality of Bani Walid (16.3 km^2), followed Sirte (12.2 km^2) and municipality of Nuqat al Khams (10.0 km^2). But the largest share of built-up areas in the coastal zone 300 m – 1 km was also in municipality of Jabal al Akhdar (36.4 %), and also followed by Derna (33.4 %) and Al Wahat (29.7 %).

Administrative	Coastal strips built up			Coastal zone	Coastal strips			Coastal zone
	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km
	Areas in km2				% of c. strips within c. zone (0m - 10 km)			
Tripoli	9.1	24.0	215.5	248.5	3.6	9.6	86.7	100
Jafara	3.7	8.5	81.5	93.7	3.9	9.1	87.0	100
Zawiya	2.4	5.9	70.2	78.6	3.1	7.6	89.4	100
Surman	0.4	0.7	24.7	25.8	1.5	2.9	95.6	100
Nuqat al Khams	3.8	10.0	87.9	101.7	3.8	9.8	86.4	100
Murqub	3.2	9.1	78.3	90.5	3.5	10.0	86.5	100
Bani Walid	5.1	16.3	201.5	222.9	2.3	7.3	90.4	100
Sirte	3.6	12.2	27.2	42.9	8.4	28.4	63.3	100
Al Wahat	1.8	4.4	8.5	14.6	12.3	29.7	58.0	100
Benghazi	4.1	9.2	124.0	137.3	3.0	6.7	90.3	100
Marj	0.2	0.6	2.7	3.5	5.0	17.8	77.2	100
Jabal al Akhdar	0.7	2.5	3.6	6.7	10.8	36.4	52.8	100
Derna	3.5	8.4	13.1	25.0	14.0	33.4	52.5	100
Butnan	2.6	8.1	35.5	46.3	5.7	17.6	76.8	100
Total	44.2	119.9	974.1	1138.2	3.9	10.5	85.6	100

Table 6. Land use/cover (built –up) classes for year 2021 in km^2 and percentage for coastal strips

The most built-up areas in the coastal zone 1 – 10 km was recorded in municipality of Tripoli (215.5 km^2), followed by Bani Walid (201.5km^2) and in municipality of Benghazi (124.0 km^2) (Fig. 10). The largest share of built-up areas in the coastal zone 1 – 10 km in regard to the total coastal zone was recorded in municipality of Bani Walid (90.4 %), followed by municipality of Benghazi (90.3 %) and municipality of Zawiya (89.4 %).

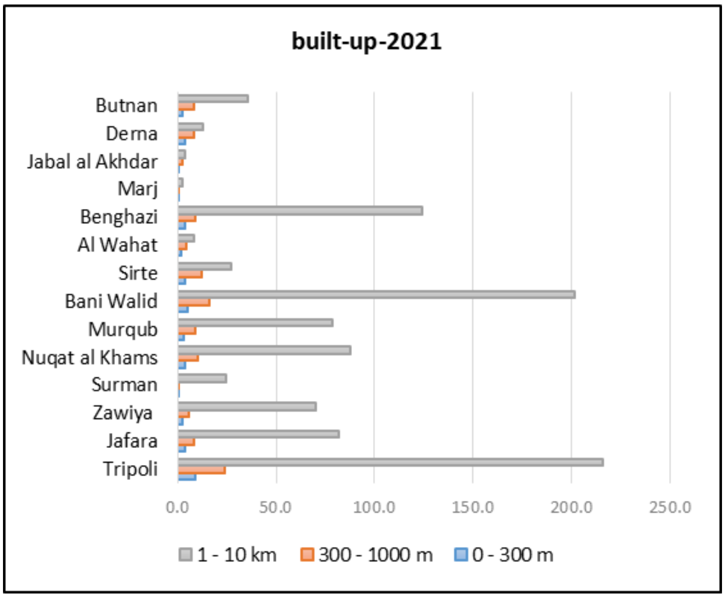


Figure 12. Built-up areas in Libya coastal zones per coastal strips base on ESA World Cover data, 2021

3.3.1.2. Other land cover classes in coastal zone

The structure of the share of other categories of land use at the municipalities' level has already been described earlier in chapter 3.3.1.

Spatial distribution of land use by coastal strips according to the following distribution: Among other categories of land cover in the coastal zone of Libya, the category forest and semi-natural areas comprised the highest % of other land cover classes in the coastal zone (3) in 2021 (83.05%). The main reason for the majority representation of this category of land is the relief and landscape characteristics of Libya and the centuries-old focus on a rural way of life. (Table.7)(Figure.13)

All coastal municipalities have the majority representation of **forest and semi-natural areas**, in the coastal strip 1-10 km, while municipalities that stand out significantly above the average of the entire coastal zone (89.2 %) are municipality of Jafara (91.1%) and Sirte (90.5 %).

