3.2 ANDALUSIA, BIO PHYSICAL BASELINE

The Andalusia region is roughly situated between coordinates 36° 00’ - 38° 44’ N and 1° 30’ - 7° 45’ W, to the south it is bordered by the Atlantic Ocean and the Mediterranean Sea, by Portugal to the west, and by the autonomous communities of Extremadura and Castilla-La Mancha to the north and Murcia to the east (Figure 3-11). Andalusia consists of eight provinces. Currently, about half of the region is natural areas and between 40 and 45% is used for agriculture. Urban areas and open water surfaces each cover approximately 3% of the area (Figure 3-5; Bermejo et al., 2011). Most of natural vegetation is Mediterranean forest which is dominated by trees such as oaks, pines and firs, with dense riparian forests, and Mediterranean shrub land. Agriculture in Andalusia has traditionally been based on cereals, olive trees and vineyards but in modern decades, traditional crops have been replaced with various intensive and extensive crops (e.g., sunflower, rice, cotton and sugar beet).

3.2.1 CLIMATE

Andalusia is one of the warmest parts of Europe, with an average temperature of 16 °C and monthly temperatures varying between January (6.4 °C in Granada) and July and August (28.5 °C in Córdoba and Seville). Figure 3-12 shows the climate zones.
In Andalusia, as classified by De Martonne (1926; Table 3-3), it shows that the general climate of Andalusia is a Mediterranean climate type even though it varies depending on the specific climatic parameters of the 62 weather stations. Almería province (in the south east of Andalusia) has arid and semi-arid climate conditions, while Málaga and Cádiz (in the south) have semi-humid, humid and very-humid climate types. The data used for calculation of climate areas show limited variation of average temperature, as recorded in weather stations (varying between 14,2 and 17 °C). In contrast, there is a significant variation in annual mean precipitation (varying between 275 and 1074 mm).

According to climatic calculations using the climate data base of MicroLEIS DSS (CDBm), Huércal Overa station (AL02), Almería is the most arid location in the study area, with an annual rainfall of 275 mm, a mean temperature of 17 °C, and potential evapotranspiration of 882.9 mm which results in an average of 10 arid
months (in which the potential evapotranspiration exceeds the actual precipitation) per year. The most humid area, on the other hand, is Gaucín (MA05) in Málaga, with an annual rainfall of 1170 mm, a mean temperature of 14.9 °C, and potential evapotranspiration of 771.7 mm, which results in, on average, 5 arid months per year (Figure 3-13).

Table 3-3. Classification of climate types according to the aridity index by De Martonne (1926): \( I = \frac{P}{(T+10)} \) with: \( I \): index, \( P \): annual rainfall (mm), and \( T \): mean temperature (°C).

<table>
<thead>
<tr>
<th>Climate type</th>
<th>Aridity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arid</td>
<td>0 - 10</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>20 - 24</td>
</tr>
<tr>
<td>Semi-humid</td>
<td>24 - 28</td>
</tr>
<tr>
<td>Humid</td>
<td>28 - 35</td>
</tr>
<tr>
<td>Very humid</td>
<td>35 - 55</td>
</tr>
<tr>
<td>Extremely humid</td>
<td>&gt; 55</td>
</tr>
</tbody>
</table>

Figure 3-13. Graphical representation of climate conditions of weather stations MA05 (Gaucín, Málaga) and AL02 (Huércal Overa, Almería). (P) precipitation; (Tm) monthly mean temperature; (ET\(_0\)) potential evapotranspiration; (AR\(_i\)) arid months in which the actual precipitation is lower than the potential evapotranspiration. Source: Spanish Meteorological Agency (AEMET, 2011).
3.2.2 GEOLOGY

According to Vera, (1994), Andalusia is divided into three main geological units (Figure 3-14). First, the northern part consists of Sierra Morena, a crystalline massif which is very ancient (Paleozoic), that was part of the Armorica continent. The second part is represented by the Neogene tectonic basin of the Guadalquivir (formed from the Langhian until present day). The third geological feature (in the south east) is the Baetic cordillera (Triassic-Lower Miocene), which is the westernmost part of the European Alpine chain.

![Classes of lithology synthesis in Andalusia.](image-url)
This mountainous area is the result of a series of tectonic movements of the African and Eurasian plates and continues to be an active seismic zone (García-Castellanos et al., 2002).

