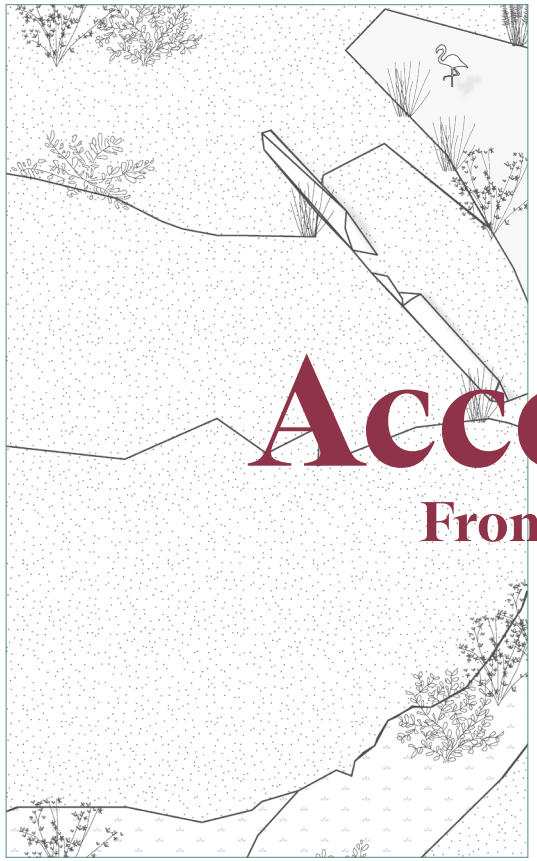

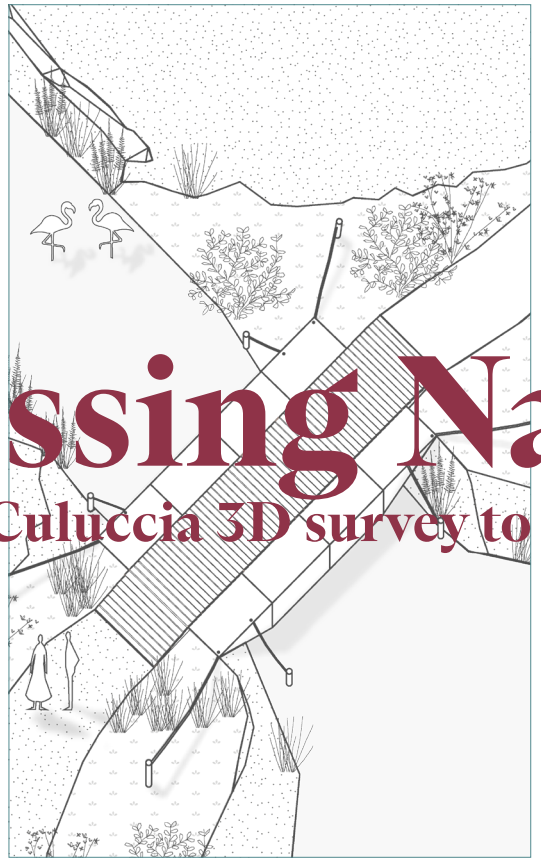

Accessing Nature

From Culuccia 3D survey to design

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December 2024

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01

Abstract

The thesis focuses on access to and connections within the portion of land delimited by the “la Sciumara” road and the Culuccia’s wetlands in Sardinia’s northern region.

The Culuccia island represents the area’s western border, while to the east is the Liscia River, which, adjacent to the beach of Barrabisa, marks another natural limit.

The “la Sciumara” route connects the coastal region of Culuccia with the most remote areas of northern Sardinia, passing one of the region’s most fascinating and beautiful natural landscapes.

In the Sardinian dialect, “sciumara” defines a road that traces the historical path of a river or a natural canal, as well as a section of a river or stream that experiences recurrent floods.

Such references to frequent and unpredictable occurrences inspired our study, which integrates geomatics data elaboration with design intentions.

With vegetation typical of wetland and coastal regions, including glasswort, reeds, rushes and Mediterranean scrub, the scenery alternates between unobstructed regions and wooded sections along the route, offering breathtaking views of the surrounding gulf and the coast.

After crossing “la Sciumara” road, you reach the Culuccia wetlands, a small but significant ecosystem that includes wetlands and salty waters and a system of canals and shallow spots that support a diverse range of plants and animals.

During migrations from Africa to Europe, migratory birds use the region as a primary stopover.
This unique combination of natural beauty and ecological richness embodies the tension between ecological preservation and tourist development.

There are three primary sections to the thesis.
An in-depth examination of the region is the focus of the first part, which corresponds to the phase in which we identified key issues and strengths, which furthered research and analysis from afar.

The second part describes the survey that we did on-site, including a drone survey to take aerial photos.
After that, data were processed to create an accurate orthophoto of the location, which helped us in the design phase.

In the third part, design explorations focus on three different sites: “la Sciumara” road, the main parking lot near the beach in Porto Liscia and the bridge that crosses the wetland, which is the only way to reach the island of Culuccia overland.

The thesis’s ultimate goal is to match more precise and detailed knowledge of this site with design experimentations in a region where ecological conditions result from difficult access throughout history.

02

Introduction

The first approach was to begin with a broader perspective of the area, starting from a smaller scale and gradually focusing on more detailed aspects.

Later, through the survey and analysis of the regulations within the Culuccia area, we gained a deeper understanding of how the area is protected and subject to various regulations.

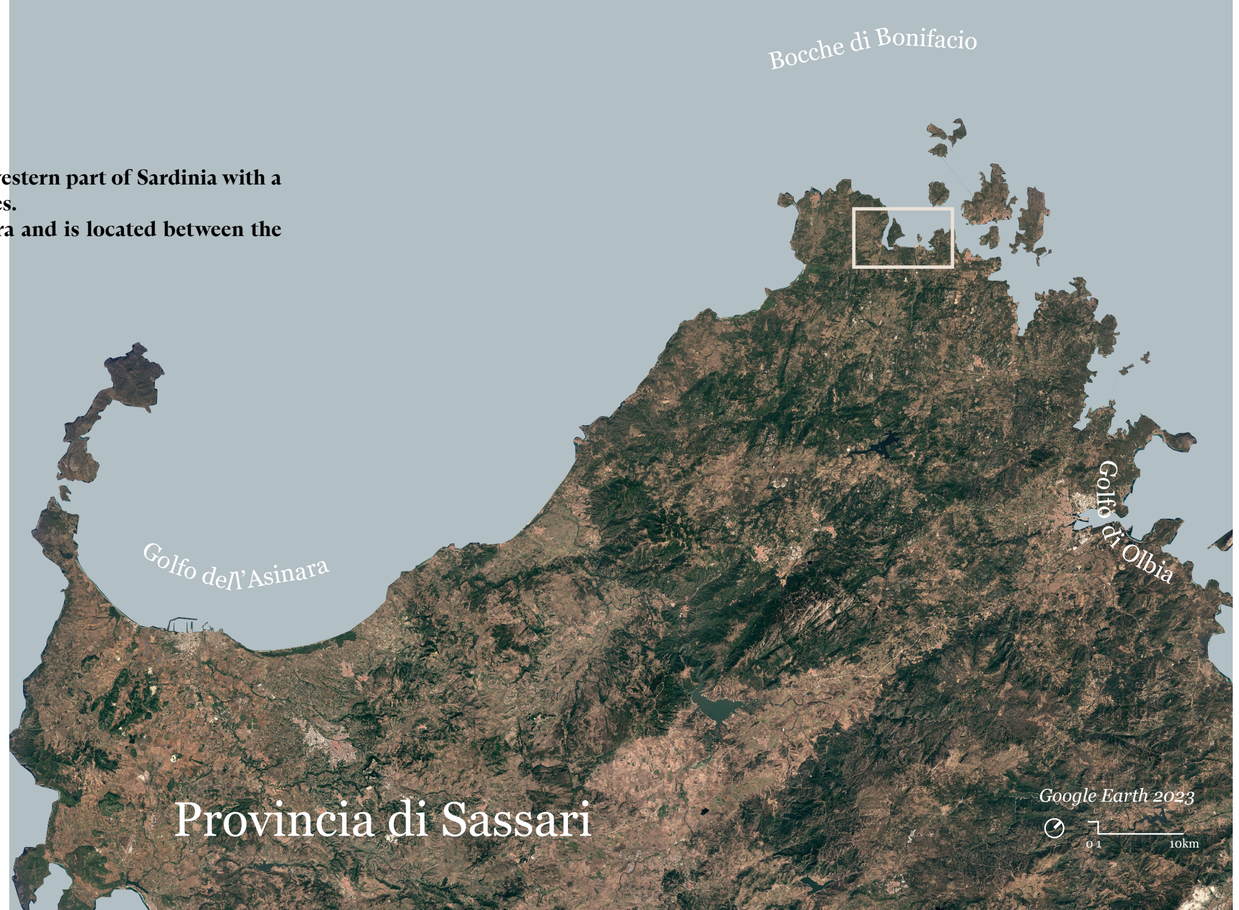
2.1 History

The beach of Porto Liscia is located in the most north-western part of Sardinia with a length of 8.8 km and covers an area of around 87 hectares.
It belongs to the municipality of Santa Teresa di Gallura and is located between the Culuccia peninsula and the mouth of the river Liscia.

"The largest bodies of water are the Porto Pozzo lagoon with its private fishing pond and an area of about 50 hectares, which in turn is connected to the 'Balisgioni' basin, the 'Padula Cioca' pond and a third retro-dune pond." [1]

Behind the beach is the pond 'la Sciumara', which since 1994 has become a permanent oasis for the protection and capture of wildlife.
Originally part of the river Liscia was flooded, but over the years it was filled in and became a coastal pond, leading to the union of the islands of Culuccia and Isuledda with the mainland.
The originally unique bay was divided into three parts: Porto Pozzo with the "Lu Banconi" stream, "Porto Liscia" with the Liscia river and Porto Puddu with the "Scopa" stream.
These three bays are subject to the phenomenon of erosion and deposition of material due to the presence of winds, both from the west and from the mistral, which favour the erosion of material towards the east and create elevations in the innermost parts.

Noteworthy in this area are the dunes of Porto Liscia and Porto Puddu, which flow directly into the sea in the eastern part, as there is no beach here.
The wetland of Porto Liscia between the Gulf of Porto Pozzo and the coast of Porto Liscia is of fundamental importance,



a destination for many birds that choose it for nesting or as a resting place, a place with different habitats and an area of scenic interest. In the humid air, soil and fresh, brackish or salt water meet and create an environment that changes over time both through the extraction or export of soil and through simple variations such as temperature or rainfall throughout the year.
Given the diversity of the waters present, only some plant and animal species with specific physiological adaptations have the ability to survive in this environment.