Administrative	Coastal strips forest seminatural2021			Coastal zone	Coastal strips			Coastal zone
	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km
	Areas in km2				% of c. strips within c. zone (0m - 10 km)			
Tripoli	8.9	12.9	171.8	193.6	4.6	6.7	88.7	100
Jafara	3.4	7.1	107.5	118.0	2.9	6.0	91.1	100
Zawiya	3.9	7.8	78.6	90.3	4.3	8.6	87.0	100
Surman	1.5	3.4	34.3	39.2	3.9	8.6	87.5	100
Nuqat al Khams	31.4	62.8	795.1	889.3	3.5	7.1	89.4	100
Murqub	24.3	49.0	564.4	637.7	3.8	7.7	88.5	100
Bani Walid	53.6	112.3	1321.9	1487.8	3.6	7.5	88.8	100
Sirte	96.8	205.0	2867.6	3169.4	3.1	6.5	90.5	100
Al Wahat	58.2	137.1	1841.6	2036.9	2.9	6.7	90.4	100
Benghazi	49.2	99.7	1065.5	1214.4	4.1	8.2	87.7	100
Marj	23.3	42.5	547.4	613.1	3.8	6.9	89.3	100
Jabal al Akhdar	19.0	34.9	496.1	550.0	3.5	6.3	90.2	100
Derna	56.6	120.3	1422.1	1599.0	3.5	7.5	88.9	100
Butnan	81.1	156.3	1586.9	1824.3	4.4	8.6	87.0	100
Total	511.3	1051.1	12900.6	14463.0	3.5	7.3	89.2	100

Table 7. Land use/cover classes (Forest/semi- natural) for year 2021 in km^2 and percentage for coastal strips

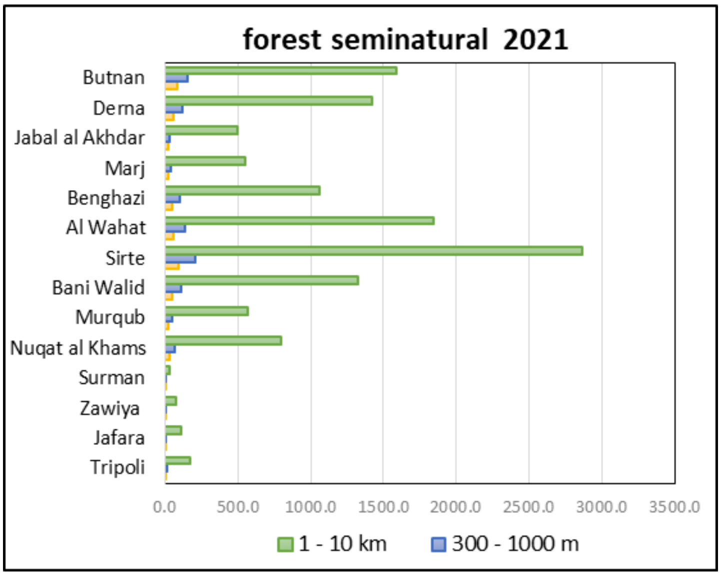


Figure:13. Forest/semi-natural areas in Libya coastal zones per coastal strips base on ESA World Cover data, 2021

Share of **agricultural** land in the narrowest coastal strip (0-300 m) in 2021 for the entire Libyan coastal zone was (0.5%) while county that stands out significantly above the average of the entire coastal zone is municipality of Marj (0.8 %).(table.8)(Figure.14)

Administrative	Coastal strips agricultural-2021			Coastal zone	Coastal strips			Coastal zone
	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km
	Areas in km2				% of c. strips within c. zone (0m - 10 km)			
Tripoli	0.3	2.3	54.2	56.9	0.5	4.1	95.4	100
Jafara	0.0	1.1	51.1	52.3	0.1	2.1	97.8	100
Zawiya	0.0	1.4	28.7	30.2	0.1	4.7	95.2	100
Surman	0.0	0.1	4.2	4.3	0.0	2.8	97.2	100
Nuqat al Khams	0.0	0.9	26.9	27.8	0.1	3.3	96.5	100
Murqub	0.9	6.6	157.5	165.0	0.6	4.0	95.5	100
Bani Walid	0.5	3.2	149.6	153.2	0.3	2.1	97.6	100
Sirte	1.6	13.3	133.6	148.4	1.1	8.9	90.0	100
Al Wahat	0.0	0.1	11.3	11.4	0.1	0.7	99.2	100
Benghazi	0.5	6.1	300.0	306.5	0.2	2.0	97.9	100
Marj	1.7	16.3	201.5	219.4	0.8	7.4	91.8	100
Jabal al Akhdar	0.4	5.4	27.5	33.2	1.1	16.1	82.8	100
Derna	0.6	3.7	106.6	110.9	0.6	3.3	96.1	100
Butnan	1.1	7.5	327.0	335.6	0.3	2.2	97.4	100
Total	7.6	67.8	1579.8	1655.2	0.5	4.1	95.4	100