The geological map of Andalusia (Project SIMANCTEL, 2006) includes 20 lithological classes (Figure 3-14), distributed within the three large units at regional scale. The Iberian Massif (Sierra Morena) is constituted by: marginal recent fluvial deposits (Quaternary); ancient fluvial deposits in the northern part (Plio-Pleistocene); limestone, dolomite, greywacke, shale, sandstone and conglomerate (Precambrian-Paleozoic); sedimentary and metamorphic rocks (Precambrian-Paleozoic); sedimentary and igneous rocks (Precambrian-Paleozoic); acid igneous rocks; basic igneous rocks; undifferentiated igneous rocks; slate, sandstone and quartzite (Paleozoic-Triassic); schists (Precambrian-Paleozoic-Triassic); undifferentiated metamorphic rocks.

The Guadalquivir basin is primarily constituted by recent sedimentary rocks: estuarine deposits (Quaternary); aeolian deposits (Quaternary); recent fluvial deposits (Quaternary); old fluvial deposits (Plio-Pleistocene); sandstone (Pliocene); limestone (upper Miocene-Pliocene).

The Betic Range is constituted by: recent fluvial deposits (Quaternary); ancient fluvial deposits (Plio-Pleistocene); sandstone (Pliocene); limestone (upper Miocene-Pliocene); marl rocks rocks (Paleogene-Miocene); sandstone, argillaceous rocks and marls (flysch and turbidites) (Cretaceous-Paleogene-Miocene); limestone and carbonate eminently rocks (Jurassic-Cretaceous-Paleogene); variegated clays, marl, sandstone, siltstone, conglomerate, gypsum and limestone (Triassic); argillite, marl, sandstone, turbidite, dolomite and limestone (Mesozoic-Paleogene); limestone, dolomite, greywacke, shales, sandstone and conglomerate (Precambrian-Paleozoic); sedimentary and metamorphic rocks (Precambrian-Paleozoic); sedimentary and igneous rocks (Precambrian-Paleozoic); acid igneous rocks; basic igneous rocks; undifferentiated igneous rocks; slate, sandstone and quartzite (Paleozoic-Triassic); schists (Precambrian-Paleozoic-Triassic); undifferentiated metamorphic rocks.

3.2.3 TOPOGRAPHY
In general, Spain is a very mountainous country, with an average elevation of 660 meter above sea level (masl) (the second highest in Europe after Switzerland; Benet, 2006). As a result of the geological history of Andalusia, topography is one of the major factors shaping the natural environment and land use.
According to the digital elevation model, the elevation values vary from 0 (coastline and Guadalquivir River basin) to 3478 masl (Baetic Range and Sierra Morena; Figure 3-15).

Slope gradients affects degradation processes as soil erosion rate through many morphological characteristics. Two examples of morphological characteristics are gradient and slope length (Torri, 1996). As shown in Figure 3-16 the slope gradient in Andalusia ranges from <3 to >50 %. The effect of slope aspect on insolation (sun exposure), which may vary between south-facing sunny, and north-facing shaded, slopes. Higher energy inputs in sunny slopes affects the rate of decomposition of organic matter, the thawing rate of snow, potential evapotranspiration and the soil salinity (mostly in arid regions).
Figure 3-16. Slope map of Andalusia.

Figure 3-17. Slope aspect in Andalusia.
Aspect also indirectly affects erosion processes due to decreased vegetation cover in dry, sun-exposed, slopes (Zachar, 1982). Slope aspect in Andalusia is shown in Figure 3-17.

### 3.2.4 GEOMORPHOLOGY

Ten main morphogenesis types are found in Andalusia: fluvio-colluvial, tidal-fluvial, aeolian, denudation, karst, structural, periglacial, volcanic, coastal and submarine.

The Iberian massif is generated by the collision between Laurasia and Gondwana plates since the Late Paleozoic. In the Mesozoic Era, this area was dominated by intense erosion, which led to the development of extensive planation surfaces. Indeed one of the most characteristic features is the presence of extensive piedmont of alluvial deposits composed of siliceous clasts with a reddish argillaceous matrix.

The most striking geomorphologic features in the Iberian Massif are related to the underlying lithology and structure. Particularly, in Sierra Morena mountains, the differential erosion of folded Paleozoic rocks with a contrasting resistance to erosion (e.g. quartzite and slates), has produced a distinctive ‘Appalachian-type’ topography (Gutiérrez et al., 2013).