Remarkable is the presence of a great diversity of habitats, but also of transient phenomena such as the migration of many bird species, which has led to its protection as a nature reserve.
"They are hotspots of biodiversity: a great variety of plant and animal species are concentrated there and even among the bird species threatened with extinction, there are many that depend on these environments." [2]

The area did not always look the way we see it today.
It has been extensively reclaimed over the centuries, which has changed the original ecosystem.
The role of the island has also changed over the years: in ancient times it was used for fishing, while in the Roman era it gained strategic importance due to its location and was used to build ports and agricultural infrastructure.
In the Middle ages, it was mainly used for agricultural or pastoral activities, as well as during the Renaissance.

As already mentioned, with the beginning of land reclamation in the 19th century, many wetlands were converted into agricultural land, resulting in the loss of biodiversity and natural habitats.
A change of direction has taken place in recent decades.

''51 years have passed since wetlands were first recognized as valuable places to be protected: on February 2, 1971, in Ramsar on the shores of the Caspian Sea, the International Convention was signed, which is now shared by more than 170 countries and which protects these ecosystems, especially as habitats for waterfowl." [3]
It is an international treaty that covers all geographical areas of the world and aims to "promote the conservation and rational utilization of all wetlands through local and national action and international cooperation as a contribution to the achievement of sustainable development throughout the world." [4]

Wetlands are highly fertile habitats that are the main source of food for many plant and animal species, including birds, mammals, reptiles, amphibians and fish.

"These areas include various ecosystems such as lakes and rivers, swamps and marshes, wetlands and peat bogs, oases, estuaries, deltas and tidal beds, coastal marine areas, mangroves and coral reefs, and artificial areas such as fish ponds, rice paddies, water basins and salt marshes." [5]
"From 1923 to 1996 the only inhabitant of the island was Angelo Sanna, known to all as ziu Agnuleddu". [6]
Throughout his life, this man lived in a condition of almost complete isolation in this area, which was only accessible to his select guests and subject to his strict rules. Because of the island's remoteness and protection, all of its natural resources have been maintained over time. In particular, "in 1985, following the victory of a civic list led by a friend of uncle Agnuleddu in all the urban planning tools of the municipality of Santa Teresa, the island of Culuccia was declared a total environmental protection zone." [7]

During time, the importance of the Porto Liscia wetland, numerous regulations have been adopted, including the "Habitats and Birds Directives" or the "Water Framework Directive" at community level, down to local regulations, even if not all the objectives set have been achieved.
Just think of the "Peschiera area" or the first part of Porto Liscia beach, where the existing biodiversity is disturbed on a daily basis by human activities such as fishing or passage over the protected area. It is part of environmental protection programs such as nature reserves and areas of "Rete Natura 2000", where importance is given to natural habitats and in particular to the migratory bird species that stop in this area.
Today, Porto Liscia is a fundamental area for Sardinia's biodiversity, boasting a valuable system of wetlands, especially along the coasts, and supporting initiatives to promote sustainability, but also to improve tourism by ensuring respect for the environment and the management of local habitats.

[1-2-3] Rossi, S. (2022). *l'Approdu, n. 02.* Sardegna: Osservatorio dell'isola di Culuccia
[4] isprambiente.gov.it/it/attivita/biodiversita/convenzioni-e-accordi-multilaterali/convenzione-di-ramsar-sulle-zone-umide
[5] isprambiente.gov.it/it/attivita/biodiversita/convenzioni-e-accordi-multilaterali/convenzione-di-ramsar-sulle-zone-umide
[6] isprambiente.gov.it/it/attivita/biodiversita/convenzioni-e-accordi-multilaterali/convenzione-di-ramsar-sulle-zone-umide
[7] culuccia.com/it/pages/the-project

2.2 Regulation

Since this is a protected area, it is necessary to provide a general description of the laws in place.

The marine area around Culuccia is designated as a '**Zona Speciale di Conservazione**' and is part of the 'Rete Natura 2000', an ecological network covering the entire European territory, established under the 'Direttiva 92/43/CEE Habitat' and necessary to protect the ecological, naturalistic and landscape value.
''According to the directive, four of the eight marine habitats worthy of protection are present in the sea around Culuccia: the lagoon, the 'Posidonia oceanica' meadows, the submerged reefs and the "sandbanks with weak permanent cover by seawater". [7]

"Rete Natura 2000 consists of 'Siti di Interesse Comunitario' (SIC) designated by Member States in accordance with the Habitats Directive and subsequently designated as "Zone Speciali di Conservazione" (ZSC), and also includes "Zone di Protezione Speciale" (ZPS) established under Directive 2009/147/CE "Uccelli" on the conservation of wild birds." [8]

ZSCs have specific characteristics: they are selected for their importance for the conservation of unique ecosystems, their continuous monitoring is necessary, they must be integrated into spatial planning through environmental impact assessments, and they must involve local communities and economic actors by promoting sustainable approaches.
The main objectives of Rete Natura 2000 are the protection of biodiversity associated with habitats or endangered species, sustainable management and ecological connectivity to support the migration of fauna and the conservation of flora.

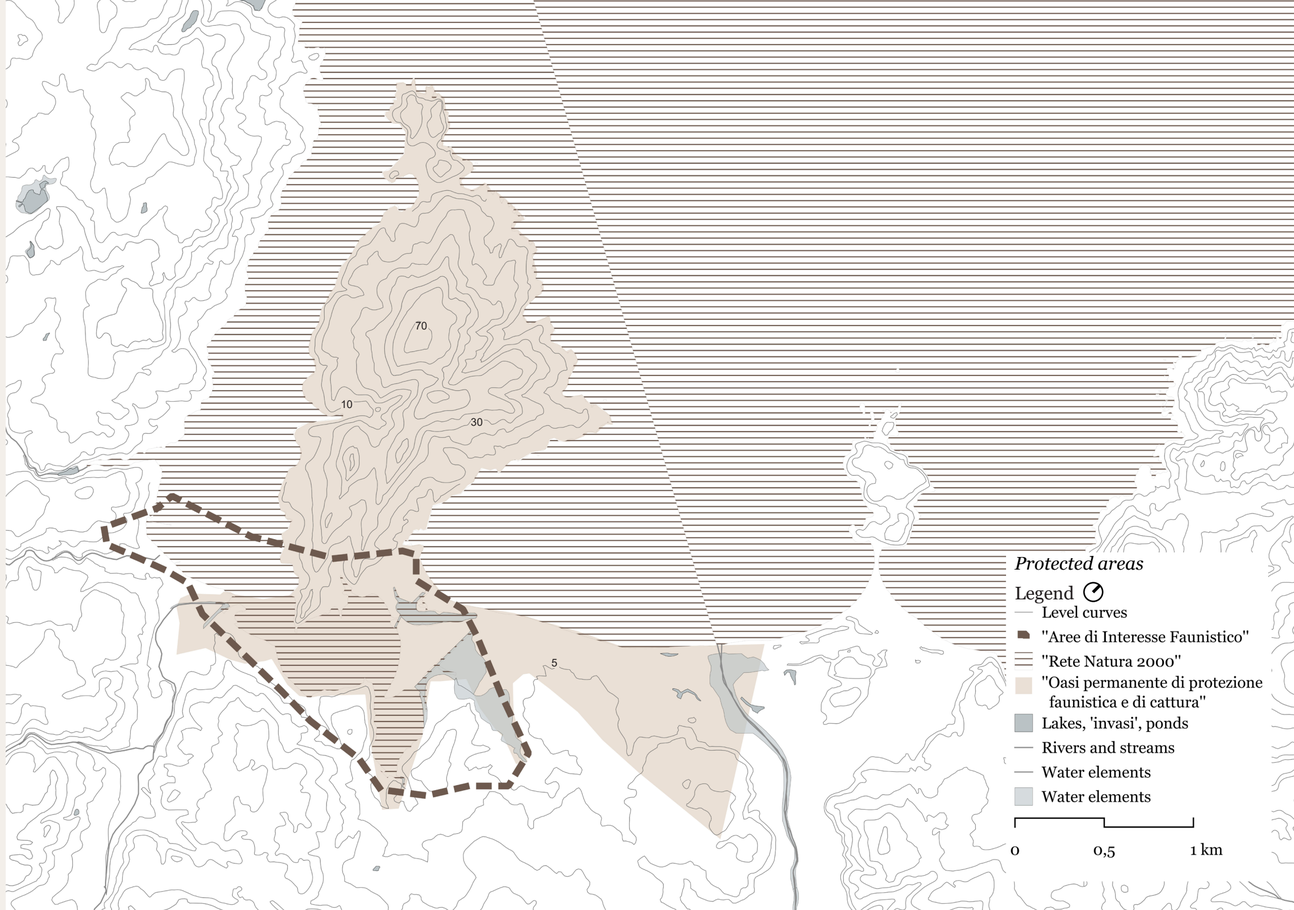
They must be integrated into spatial planning with environmental impact assessments and the local community and economic operators must be constantly involved in compliance with the protection provisions.

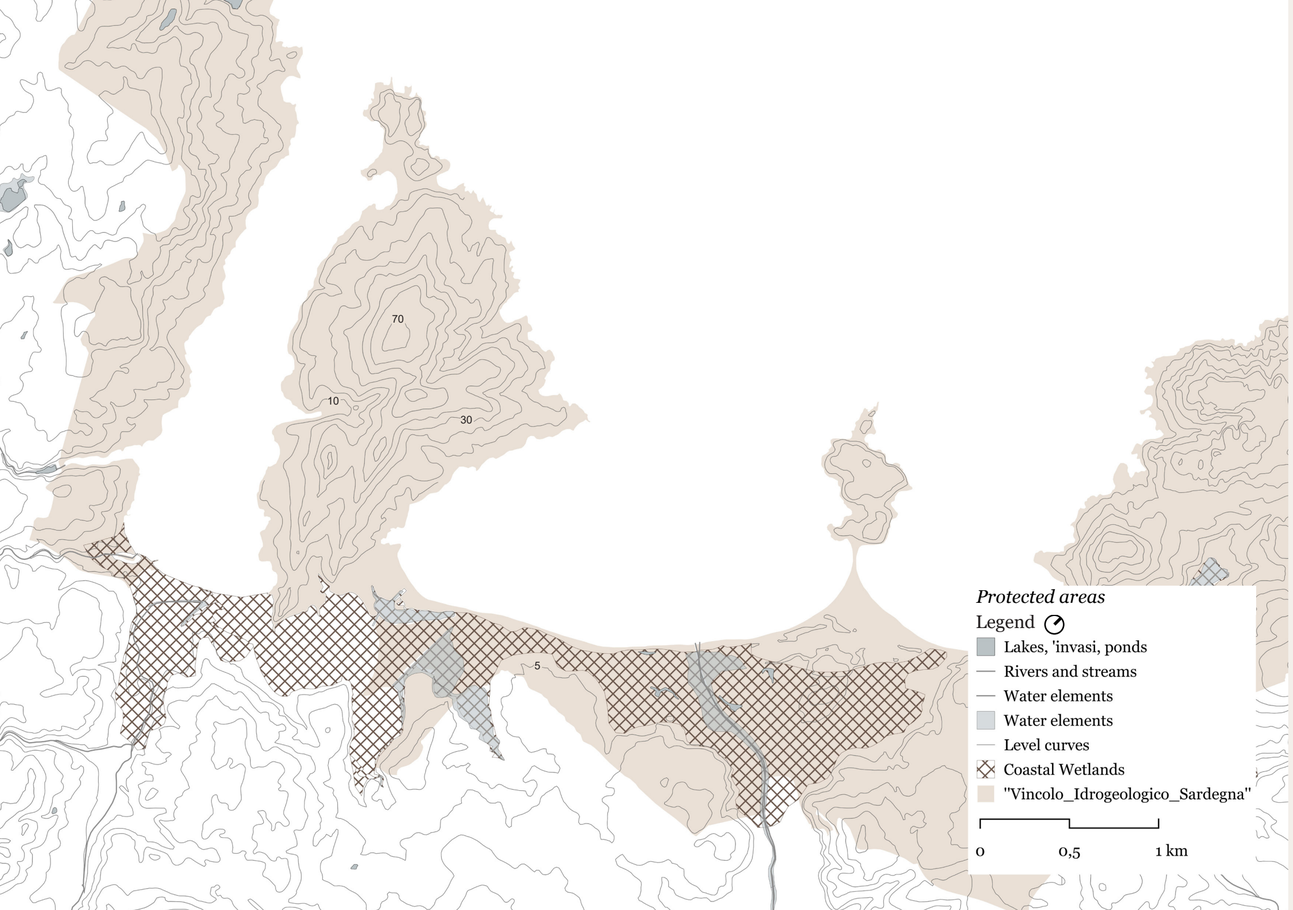
Although the area is subject to the Rete Natura 2000, it does not exclude human activities, as the "Direttiva 92/43/CEE Habitat guarantees the protection of nature also taking into account "economic, social and cultural needs as well as regional and local particularities." [9]