Table 8. Land use/cover classes (agricultural areas) for year 2021 in km2 and percentage for coastal strips

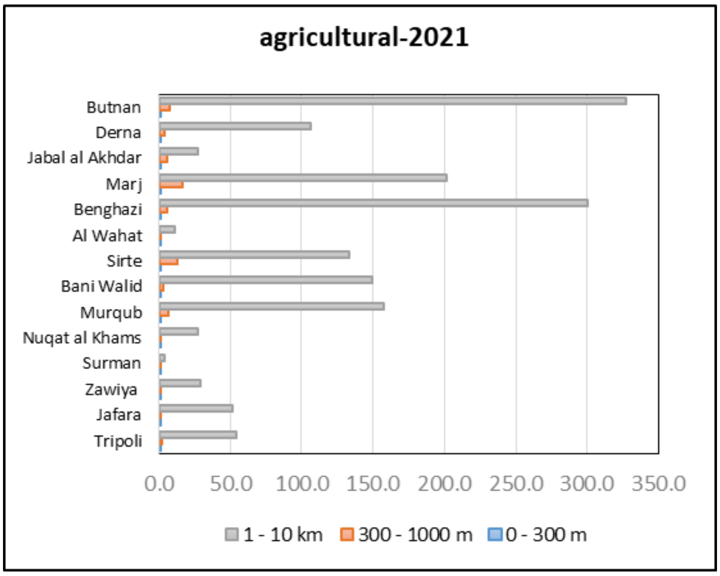


Figure:14. Agricultural areas in Libya coastal zones per coastal strips base on ESA World Cover data, 2021

Share of **waterbodies** in the narrowest coastal strip (0-300 m) in 2021 for the entire Libya coastal zone was 20.7 % while municipalities that stand out significantly above the average of the entire coastal zone are municipality of Surman (100.0 %) and municipality of Zawiya & Marj (99.4%) then municipality of Murqub (98.3%).(Table.9)(Figure.15)

Administrative	Coastal strips waterbodies-2021			Coastal zone	Coastal strips			Coastal zone
	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km
	Areas in km2				% of c. strips within c. zone (0m - 10 km)			
Tripoli	0.7	0.0	0.1	0.9	84.6	5.1	10.3	100
Jafara	0.3	0.0	0.0	0.3	87.4	0.0	12.6	100
Zawiya	0.3	0.0	0.0	0.3	99.4	0.0	0.6	100
Surman	0.1	0.0	0.0	0.1	100.0	0.0	0.0	100
Nuqat al Khams	1.1	0.1	4.7	5.9	18.2	2.0	79.8	100
Murqub	1.1	0.0	0.0	1.1	98.3	1.7	0.1	100
Bani Walid	1.0	0.4	7.2	8.7	11.3	5.1	83.6	100
Sirte	2.1	6.9	11.2	20.2	10.5	34.1	55.5	100
Al Wahat	1.4	0.7	10.9	13.0	11.1	5.0	83.9	100
Benghazi	2.0	3.8	9.3	15.1	13.2	25.2	61.7	100
Marj	1.1	0.0	0.0	1.1	99.4	0.1	0.5	100
Jabal al Akhdar	0.5	0.4	0.0	0.9	59.0	41.0	0.0	100
Derna	1.7	1.4	0.0	3.2	55.1	43.6	1.3	100
Butnan	1.5	0.3	0.0	1.8	85.4	13.9	0.7	100
Total	15.0	14.0	43.6	72.6	20.7	19.3	60.1	100

Table 9. Land use/cover classes (water bodies) for year 2021 in km2 and percentage for coastal strips