The Baetic Range represents a mountain belt with high peaks. This chain is affected by considerable convergence (4mm/yr) and tectonic activity. The Baetic may be divided in two principal zones, the inner and the outer zones. The inner zone is dominated by a structurally complex and metamorphosed basement and rocks forming an anticlinal stack. The outer zone is formed by allochthonous south-verging structural units made up of Mesozoic and Cenozoic sedimentary sequences detached from the Paleozoic basement. The Betics chain also includes numerous postorogenic Neogene and Quaternary basins. Most of these basins are related to the north-south compression vectors, currently affected by tectonic inversion. In this area, the main geomorphic factor is tectonic activity, which affected the landscape. The Eastern Betic Range shows examples of fault-controlled mountain front and alluvial fan system. The development may be affected by tectonic activity, climate variability and base level changes. In this area, the evolution of the drainage network, largely guided by postorogenic basins. The study of this basins is important for understand long-term changes in fluvial systems. Limestone karst is well-developed, mostly in the Outer zone, controlled by active faults, karren fields and cave system (Gutiérrez et al., 2013).
The Sorbas basin presents landforms related to Messinian gypsum dissolution, but are also developed on Triassic evaporite.

Evidence of Quaternary glaciations is restricted to the Sierra Nevada. These mountains represent the southernmost glaciated area in Europe, which probably occurred before the global Last Glacial Maximum. The spatial distribution of large landslides in the Betics is mainly controlled by litho-structural factors, active tectonics and fluvial incision (Gutiérrez et al., 2013).

The morphological depressions control the path of the main fluvial system. The most important depression in South Spain is the Guadalquivir basin. This basin represents a foreland basin of Baeticus chain. The East/Northeast, West/Northwest Guadalquivir basin has been open to the sea during its entire evolution. The southern half of the basin is dominated by olistostromes, whereas the northern half is mainly underlain by autochthonous soft marl sediments. The upper and the middle reach of the valley, currently show the rectilinear northern margin of the basin, displays an extensive terrace sequence on the southern margin. In the lower reach, the river splits into several anostomosed channels flowing through marshland separated from the sea by a long spit bar with a large superimposed dune field (Gutiérrez et al., 2013). The Iberian Peninsula shows a very extent and diversity of the coastal environments. The main factors that control the geomorphology and Quaternary geology of the Spanish coasts include: Eustatic changes, Litho-structural factors (neotectonic deformation); Geographic location between Europe and Africa continents (Straits of Gibraltar); Tidal range; the prevailing winds respect the coastline and Human activity. Generally, the coasts have been affected by uplift, which has produced marine terraces.

The Geomorphic features of the Atlantic coast in the Gulf of Cadiz are largely controlled by the different geological units and the presence of active faults. In the Guadalquivir basin, the low relief coast has extensive estuaries and marshes associated with the lower reach of the main river, partially closed by a large dune fields. The Atlantic coast developed in the Strait of Gibraltar has a strong structural control and shows a good sequence of raised marine terraces and cliff, interrupted by small bay and caves. The geomorphology of the coasts in the Mediterranean is largely dominated by distribution of area affected by positive and negative tectonics and micro tidal regime.
3.2.1 HYDROLOGY

Figure 3-18 shows that in Andalusia there are four main basins, Guadiana in the northwest, Guadalquivir in central Andalusia, Segura in the southeast, and Sur in the south. The most important river is the Guadalquivir and its main tributaries: Guadalimar, Guadiana Menor, and Genil.

3.2.2 SOILS

De la Rosa et al. (2009) stated that using soil type information in decision-making is at the heart for sustainable use and management of agricultural land.

Typical soils of Andalusia compose an exceptionally diverse sample of the diversity of Mediterranean soils (De la Rosa, 1984). According to FAO classification (FAO-UNESCO-ISRIC, 1988), the main soil orders are Cambisols (33%), Regosols (20%), Luvisols (13%) and Leptosols (11%) (CSIC-IARA, 1989). Figure 3-19 shows the most typical soils of Andalusia and Mediterranean region and Figure 3-20 shows the dominant soil sub-group and land use in the 62 natural regions of Andalusia.
Figure 3-19. Typical soils of Andalusia, and the Mediterranean region in general (De la Rosa el al., 1984). Codes indicate location province (Al, Almería; CA, Cadiz; CO, Cordoba; GR, Granada; HU, Huelva; JA, Jaen; MA, Málaga; SE, Seville) and number in the SDBm database, followed by comarca (landscape unit).
3.3 **El-Fayoum Province, biophysical baseline**

El-Fayoum province is located in the northern part of Egypt, approximately 90 km south of Cairo, and includes six districts with a total area of 6086 km$^2$, approximately between coordinates 29° 02’-29° 35’ N and 30° 23’-31° 05’ E (Figure 3-21). It offers a great potential for agriculture, thanks to the water supply from the River Nile. The area selected for this study is the El-Fayoum depression, which excludes the desert part of the province.