The Directive recognizes the value of areas where traditional activities have enabled a balance between human activities and nature by preserving natural, but also semi-natural habitats such as traditional agricultural areas, the use of forests or pastures.

The proposal for the Rete Natura 2000 was implemented in February 2019 following the resolution of the Sardinian Regional Council no. 8/70, which guarantees the conservation of natural habitats and rare or endangered plant and animal species.

The species selected as a special protection area in the territory of Culuccia are "a dolphin, the bottlenose dolphin and four species of seabirds: cory shearwater, Mediterranean shearwater, Corsican gull and cormorant." [10]





'Rete Natura 2000' is constantly expanding and is characterised by its effectiveness, which is based on cooperation between institutions, local communities and economic actors.

The mainland is instead protected by regional legislation as 'Oasi permanente di protezione faunistica e di cattura', established on the basis of **Law 157/1992** and **Regional Law 23/1998** to protect Sardinia's wild fauna by prohibiting hunting and ensuring the sustainability of natural resources.

The objective of the '**Piano Paesaggistico Regionale del 2006**' is also applied to this area: "to preserve, protect, enhance and transmit to future generations the environmental, historical, cultural and settlement identity of the Sardinian territory; to protect and preserve the cultural and natural landscape and its biodiversity; to ensure the protection of the territory and to promote forms of sustainable development in order to preserve and enhance its qualities." [11]

The island is therefore to be considered an "Area di notevole interesse pubblico", which protects "the bay systems and headlands, rocks, islets and cliffs, the dune fields of Liscia beach, the coastal wetlands and the areas of interest for wildlife". [12]

This is regulated by **D. Lgs. n. 42/2004**, which refers to **Art. 136** – Buildings and areas of significant public interest and **Art. 157** – Penalties for encroaching on restricted areas without authorization.

The 'aree di interesse faunistico' (**D. Lgs. n. 42/2004** - **Art. 143** – piano paesaggistico) are areas designated for the protection of wildlife and habitats that harbour species of community or local interest.

At a local level, however, the '**Piano Urbanistico Comunale**' identifies this area as one of the highest qualities of Gallura and therefore protects it at an ecological level with small restoration or enhancement measures for the existing area.

As indicated in the landscape plan, the 'Coluccia' park is located in sub-zone G8.6, in one of the most valuable areas of the municipality. Any intervention must be carried out exclusively on public initiative, with great importance being attached to environmental sensitivity.

"In the sub-zone under study, only interventions aimed at restoring and enhancing the natural features present in the area, particularly in terms of vegetation, are permitted.
With regard to the use of the land, the restoration of the existing paths is allowed, without altering the morphology of the places, with a surface consisting exclusively of beaten earth, paving or similar, excluding bituminous surfaces and respecting the existing vegetation as much as possible; it will also be possible to create some light infrastructures to enhance the existing in compliance with the above provisions.
The access to the sea will be planned as a pedestrian path with the mentioned characteristics, taking into account the particularities of the places." [13]

The area of the Culuccia Park and the adjacent wetland is subject to 'Vincolo Idrogeologico' (**R.D 3267/23**) and 'Aree a Pericolosità Idrogeologica' (**L. 267/98**), which aim to prevent phenomena

of hydrogeological instability, protect water resources and ensure environmental sustainability.

The area is also linked to 'Vincolo Fascia Costiera 300', regulated by **art. 142 of D. Lgs. n. 42/2004**, in which the law imposes restrictions on interventions aimed at transforming the area in order to preserve its natural beauty.

The limitations put in place to safeguard the environment could interfere with the demands of the economy.
In this particular case, we are close to Costa Smeralda, a place that experiences the phenomena of "overtourism", particularly in the summer. One of the rare places that is defined by slow and controlled tourism is Culuccia Island, an uncontaminated region in the center of this phenomena.

The current limits must be viewed as chances to create timely and sustainable projects that support local well-being, conservation, and economic development while honoring and improving the environment.
Being a protected area, Culuccia Island has evolved throughout time to include activities related to an ecosystem that is distinctly different from many others.
This has made the island appealing to ecotourism and private tourism, which aims to showcase the area's natural beauty without causing harm to it.

Activities that can be created include educational initiatives that engage both residents and visitors to raise awareness of the significance of the island of Culuccia and the nearby wetland.
To encourage care for these places from a young age, there are actually existing activities for kids that involve collecting trash and providing information about the creatures and natural ecosystems along the Porto Liscia beach and the wetland.
Additionally, several of the activities included in one of our project interventions have been influenced by this.

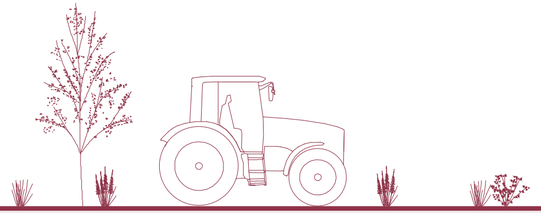
It is precisely on these aspects that our project proposals are based, that is, on the maintenance and enhancement of the landscape trying to improve the existing problems related to the accessibility of the area.

This promotes responsible tourism since it allows visitors to visit in an informed way while still respecting the location's limitations.

[8] Rossi, S. (2023). *l'Approdu, n. 03.* Sardegna: Osservatorio dell'isola di Culuccia
[9-10] mase.gov.it/pagina/rete-natura-2000
[11-12] Cugudda, Chiodello. (2023). *l'Isola di Culuccia conoscenza del territorio e strategie per la valorizzazione*.
[13] Comune di S. Teresa Gallura, (2017). *Norme tecniche di attuazione P.U.C.*

Porto Liscia wetland
Photo Lorenzo Rivella

03



Web of connections

The geographical examination of a hard-to-reach location was one of our initial methods for studying the region.
The goal of this analysis was to employ new marked and unmarked routes, such the "Cammino100Torri," which will only be used by a tiny percentage of tourists, to connect the Island to the surrounding areas through carefully planned tourism.

This facilitates access to the island, increasing connectivity and enabling a new segment of the tourism industry to get familiar with the locations.

Additionally, our research revealed that public transportation is quite inconvenient for getting to the island; in fact, private vehicles, like cars, are required to get there from the closest towns.

3.1 Proximity

The area of the wetlands next to the island of Culuccia and the beach of Porto Liscia is diverse and contains significant and protected ecosystems. From the coastline, you can see that there are three main beaches: "Porto Liscia" on the left, "Barrabisa" on the right, and "Porto Pollo" is located along the strip of land that links the "Island of Gabbiani" with the mainland.

One significant constant on these beaches is the wind, where windsurf and kitesurf are the main attractions, bringing every year a large number of tourists in every season.
Because of this phenomena, sand particles or other particulates are transported from one place to another, causing the coasts to change throughout the year. As the seasons shift, this enables a new perspective on the region.

The beaches are framed by the dune area behind them, where certain plants, such sea lilies, have grown.

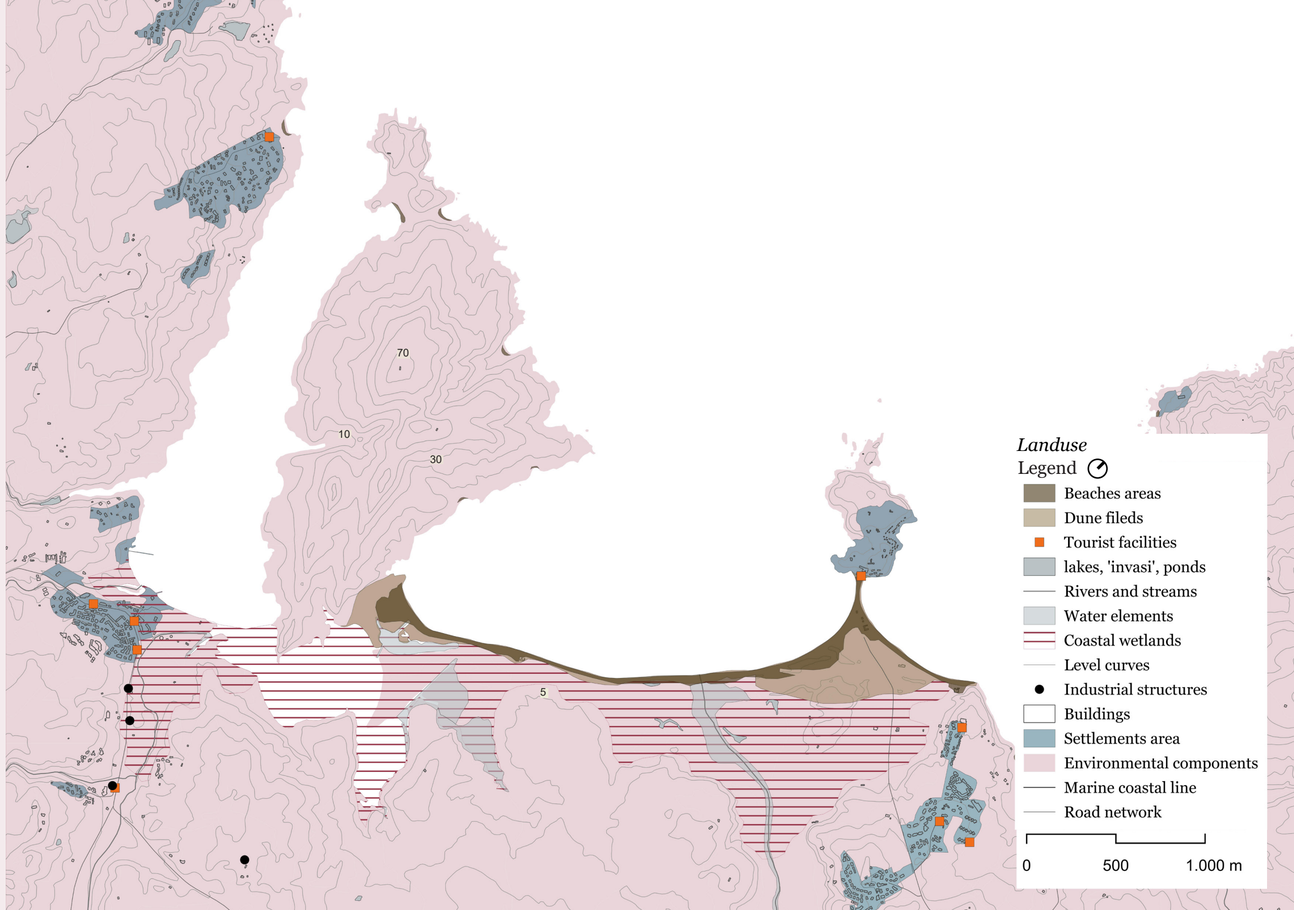
Rivers and lakes like "Liscia river" and the "rio Lu Banconi", as well as lakes that are a component of wetlands like the "Padula Cioca", are present in this area of Sardinia.
Also, these water elements can vary during season, having for example the mouth of the Liscia river into the sea during the rainy seasons.
The large, humid region that is part of this territory is known as a coastal wetland. It is distinguished by a terrain that may support a variety of plant and animal species, as well as bird species that migrate to these areas.