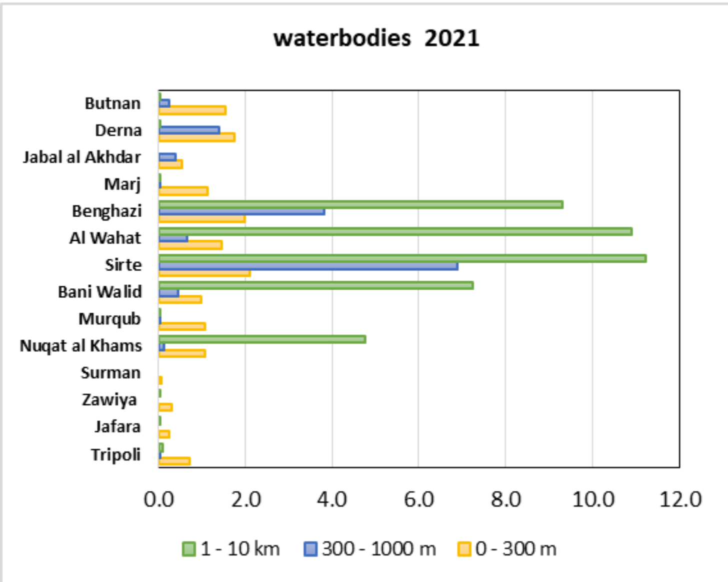


Figure:15. (Water bodies) in Libya coastal zones per coastal strips base on ESA World Cover data, 2021

Share of wetlands in the narrowest coastal strip (0-300 m) in 2021 for the entire Libya coastal zone was 7.2 % while municipalities that stand out significantly above the average of the entire coastal zone are municipality of Jafara (100.0%) and municipality of Murqub (98.8 %). See (Table.10)(Figure.16)

Administrative	Coastal strips wetlands-2021			Coastal zone	Coastal strips			Coastal zone
	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km
	Areas in km2				% of c. strips within c. zone (0m - 10 km)			
Tripoli	0.07	0.03	0.02	0.12	59.2	23.6	17.3	100
Jafara	0.01	0.00	0.00	0.01	100.0	0.0	0.0	100
Zawiya	0.00	0.00	0.00	0.00	94.9	0.0	5.1	100
Surman	0.01	0.00	0.00	0.02	86.9	0.0	13.1	100
Nuqat al Khams	1.06	0.18	18.72	19.97	5.3	0.9	93.8	100
Murqub	0.03	0.00	0.00	0.03	98.8	1.2	0.0	100
Bani Walid	0.22	4.16	29.35	33.72	0.6	12.3	87.0	100
Sirte	0.06	0.37	2.59	3.03	2.1	12.3	85.7	100
Al Wahat	0.03	0.05	2.10	2.18	1.6	2.2	96.2	100
Benghazi	0.34	5.15	9.76	15.25	2.2	33.8	64.0	100
Marj	0.06	0.00	0.00	0.06	97.6	2.4	0.0	100
Jabal al Akhdar	0.24	0.79	0.00	1.02	23.3	76.7	0.0	100
Derna	3.04	2.62	1.86	7.52	40.4	34.9	24.7	100
Butnan	0.95	1.08	0.64	2.67	35.8	40.4	23.9	100
Total	6.1	14.4	65.0	85.6	7.2	16.9	76.0	100

Table 10. Land use/cover classes (wetland) for year 2021 in km2 and percentage for coastal strips

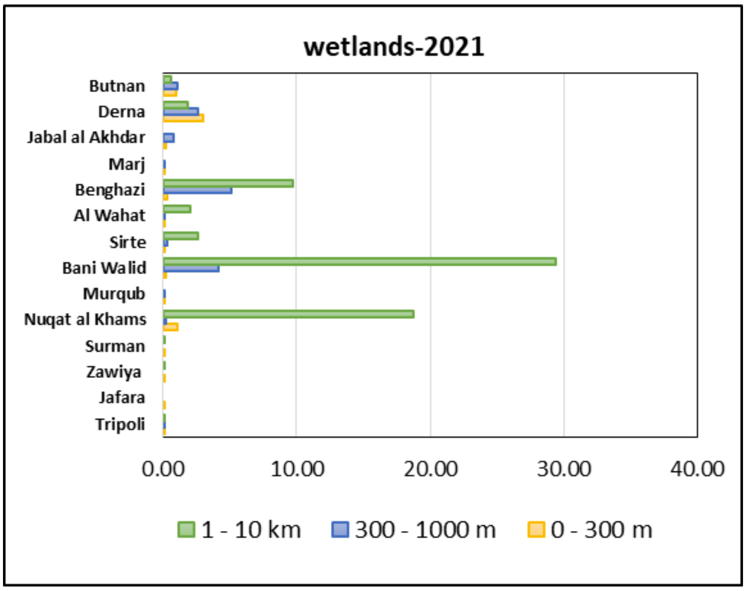


Figure:16. (wetland) in Libya coastal zones per coastal strips base on ESA World Cover data, 2021

Regarding indicator parameter % of other land cover classes within coastal strips of different width compared to wider coastal units (5), the largest share of agricultural areas (95.4 %) and forest and semi-natural areas (89.2 %) as expected, is found in the largest coastal (spatial) strip of 1 - 10 km.