"Among the birds at risk of extinction, many depend on these environments: biodiversity hotspots in which a great variety of plant and animal species is concentrated" [1]

The curves levels defined a very intricated territory, especially in the "Island of Culuccia", which reaches an altitude of around 70m in the highest area of the peninsula.
This area is also wild and controversial due to its abundance of beaches with hidden natural caves and its high and low cliffs.
This slope can be seen from the island's entrance, where you can additionally observe the main uphill routes. Special vehicles are utilized on the island to go about as quickly as possible.
Furthermore, the presence of wild creatures that might be hostile, particularly at night, makes it potentially risky to walk around the area.

There are just a few populated localities with facilities for tourists that permit visitors to stay, such as like Porto Pozzo, Pollo Pollo or Conca Verde. These facilities are not present in a great amount, due to the small dimensions of the inhabited centers, populated especially during the warm seasons.
As the map shows, staying in these places is harder, particularly in the fall and winter when there are fewer service activities and refreshment facilities.

[1] Rossi, S. (2022). *l'Approdu, n. 02.* Sardegna: Osservatorio dell'isola di Culuccia



3.2 Proximity networks

To increase accessibility to the project area, connections by land or sea had to be studied.
To reach Sardinia, you can take a ferry. Ferries depart from the main Italian ports: Genoa, Livorno, Piombino, Civitavecchia, Naples and Palermo.
You can also reach Sardinia by ferry from the French coasts, from Corsica or from Spain.

As we focus mainly on the north-east of the island, where our object of study is located, we know that the main routes depart from the ports in the following places: Corsica, Genoa, Livorno and Civitavecchia, arriving at the port of Olbia and Santa Teresa.

"The most important port is that of Olbia, which boasts more than three million visitors a year and is considered the main access point to the Costa Smeralda." [2]

If you decide to travel by plane instead, you can land at Alghero or Olbia airports. These are the two airports in the north of Sardinia.

"Olbia Costa Smeralda Airport, the largest of the two airports in northern Sardinia and the second largest in Sardinia, is located just three km from the center of Olbia." [3]

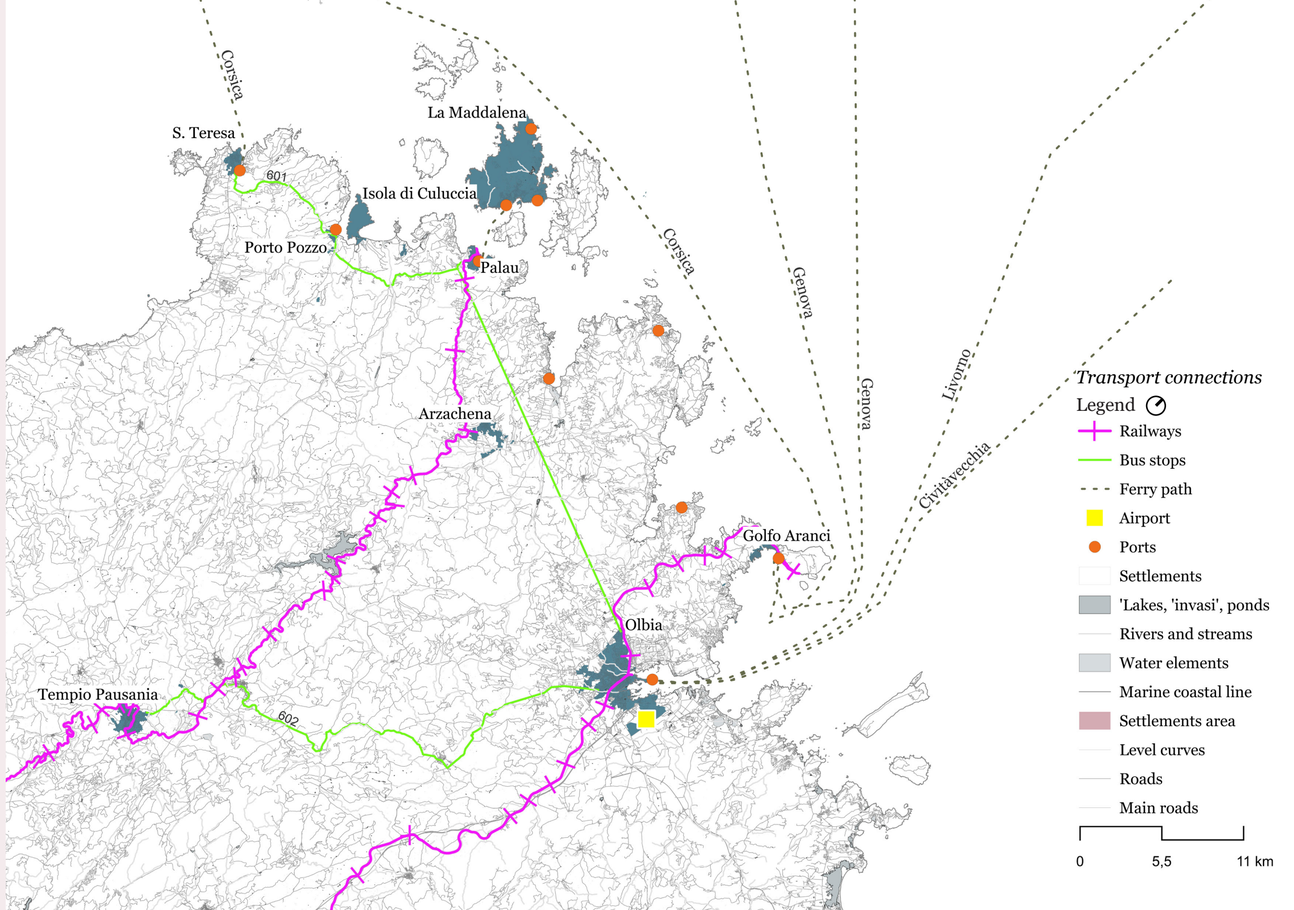
This is closest to our area of interest.
As for traveling within the island, you can choose to travel by train or bus.

We have explored various options for reaching the island of Culuccia by public transport, starting from the major urban centers in northeastern Sardinia.
None of them lead directly to our area, but the closest point you can reach is Porto Pozzo. From there you can reach the Island by sea or by land with private vehicles.

The bus lines that lead to Porto Pozzo from the main population centers are well organized and, as we can see from the map, the arrival times are quite short, only if you come from Tempio Pausania you will need to change busses to get to our arrival point.

If we wanted to reach Culuccia by train instead, it would be possible to do so via the **"tourist train lines of "Trenino Verde", which travel mainly during the summer season."** [4]
The train departs from Tempio Pausania, from where you can travel comfortably by train from all over Sardinia, and arrives in Palau, from where you can then take the bus to Porto Pozzo.
The train journey takes 3 hours and 30 minutes.

We may observe information on transportation for arriving on the island of Culuccia in a reinterpreted representation on this map. We tried to analyze the public transports that connect the most important cities of northern Sardinia with our project area.
In contrast to the transport map we previously examined, this one is mainly concerned with the travel times to the island.
Additionally, we can determine the frequency of these transports by measuring the line intensity.

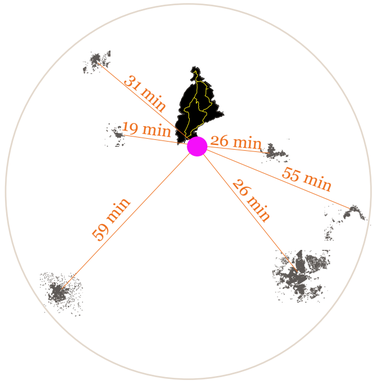


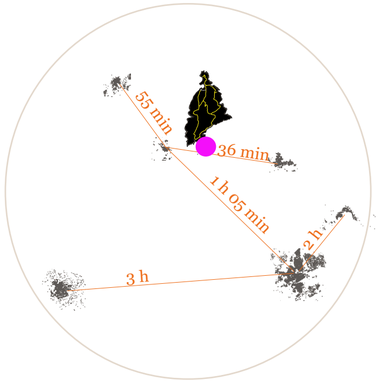
The availability of public transportation is essential for locals.

For instance, bus number "601" is an essential link to other parts of the island, including Arzachena, Santa Teresa di Gallura and San Pantaleo, in addition to connecting Olbia and Palau.
The strength of the lines on the map indicates that bus "601 Olbia-Palau", is the most frequent. We realize that this bus runs nine times on holidays and twenty-five times on weekdays.
This reduces the need for a private vehicle, permitting people to travel for social, educational, and professional purposes.

The "602" is another helpful bus that connects the areas we have examined.
It primarily runs between Tempio Pausania and Olbia, which is a crucial connection point because it has the most ferries and the biggest airport in northern Sardinia.