The previous tables shows the area and percentage of each classification in each Coastal Strips and the percentage of representation of this classification in the total area of the Coastal Strips, Forest-seminatural constitutes 87.5% and its area is 511 km^2 of the

area of coastal strips 0-300 m. The length of the coast for all municipalities is 584.17 km^2, the area of built-up is 44.2 km^2, and its percentage of the total area is 7.6%.
As for Coastal strips 300-1000 m, forest-seminatural constitutes 82.9% and its area is 105.11 km^2 of the area of Coastal strips 0-300 m, which is 1267.15 km^2, and the built-up area is 44.2 km^2 and its percentage of the total area is 7.6%

3.3.1.3. Low elevation coastal zones

Low Elevation Coastal Zone (LECZ) is an additional analytical unit proposed by Baučić et al. (2022) LECZ is constructed from Copernicus DEM 30 m resolution as an area contiguous to the coast, below the threshold of 5 m above sea level (ASL) and within the coastal zone of 10 km width.
In the Libyan coastal zone area there is 4271.66 km^2 of LECZ (7), covering even 24.5 % of entire coastal zone.

Administrative unit	Coastal zone (CZ) - 0-10 km [km²]	Low Elevation Coastal Zone (LECZ) [km²]	Percentage of LECZ within CZ
Libya	17414.53	4271.66	24.53%
Tripoli	499.92	17.14	0.06%
Jafara	264.24	1.15	0.02%
Zawiya	199.41	1.24	0.03%
Surman	69.40	0.89	0.56%
Nuqat al Khams	1044.76	786.98	74.82%
Murqub	894.38	14.20	0.42%
Bani Walid	1906.33	1171.00	60.94%
Sirte	3383.99	742.52	5.46%
Al Wahat	2078.14	961.01	45.89%
Benghazi	1688.59	362.43	21.41%
Marj	837.24	14.14	0.52%
Jabal al Akhdar	591.88	13.19	1.35%
Derna	1745.62	75.30	0.76%
Butnan	2210.62	110.46	0.00%

Table 11. LECZ areas in different administrative units and their percentages within 0- 10 km

The largest areas under the LECZ are located in the municipality of Bani Walid (1171.0 km^2) and then municipality of Al Wahat (961.0 km^2), and the highest share of LECZ in total area is recorded in municipality of Nuqat al Khams (74.82 %).

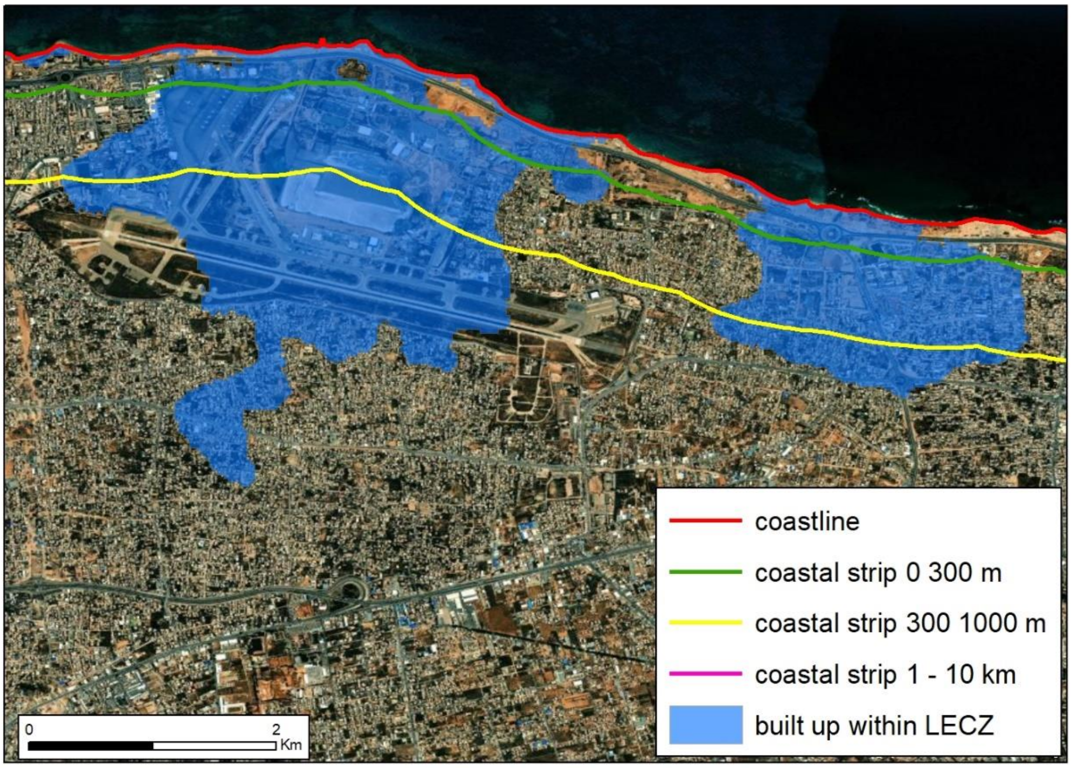


Figure16: Built-up area within LECZ area – Municipality of Tripoli 2021

In the coastal zone of Libya in 2021 there was 140.237 km^2 of built-up area within LECZ (8) (Tab. 12; Fig. 16), which represents the (3.28 %) area within LECZ that is covered by built-up (9). The highest share of built-up area within LECZ in 2021 was recorded in municipality of (%52,78) Tripoli.