By car from Culuccia





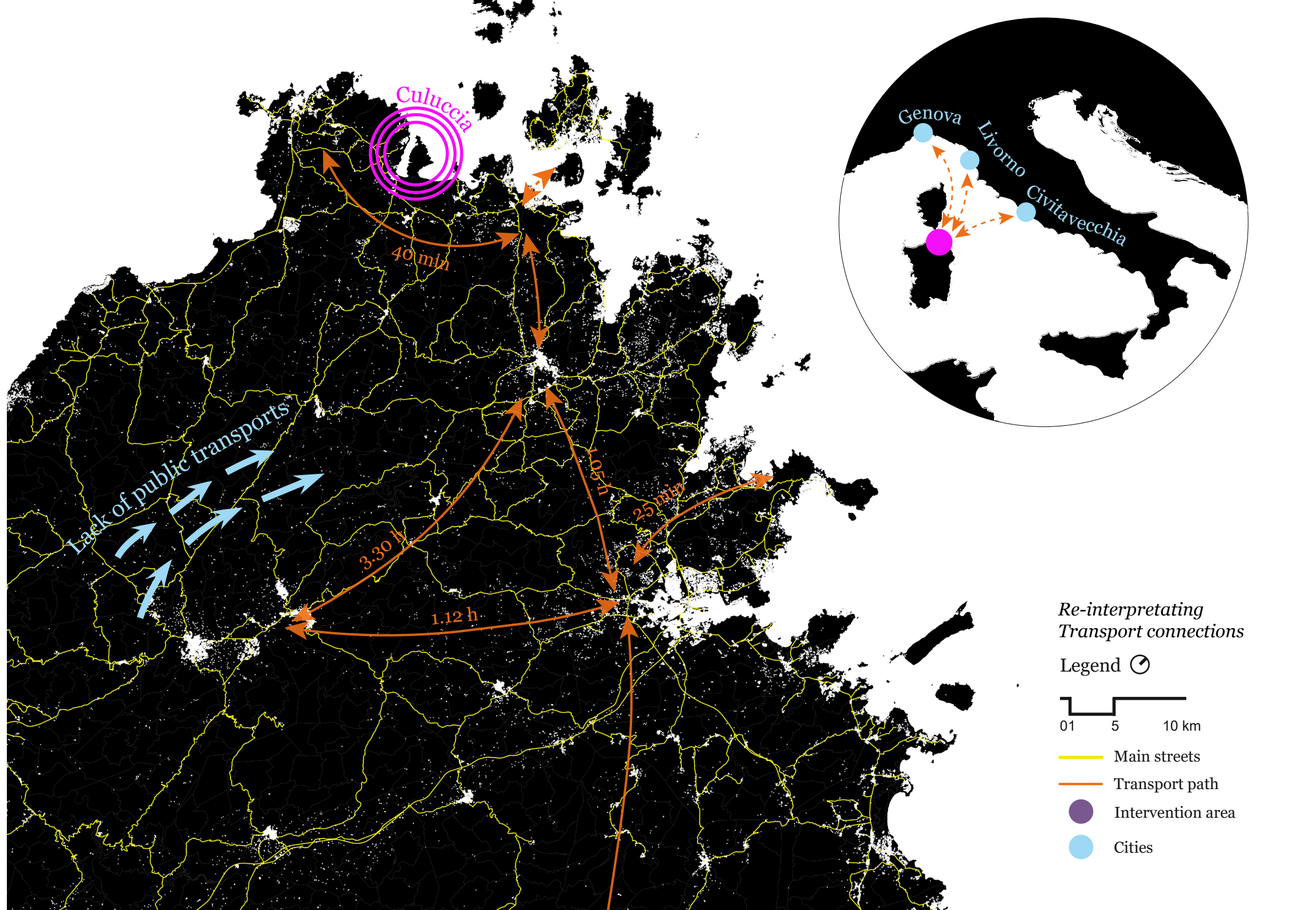
By bus near Culuccia

The bus runs six times during the week and only three times on holidays. However, inhabitants in the southwest of the island have to depend on their cars due to the absence of public transportation options, which results in unequal accessibility across different areas.

[2] traghettilines.it/it/traghetti-sardegna.aspx?from=PMAX&gad_source=1&gclid=CjwKCAjw3624BhBAEiwAkxgTOpgUhqwRFj4gDHlgQuhcVS07eQE4tjPpRoHIPx3BNJxamzdPjXmFqBoCNKYQAvD_BwE

[3] only-sardinia.com/altri/gli-aeroporti-del-nord-sardegna-motori-di-sviluppo-economico-e-turistico/

[4] bandhulera.it/come-spostarsi-con-i-mezzi-pubblici-in-sardegna/



3.3 Getting closer

Because Sardinia has so many natural trails, trekking is quite popular there.
The northern part of Sardinia is characterized by impressive routes that can be tackled by mountain bike or on foot, depending on your preparation.

These include the 'Cammino di Santu Jacu', the 'Sentiero Italia', which can be tackled by bike or on foot, the network of paths on the island of Caprera and the 'Cammino 100 Torri'.

"**Cammino di Santu Jacu**" crosses the whole of Sardinia over a distance of around 1600 km and leads to ancient places of worship such as churches or the ruins of San Giacomo (Jacu in Sardinian).
The path was born with a hypothesis at the end of 2009 thanks to a group of people who knew the Caminos in Spain, until it was 'marked' for the first time in 2012, becoming the first official path of the tourist-religious routes in Sardinia.
Due to the mild climate in the region, the path can be followed on foot, by bike or on horseback in all months of the year.
The path is divided into four axes: the central axis, the northern path, the Sinis variant and the Sulcis variant.

"**Sentiero Italia**" was created thanks to the support of the Italian Alpine Club, which has set itself the goal of bundling initiatives that promote the economy.

"It leads through twenty regions, sixteen UNESCO sites and numerous national and regional parks." [5]

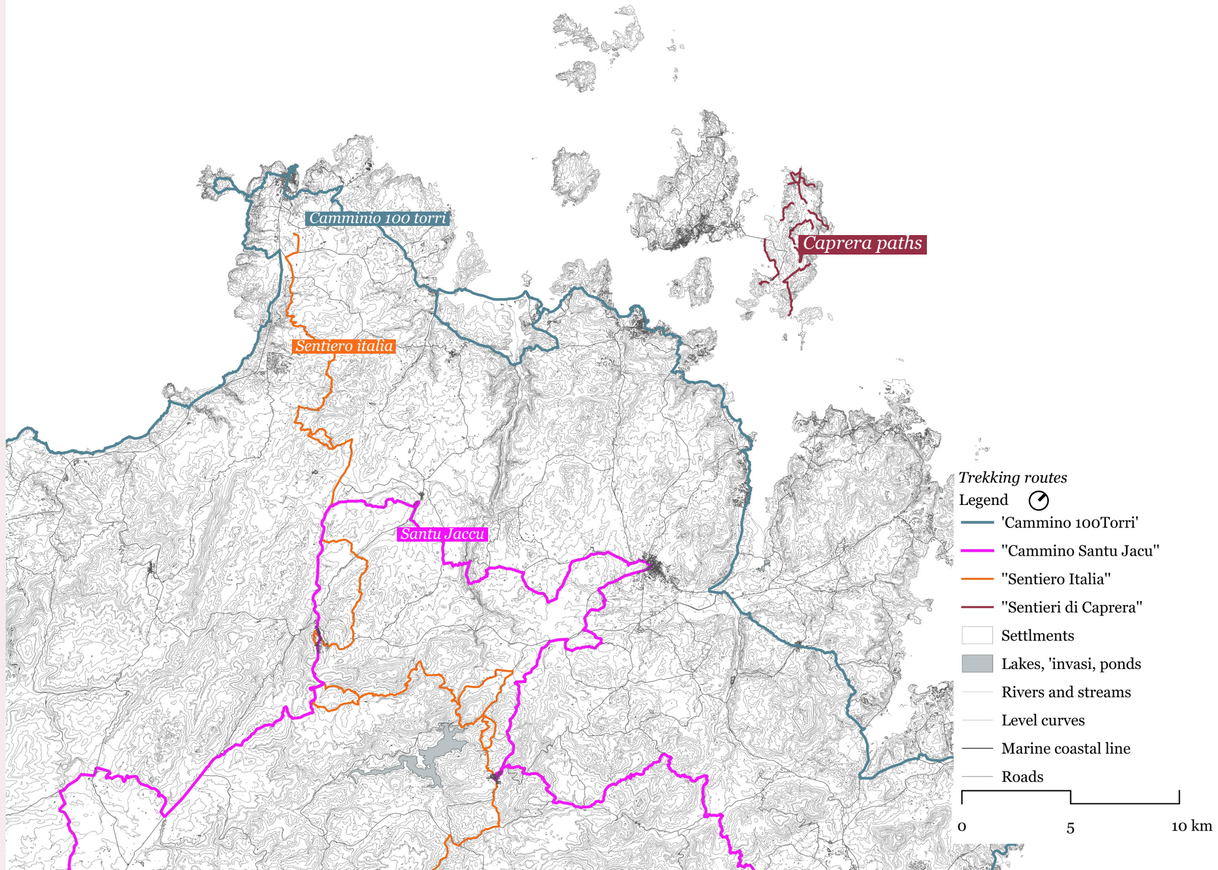
In 2020, the 'Sentiero Italia' was created, the longest hiking trail on the island with a length of around 100 km, accessible to both hikers and mountain bikers.
This required the involvement of the Sardinia Region, the regional agency 'Forestas' and volunteers from the island's CAI sections.

The route runs from Santa Teresa di Gallura in the north to Castiadas in the south. You will be able to see the highest peaks in Sardinia, including Monte Spada, Punta Lamarmora, Bruncuspina and numerous other viewpoints.

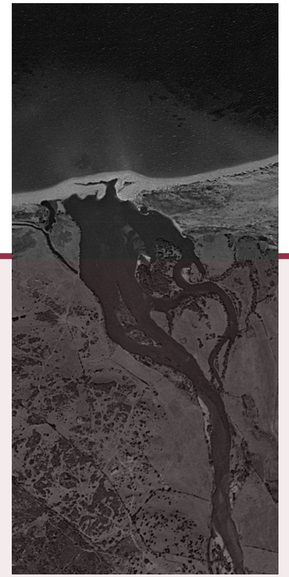
The network of "**Sentieri di Caprera**", which consists of sixteen paths, was created in 2011 with the aim of restoring the old network of paths created for military purposes at the end of the 19th century.
The routes run along well-trodden and marked paths, which can be linked by small stretches on asphalt roads with short paths and minimal differences in altitude and can be walked without any athletic preparation.
These are linked to more challenging routes with height differences that are only suitable for the most experienced.

"**Cammino100Torri**" is a hiking trail that crosses the whole of Sardinia in an anti-clockwise direction, mainly with stretches overlooking the sea, but also with stretches that are more inland, such as in forests or over mountains.