The largest built-up areas under the LECZ are located in the municipality of Bani Walid (59.09 km2) and Nuqat al Khams (32.424 km^2) (table.12)

The largest built-up areas under the LECZ in the narrowest coastal strip (0-300 m) are located in the municipality of Tripoli (3.956 km^2) and Benghazi (3.586 km^2) (Fig. 17)

In Libya coastal zone, the most built-up areas within LECZ in 2021 were located in the coastal strip 1-10 km (92.224 km^2).

Administrative unit	Built-up in different coastal strips in LECZ [km²]			Built-up in LECZ [km²]
	0 - 300 m	300 - 1000 m	1 - 10 km	
Libya	20.948	27.065	92.224	140.237
Tripoli	3.956	2.913	2.180	9.049
Jafara	0.374	0.000	0.000	0.374
Zawiya	0.304	0.000	0.000	0.304
Surman	0.108	0.001	0.000	0.110
Nuqat al Khams	2.906	6.083	23.437	32.427
Murqub	1.706	0.351	0.083	2.140
Bani Walid	2.985	4.513	51.594	59.092
Sirte	1.611	5.395	4.435	11.441
Al Wahat	1.481	2.131	1.648	5.261
Benghazi	3.586	5.130	8.603	17.319
Marj	0.125	0.013	0.000	0.138
Jabal al Akhdar	0.256	0.051	0.000	0.307
Derna	0.845	0.070	0.228	1.143
Butnan	0.703	0.413	0.014	1.131

Table 12. Built-up areas [km²] within LECZ by coastal strips and administrative units

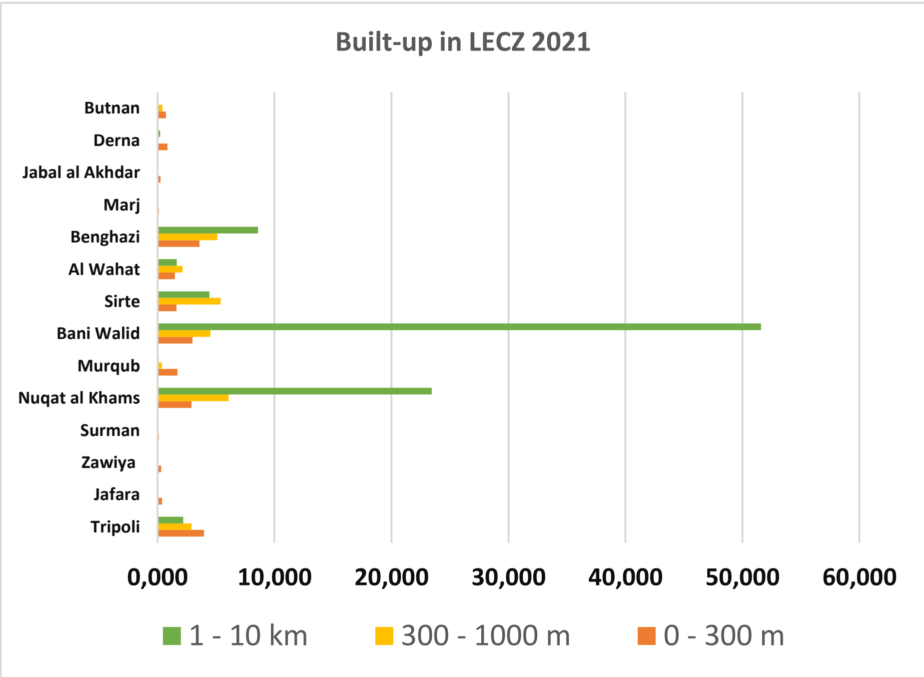


Figure 17. Built-up areas in Libya coastal zones per coastal strips within LECZ

The largest share within (%) other land cover classes within LECZ (11) is occupied by forest and semi-natural areas (91.9 %) , 3927.56 km^2 , followed by built-up areas (3.28 %), 140.24 km^2 (Table. 13). The largest areas of forest and semi-natural under the LECZ are located in the municipality of Bani Walid (1061.56 km^2), also an built-up areas (59.09 km^2), wetlands (33.69 km^2) but the largest areas of water bodies (18.21 km^2) Located in municipality of Sirte.

Administrative unit	Low Elevation Coastal Zone (LECZ) 2021[km²]					Total [km²]	built\LEZ
	built-up	agricultural	forest-seminatural	waterbodies	wetlands		
Libya	**140.24**	**52.31**	**3927.56**	**66.54**	**85.25**	**4271.66**	**3.28 %**
Tripoli	9.05	0.28	7.16	0.56	0.10	17.15	52.75 %
Jafara	0.37	0.00	0.62	0.14	0.01	1.15	32.57 %
Zawiya	0.30	0.00	0.77	0.16	0.00	1.24	24.45 %
Surman	0.11	0.00	0.72	0.05	0.01	0.89	12.31 %
Nuqat al Khams	32.43	8.06	720.94	5.70	19.88	787.00	4.12 %
Murqub	2.14	0.68	10.65	0.72	0.03	14.22	15.06 %
Bani Walid	59.09	8.43	1061.56	8.27	33.69	1171.04	5.05 %
Sirte	11.44	8.77	701.18	18.21	2.97	742.56	1.54 %
Al Wahat	5.26	2.50	938.47	12.65	2.17	961.04	0.55 %
Benghazi	17.32	8.83	306.56	14.52	15.22	362.46	4.78 %
Marj	0.14	1.84	11.33	0.79	0.05	14.14	0.98 %
Jabal al Akhdar	0.31	1.28	9.80	0.79	1.01	13.20	2.33 %
Derna	1.14	2.58	61.41	2.72	7.47	75.32	1.52 %
Butnan	1.13	9.05	96.39	1.26	2.65	110.48	1.02 %

Table 13. Land use / land cover classes in the LECZ

3.3.1.4. Protected areas in coastal zone

In the Libya coastal zone in 2021, there was 194.95 km^2 of protected areas, which covers 1.119 % of the area of the coastal zone. The most protected areas in the Libyan coastal zone for the year 2021 were located in the municipality of Al-Jabal Al-Akhdar, and the second municipality in terms of coverage-protected areas was the municipality of Marj (Table 14).

Administrative unit		protected areas	Non-protected areas	Coastal zone 0-10 km²
Libya	**Area in km 2**	194.95	**17219.583**	**17414.530**
	% in coastal zone	**1.119**	**98.881**	**100**
Tripoli	Area in km 2	0.0	499.9	499.9
	% in coastal zone	0.0	100.0	100.0
Jafara	Area in km 2	0.0	264.2	264.2
	% in coastal zone	0.0	100.0	100.0
Zawiya	Area in km 2	0.0	199.4	199.4
	% in coastal zone	0.0	100.0	100.0
Surman	Area in km 2	0.0	69.4	69.4
	% in coastal zone	0.0	100.0	100.0
Nuqat al Khams	Area in km 2	0.0	1044.8	1044.8
	% in coastal zone	0.0	100.0	100.0
Murqub	Area in km 2	3.5	890.9	894.4
	% in coastal zone	0.4	99.6	100.0
Bani Walid	Area in km 2	0.0	1906.3	1906.3
	% in coastal zone	0.0	100.0	100.0
Al Wahat	Area in km 2	0.0	3384.0	3384.0
	% in coastal zone	0.0	100.0	100.0
Sirte	Area in km 2	0.0	2078.1	2078.1
	% in coastal zone	0.0	100.0	100.0
Benghazi	Area in km 2	0.0	1688.6	1688.6
	% in coastal zone	0.0	100.0	100.0
Marj	Area in km 2	87.9	749.3	837.2
	% in coastal zone	10.5	89.5	100.0
Jabal al Akhdar	Area in km 2	103.5	488.4	591.9
	% in coastal zone	17.5	82.5	100.0
Derna	Area in km 2	0.0	1745.6	1745.6
	% in coastal zone	0.0	100.0	100.0
Butnan	Area in km 2	0.0	2210.6	2210.6
	% in coastal zone	0.0	100.0	100.0

Table 14. Protected areas at municipality level in year 2021

Looking at the narrowest coastal strip 0-300 m, it has 3.46 km^2 of protected areas or (1.77 %) within the coastal zone. By absolute number, municipality of Al-Jabal Al-Akhdar has the largest protected area in the narrowest strip of 2.17 km^2. Also, the Municipality of Al-Jabal Al-Akhdar represents (2.10%) of the protected areas within the narrowest coastal strip (Table 15).