[5] sentieroitalia.cai.it/

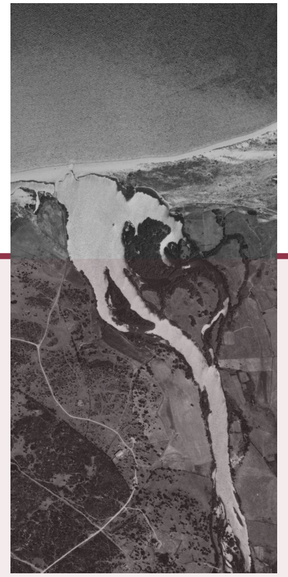


3.4 Getting closer and closer



Ortophoto

1954



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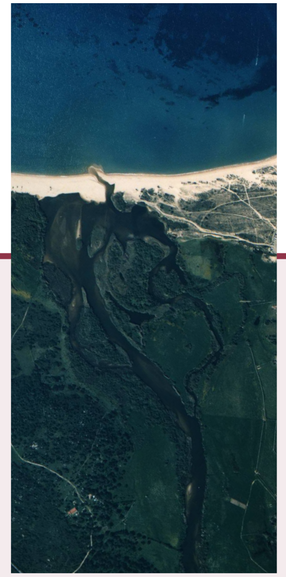
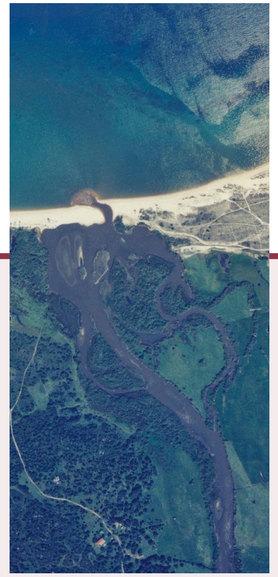
1968



Ortophoto

1998

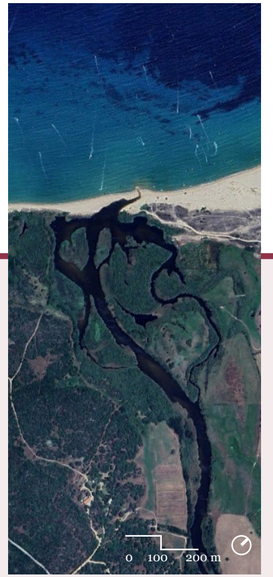


Ortophoto

2002

Ortophoto

2019

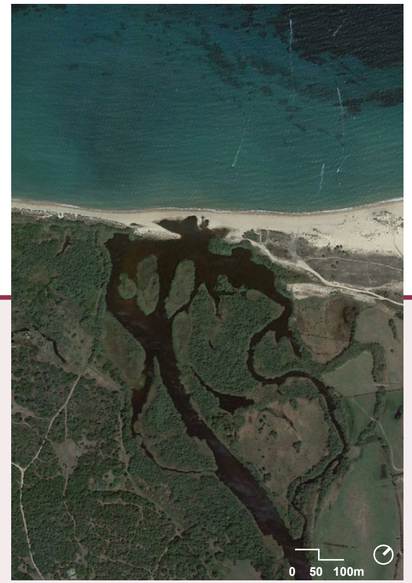


Google Earth

2023

Google Earth

01.2019



Google Earth

06.2020

The study of Liscia river was necessary to advance the hypothesis of a connection towards the Island of Culuccia and the adjacent wetland area.

Liscia river originates in the Limbara range and travels 64 km to the beach of the same name.
The basin's total area is 562 km^2.

The only route present in the area adjacent to the island of Culuccia and its wetland is the "**Cammino100Torri**", a trekking route that marks the entire coast of Sardinia.

This path does not pass through the roads of the territory, but instead diverts this territory and does not include it during its path.

Compared to the other trails that are in a more natural setting and border the Sardinian the coast, this section of the walk is actually the only one that has a significant asphalt surface.

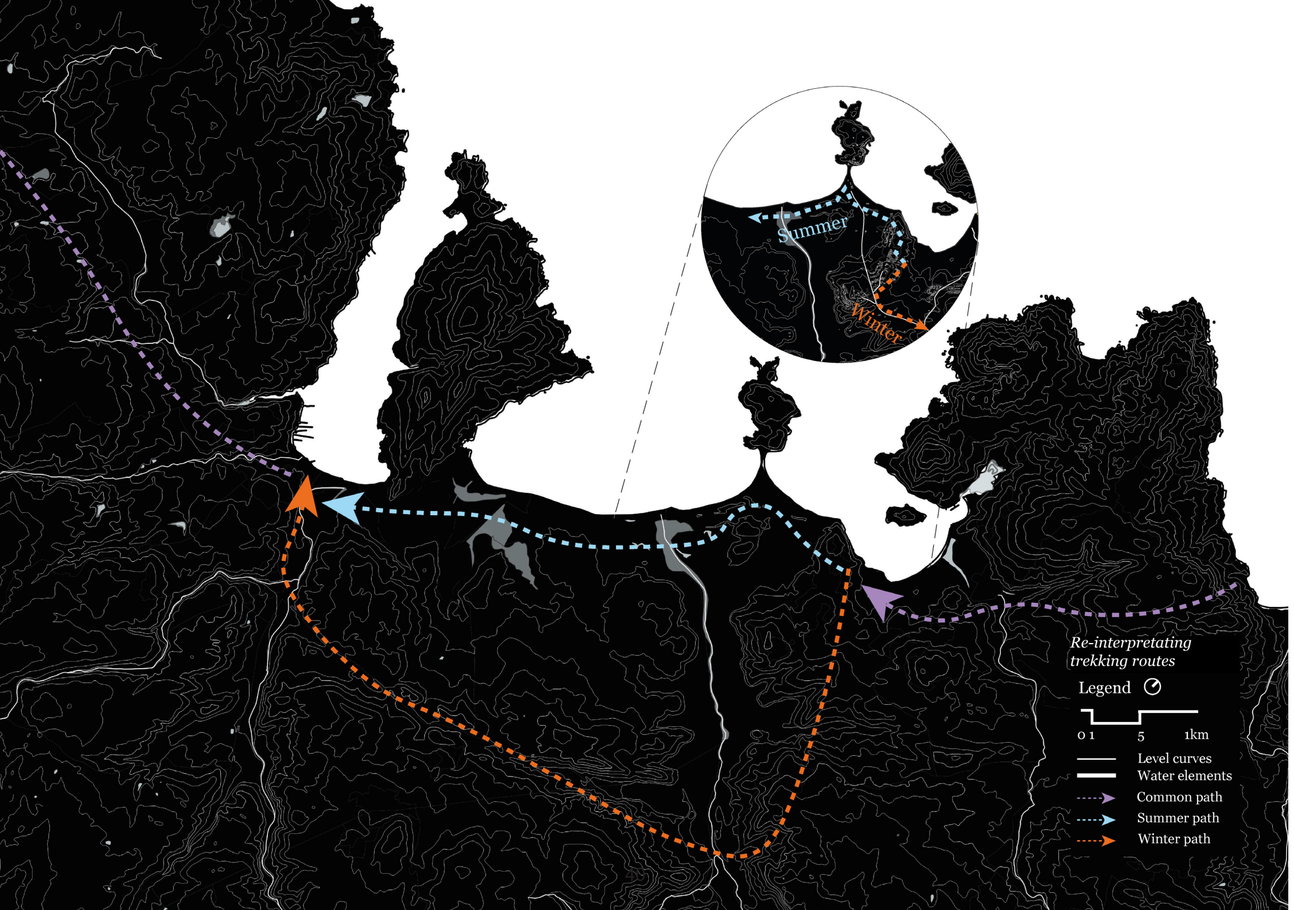
We therefore considered a different route that goes over the Barrabisa and Porto Liscia coasts.
We conducted some research on the Liscia River mouth to enable this.
The photographs show that the volume of water present has significantly decreased over time, which has also had an impact on the way out towards the sea.

Not only does the Liscia River change over the years, but it also changes with the seasons.

The river runs into the sea in the winter, but it recedes in the summer, making it possible to walk from Barrabisa Beach to Porto Liscia Beach.

Thanks to this study, we are now able to make assumptions about the "Cammino100Torri" using the path in the beach during summer.

All this allows the connection to the wetland and the island of Culuccia, with the aim of encouraging explorers to discover new suggestive territories always respecting the sensitive area that surrounds this corner of Sardinia.



The "Cammino100Torri" route is the only one to cross the portion of territory between the "Island of Culuccia" to the west and the "Beach of Barrabisa" to the east.

As stated above, is hiking trail that crosses the whole of Sardinia in an anti-clockwise direction, mainly with stretches overlooking the sea, but also with stretches that are more inland, such as in forests or over mountains.

The trail can only be walked by experts, as there are considerable differences in altitude.

It was initiated in 2013 from the desire to create a path that does not detach itself from the coast.

"At the moment, the marking of the path is being completed and work is underway on the CAI signage".[6]

The path of interest for the area of the island of Culuccia and its wetlands is the 'Via Gallura', which starts from the municipality of Porto San Paolo and leads to Castelsardo via areas such as Olbia, Tempio-Pausania, Arzachena, Santa Teresa di Gallura.

Its strength is its proximity to Olbia airport and the annual presence of tourists in this part of Sardinia.

The route called "Via Gallura - Palau - Porto Pozzo", begins in Palau and travels along the Costa Serena coastline.

With Porto Pozzo as its ultimate aim, it then descends towards the hamlet of Barrabisa, a stop that is required due to the existence of establishments like bars and groceries, until it reaches the Liscia bridge, crosses it, and bypasses the area of the Isola di Culuccia and the surrounding wetland.

The percentage of traveled beach is 0%, so our proposal try to increase this percentage.
So, we suggested that at the turning point for Porto Pollo, this goes up along the beach, arrives at the strip of land that connects the Isola dei Gabbiani to the mainland and continues along the Barrabisa beach to the mouth of the river.

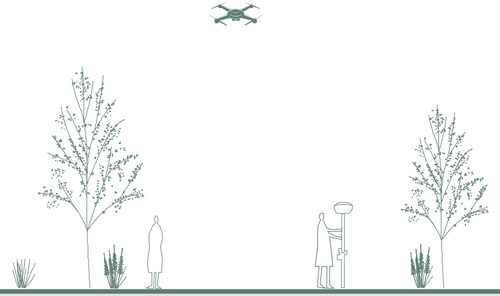
The alternative route must be done in summer or in the driest periods, in such a way as to be able to pass through the stretch of beach crossed by the water in winter.

From here, you travel to Porto Liscia's beach until you arrive at the island of Culuccia's entrance, where you can pause and explore the area around it.

From here, one can continue on by boat to the ultimate goal, Porto Pozzo.

[6] cammino100torri.com/2020/12/07/via-gallura/

04



Geomatics and photogrammetric data processing

Being able to analyze and experience the project area in person, thanks to the experience with Team DIRECT, made us more sensitive to understanding the existing situation.
Using specialized equipment aided in our analysis and enabled us to use the knowledge we had gained thus far.
As a result of the survey, we were able to acquire 3D models, which we then used to develop our project proposals.

4.1 Photogrammetry

4.1.1 What is

"The term photogrammetry is derived from three Greek words: "photos" (light), "gramma" (drawn or written), and "metron" (to measure)." [1]

Photogrammetry is a technique that makes it possible to reconstruct and measure an object without touching it, which is why it is also known as "remote sensing". Surveying can be done in both two and three dimensions, using both photograms (analogical images) acquired by traditional photogrammetric cameras and digital images.