Administrative unit	Coastal strips			Coastal zone	Coastal strips			Coastal zone
	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km	0 - 300 m	300 - 1000 m	1 - 10 km	0 - 10 km
	Areas in km2				% of c. strips within c. zone (0m - 10 km)			
Libya	3.46	10.12	181.37	194.95	1.77	5.19	93.04	100
Murqub	0.00	0.10	3.46	3.46	0.00	2.84	100.00	100
Marj	1.29	5.44	81.20	87.93	1.46	6.19	92.35	100
Jabal al Akhdar	2.17	4.58	96.71	103.46	2.10	4.43	93.48	100

Table 15. Protected areas in km2 and percentages in the coastal strips per year 2021

4. Discussion

By calculating the key components of CCI 25 from open spatial data sets, an insight into the state of the environment of the coastal area of Libya for 2021 was obtained (Tab. 16). Some of the most significant determinants of the coastal environment of Libya in 2021 are:

- share of built-up area in coastal zone is **6.54 %**
- share of built up area within the narrowest coastal strip (0-300 m) is **3.9 %**
- forest and semi-natural areas is most widespread land class in coastal zone of with **83.05 %** share
- 4271.66 km^2 is located in LECZ, 140.24 km^2 of which are built-up areas (3.28 %)

Table 16. Summary overview of CCI 25 indicators units for Libya – year 2021

CCI 25 FOR LIBYA – YEAR 2021			
Indicator unit	Value (coastal zone)	Highest share / value	Administrative unit
1. km^2 of built-up area in the coastal zone	1138.2 km^2	248.5 km^2	Tripoli
2. % of built-up area in coastal zone	6.54 %	21.83 %	Tripoli
3. % of built up area within the narrowest coastal strip (0-300 m)	3,9 %	14..0 %	Derna
4. % of other land cover classes in coastal zone	Forest and semi-natural 83.05 %	Forest and semi-natural 3169.39 km^2	Sirte
7. km^2 of LECZ	4271.66 km^2	1171.00 km^2	Bani Walid
8. km^2 of built-up area within LECZ	140.24 km^2	59.09 km^2	Bani Walid
9. % of built-up area within LECZ	3.28 %	52.78 %	Tripoli
11. % of other land cover classes within LECZ	Forest and semi-natural 91.94 %	Forest and semi-natural 24.85 %	Bani Walid
6. km^2 of protected areas within coastal zone	194.95 km^2	103.46 km2	Jabal al Akhdar

The fundamental spatial factor of land use distribution is relief, due to which the most represented land use category is forest and semi-natural areas. The relief also greatly affects the population density of the area in question, which is much lower compared to the national average.

The most vulnerable spatial zones in the context of the GES are municipality of Bani Walid and Nuqat al Khams, on whose territories are the largest areas of the built-up area (in the LECZ zone).

The latest population census data for Libya indicate an increase in the population of the Libyan coastal municipality mentioned in the report, especially (the municipality of Tripoli "the capital city " and the municipality of Benghazi), for various reasons as a result of the recent circumstances after 2011.

The economic importance of the Libyan coastal zone gradually increases, leading to an increase in pressure for urbanization and development. This growing interest results in production of artificial modifications, often irreversible and leading to negative side-effects on the ecological and sociological aspects of the coastal zone. Onwards, 19.95% of the share of low-lying areas in Libyan coastal zone, in the context of climate change and still its uncertain impacts, presents a challenge for future planning and management of coastal zones. New risks will be imposed over built-up and natural areas, also indirect ones such as Caused by oil pollution, marine litter, untreated sewage, seawater intrusion, unplanned urban expansion, desertification and declining vegetation cover and some of coastal storm of built-up areas.

As there are various geographic, socio-economic, cultural and environmental contexts, particular coastal zone regions should apply various measures and actions to achieve GES. In order to define GES in a more objective way a sort of a technical manual should be prepared that will allow better understanding of concepts of integrity and diversity of coastal ecosystems and landscapes and their importance for the ecosystem approach. Some of the guidelines that should be followed in order to achieve GES are

- no further construction within the setback zone and low-lying terrain;
- change of coastal land use structure, dominance of urban land use reversed;
- keep, and increase, where needed, landscape diversity.
- Particular management actions regarding land cover change could include:
- analysis of existing built-up areas and their categorization into those that are necessary, those that can be reduced and those that can be returned to nature (e.g. abandoned industrial zones, etc).
- when planning new built-up areas, first analyse whether human needs can be achieved through better management of existing built-up areas and their functional transformations.

- in existing built-up areas: improve monitoring of environmental impacts and implement measures to reduce negative impacts (such pollution, habitat fragmentation, noise, light pollution, water cycle)
- for new construction areas, examine the use of nature-based solutions and ensure financial or other benefits for their implementation
- encouraging the use of space in a way that consumes spatial/natural resources as little as possible: e.g. restricting land-take for the so called “secondary” housing
- protect, restore, conserve and enhance threatened coastal habitats.

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