Photogrammetry is the art and science of determining the position and shape of objects using photographs. The results of photogrammetric measurements can be: numbers such as coordinates of an object in a three-dimensional coordinate system, drawings such as topographic maps or images such as orthophotos or digital images.

The 3D coordinates of points of an object are determined by measurements made in two or more photographic images taken from different points of view. The identification of common points on different images of the same object defines a line or ray and the intersection in space of two or more of these rays determines the 3D position of the point.

Although photogrammetry was born for architectural survey, nowadays it is widely used in topographic aerial survey and mapping, and for military purposes. The use of remote sensing, a new scientific instrument, expanded the field of photogrammetry. In addition to utilizing a traditional camera, one can also capture the scene using specialized sensors that use electromagnetic radiation that is outside of the standard visual range. This allows for the simultaneous recording of many spectrum segments.

Active systems' longer wavelengths function in nearly any meteorological state and can cut through clouds and haze.

After the American Society for Photogrammetry was established in 1934, the term "photogrammetry," which had been in use since the late 19th century, gained widespread usage in the United States.

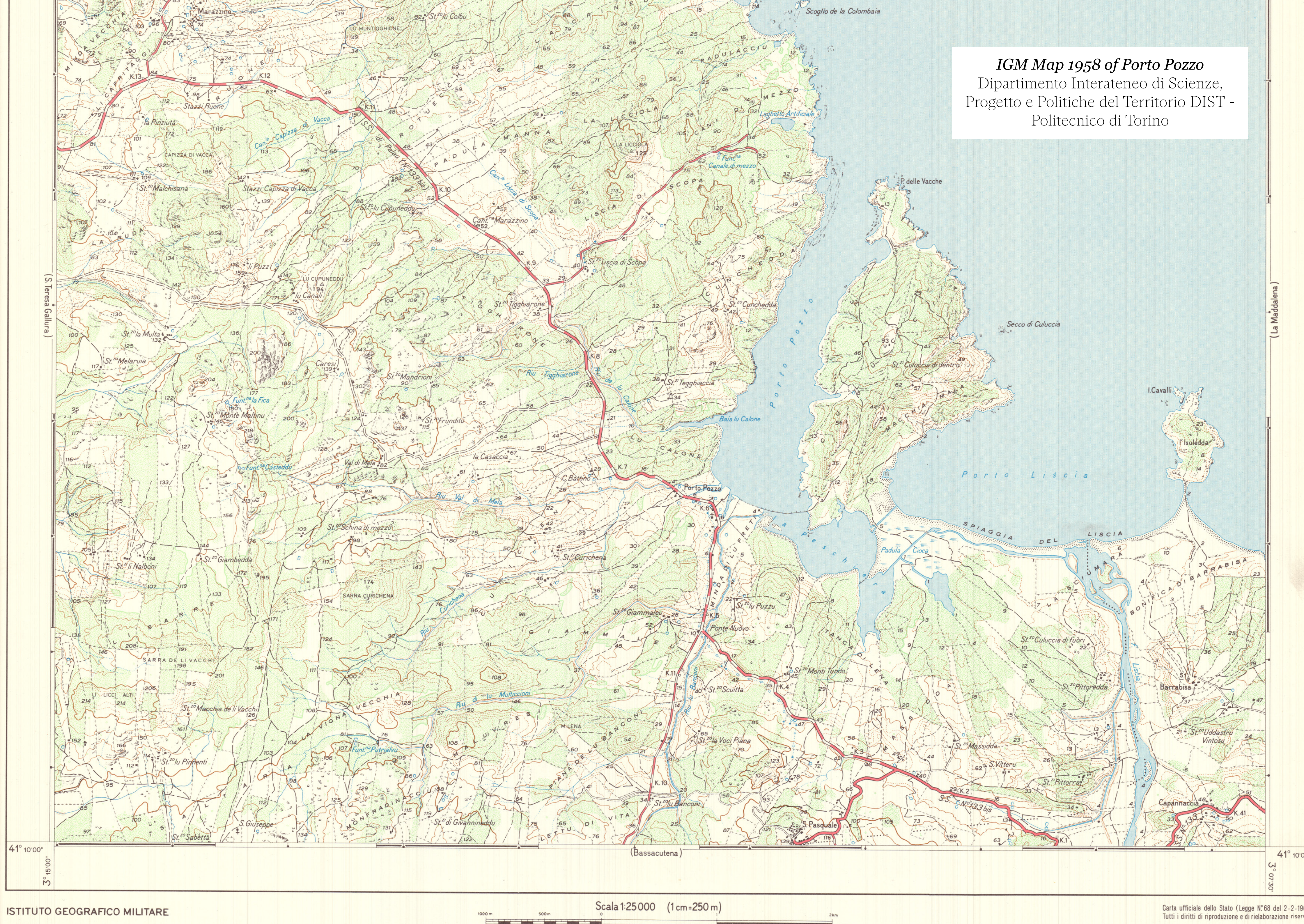
In view of these developments, the definition of photogrammetry from the fourth edition of the Manual of Photogrammetry [Slama, 1980] is: "Photogrammetry is the art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena." [2]

The creation of topographic maps is the primary use of photogrammetry. The "Digital Terrain Model" (DTM), which contains data on the morphology and use of the land, is a by-product that is easily obtained when creating such items using contemporary techniques.

Additionally, networks of reference locations can be established using photogrammetry to frame upcoming topographic studies.

However, the most significant contribution is that almost all geospatial information originates from photogrammetry.

[1-2] American Society for Photogrammetry and Remote Sensing. (2004). *Manual of Photogrammetry. 5th ed.* Bethesda (MD): J. Chris McGlone.



IGM Map 1958 of Porto Pozzo
Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio DIST - Politecnico di Torino

4.1.2 History

The French colonel A. Laussedat is traditionally regarded as the founder of photogrammetry, having presented a report at the Committee of the Academy of the Sciences in Paris in 1859 regarding the possibility of defining points' coordinates of an object based on the spatial intersection of projective rays referred to a pair of photographs.
Deville also created the first stereoscopic-plotting instrument and published an early treatise on photogrammetry in 1895.

When the French Academy of Sciences declared in 1839 that Louis Jacques Mande-Daguerre had succeeded in refining the earlier research conducted by Joseph Nicephore Nièpce, photography (drawing with light) was formally born.

For the first time, Daguerre was able to capture real-world things on a photo-sensitive film in less minutes of exposure than was required for Nièpce's first authentic photograph in 1821.

In his initial experiments, Nicéphore Niépce placed a piece of silver salt-coated paper, which is known to turn black in the presence of light, creating the first image of nature.
However, when the coated paper turns to black in the daylight, the image disappeared.

Louis Daguerre is typically given credit for taking the first successful permanent photograph, which was taken on a copper sheet covered in silver. Several light-sensitive materials were tested to capture the image from the camera obscura.

The earliest acquisitions were in black and white, but in 1861, a film that could capture the colors of the scene being taken was created. James C. Maxwell, a Scottish physician, is credited with discovering in 1855 that color images could be created using red, green, and blue (RGB) filters.

G. Félix Tournachon made the transition from ground to aerial photography in 1856 when he outfitted an aerostatic balloon to carry out the first aerial stereoscopic acquisition of Paris.

Ingenious uses were even made of carrier pigeons, which were equipped with a photographic camera for military acquisitions.

E. von Orel's brilliant creation of the "stereo-autograph" in 1909 was made possible by Pulfrich's 1901 development of stereo-photogrammetry. For the first time, this device made it possible to continuously trace contour and planimetric lines, although only from terrestrial photograms.
The first successful attempt to use photogrammetry for building measurement was made by A. Meydenbauer about the same period.

"Later studies brought W. Bauersfeld in 1923 to apply the concept of stereo-autograph to retrieve aerial photograms; he called the new instrument the stereo-planigraph."[3]
Then technological advancements made it possible to construct more effective photogrammetric cameras and plotter devices, which ultimately made photogrammetry a precise and affordable restitution technique.

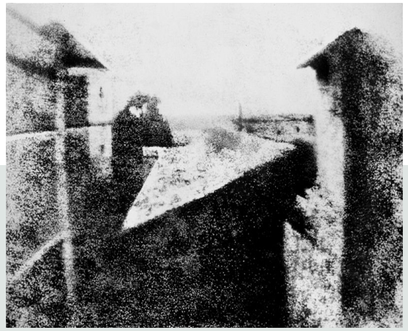
IGM Map 1899

From this modest start, photogrammetry in America developed gradually until World War I brought attention to the benefits of aerial photography for both military and civilian applications. Many of the U.S. geological survey's topographic engineers who served in the armed forces, along with others, returned with findings that inspired a great deal of interest in the potential application of aerial photography to the creation of planimetric and topographic maps.

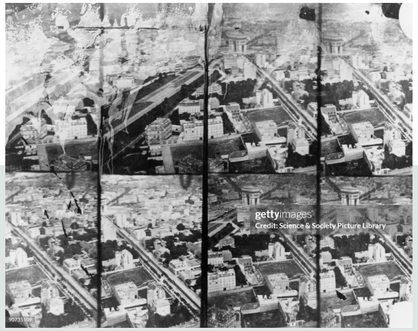
Following World War I, numerous groups in Europe and America created a wide range of improved instruments, cameras and techniques.
The reparations provisions of the peace treaty significantly expedited the post-war recovery of the production capacity of Europe's main industries, especially Germany's.

In order to plan for Europe's recovery, updated maps were desperately needed. Between World Wars I and II, photogrammetry advanced quickly. Photogrammetry had developed into a sophisticated technology by the end of the 1930s and was being used all across the industrialized world.

"In the United States interest was sufficient to motivate universities to conduct research and training in photogrammetry and led to the founding of the American Society for photogrammetry in 1934, as a member organization of the International Society for Photogrammetry." [4]
New technologies were obviously in the works by the end of World War II in 1945, and the quick development of electronic computers was what enabled the analytical treatment using photogrammetric techniques possible.



View from the Window at Le Gras' (1826), world's first photograph by Joseph Nicephore Niepce



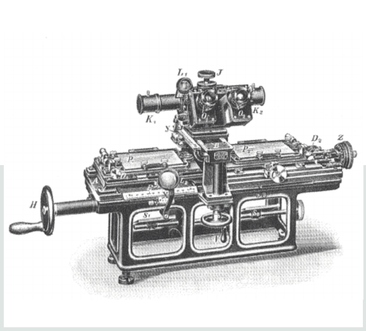
First ever aerial photograph from a balloon (1858) by Gaspard Felix Tournachon

Carrier pigeons, equipped with a photographic camera for acquisitions

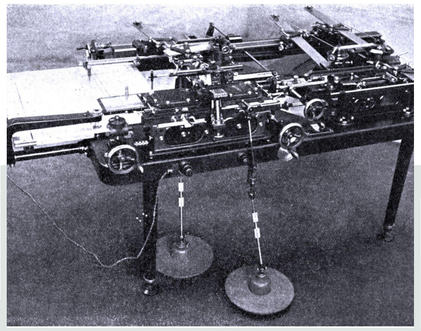
Aerial surveying and the creation of maps and charts were both impacted by electronic computing, which made it possible to substitute analytical calculation for analogic photogrammetric instruments.
At the same time, aerial triangulation has advanced significantly, reducing the reliance of photogrammetry on terrain to get support point coordinates.
The U.S. military geodesy program, which combined the many geodetic datums of the various landmasses into a single, uniform, Earth-centered system, the World Geodetic System (WGS), with both geometric and physical components, was beneficial to global photogrammetric operations.
The creation of differential rectification technologies to create orthophotos is one important advancement of the analytical period.

The advent of digital photogrammetry marked the beginning of a new technique in which specialized computers are used to process images using more sophisticated calculation algorithms, automate many of the traditional photogrammetric operations, and, more generally, collect territorial data.
Photogrammetry is a powerful method of land surveying and an important source of information for cartography because of its ability to capture and reduce synoptic views of terrestrial landscapes.

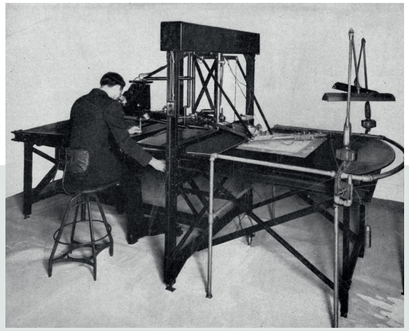
[3] Gomarasca, Mario A. (2009). *Basics of Geomatics*. Heidelberg: Springer.
[4] American Society for Photogrammetry and Remote Sensing. (2004). *Manual of Photogrammetry. 5th ed.* Bethesda (MD): J. Chris McGlone.



Pulfrich's 1901 development of stereo-photogrammetry



"Stereo-autograph" in 1909 by Von Orel



Technological advancements made it possible to construct the "Stereo-plotter" in 1939

4.1.3 Foundamentals of mathematics

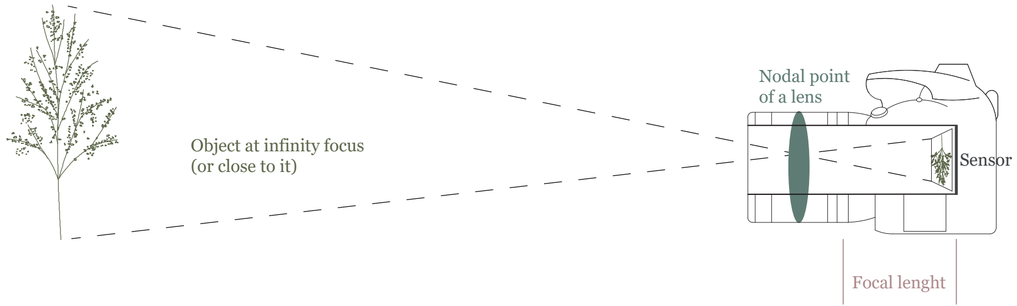
The goal of photogrammetry is to meticulously recreate the geometric connection between the object and image at the moment of acquisition.
According to the geometric model of central perspective, this is accomplished by identifying the capture centers of the individual frames between the image points and the object points of the stars of projection rays in space.

We can discuss the following based on the data representation format and, consequently, the fixing tools: digital photogrammetry if the image is recorded digitally, or traditional photogrammetry if the image is on photographic medium.

Additionally, we may distinguish between two data classes in digital photogrammetry that call for distinct acquisition techniques: images with complex capture geometry (such as linear scan or oscillating mirror) and images with central capture geometry.

Historically, there have been two different approaches to rigorous reconstruction: analytical, where the reconstruction is left to rigorous mathematical modeling assisted by digital processing, and analog, where the geometric correspondences are physically restored by optical, mechanical, and electronic components.

Digital photogrammetry refers to either a direct digital capture (digital photogrammetric cameras) or the digitization of the frames using photogrammetric scanners.
Frames having a strict central perspective of the items shown in which the projection center and the capture center coincide are found in traditional photogrammetry.



Focal lenght explanation

It can be classified as either aerial if the capture occurs from above or terrestrial if the items are positioned on the earth's surface and the cameras are likewise positioned on the ground.

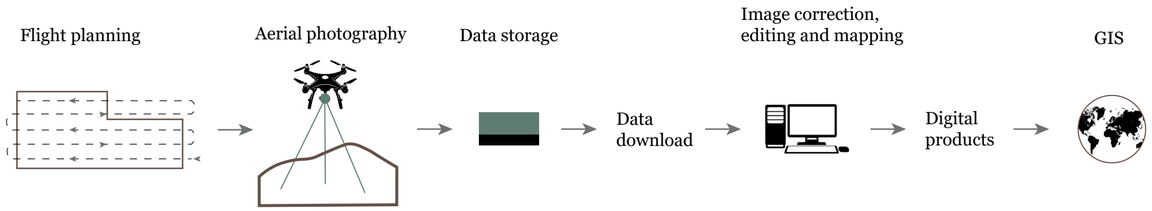
The following is a summary of the conventional photogrammetric procedure: image registration and acquisition; picture orientation and stereoscopic reconstruction of the item's three-dimensional model and restitution, which involves measuring the object and formalizing its dimensional properties.

The main characteristic of the large-sized photograms produced by photographic cameras used for photogrammetry is that they are created instantly using a special geometric scheme for the whole shown object space.

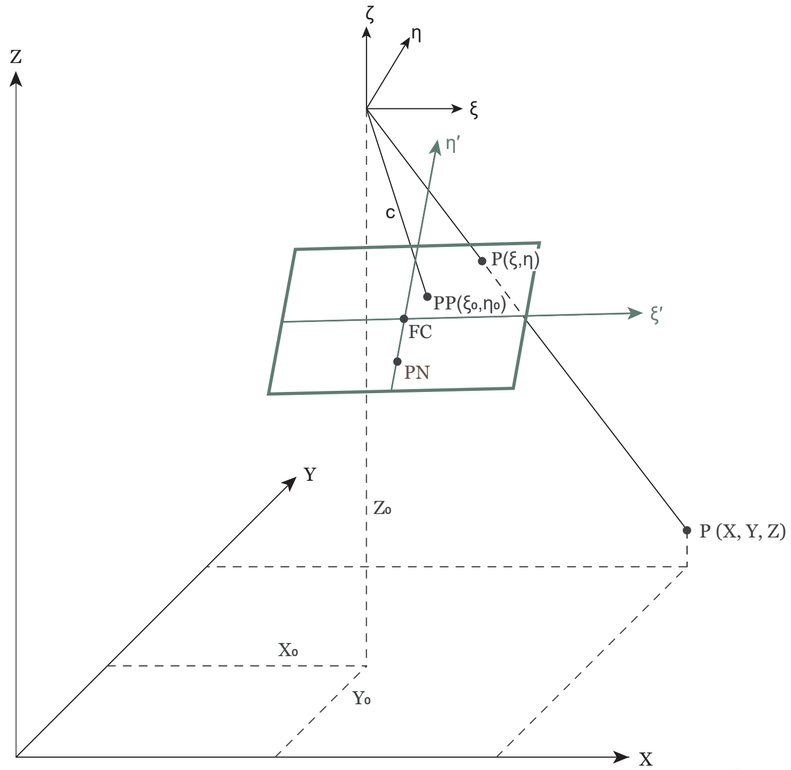
This indicates that each object point has a unique corresponding picture point that is determined by transformation laws that connect the two spaces, object and image, and whose parameters are the same for every point.

The process of orienting the photograms involves determining these parameters.
With axes ξ and η and an origin in the Principal Point (PP), the image space is distinguished by its own reference system.

"The coordinates ξ0 and η0 of the principal point PP and the principal distance c identify the position of the projection center on the image plane and define the internal orientation of the frame." [5]



Data acquisition process



Relationship between the coordinates of image points and object points

"The coordinates X0, Y0, Z0 of the centre of the shot with respect to the object reference system and the three rotation angles ω, ϕ, κ, which identify the position of the camera at the time of the shot, define the external orientation of the frame." [6]

There are nine parameters in all for reconstructing a frame's geometry, and they can be chosen in many ways.

The manufacturer's internal orientation parameters are consistent and unique to the camera. Position (GPS) and attitude (inertial platform) measurements can be used to estimate the exterior orientation parameters.
Most of the time, at least up till now, these parameters have to be approximated indirectly, such with support points.

"Collinearity equations formalize the direct and inverse relationships between image coordinates (ξ and η, ζ) and object coordinates (X,Y,Z), calling into question the nine internal and external orientation parameters." [7]

$$\xi = \xi_0 - c\,\frac{r_{11}(X - X_0) + r_{12}(Y - Y_0) + r_{31}(Z - Z_0)}{r_{13}(X - X_0) + r_{23}(Y - Y_0) + r_{33}(Z - Z_0)}$$

$$\eta = \eta_0 - c\,\frac{r_{12}(X - X_0) + r_{22}(Y - Y_0) + r_{32}(Z - Z_0)}{r_{13}(X - X_0) + r_{23}(Y - Y_0) + r_{33}(Z - Z_0)}$$

$$X = X_0 + (Z - Z_0)\,\frac{r_{11}(\xi - \xi_0) + r_{12}(\eta - \eta_0) - r_{13}}{r_{31}(\xi - \xi_0) + r_{32}(\eta - \eta_0) - r_{33}}$$

$$Y = Y_0 + (Z - Z_0)\,\frac{r_{21}(\xi - \xi_0) + r_{22}(\eta - \eta_0) - r_{23}}{r_{31}(\xi - \xi_0) + r_{32}(\eta - \eta_0) - r_{33}}$$

Every object point has an image point, according to the direct equations, and every image point has an infinite number of object points that depend on Z, according to the inverse equations.

Only with binocular vision can one receive the third dimension of objects, which is the sense of depth represented by the heights or depressions of the viewed item.

Three-dimensional vision is made possible by the eyes' simultaneous observation of the same object from two different perspectives (convergence), which causes the brain to fuse the two views. In photogrammetry, a three-dimensional image of the observed object, known as stereoscopic vision, can be obtained under specific conditions by capturing the same scene from two distinct points of view, or projection centers.

"The conditions to be met to allow stereoscopy are the following:
- The individual images used for stereoscopic vision must cover, at least in part, the same area; the stereoscopic effect will be possible only on the common covering part;

- The capture must be performed at a sufficiently constant height, so that the frames have approximately the same scale;

- The capture axes must be as parallel as possible to each other;
A minimum distance must be respected between the positions of the capture centers of the two frames participating in the restitution." [8]
From an operational perspective, controlling the horizontal and vertical parallaxes is the only way to do stereoscopy between two frames.
"If you shoot two frames in normal orientation, they will have horizontal parallaxes in the direction of the base, but no vertical parallaxes." [9]

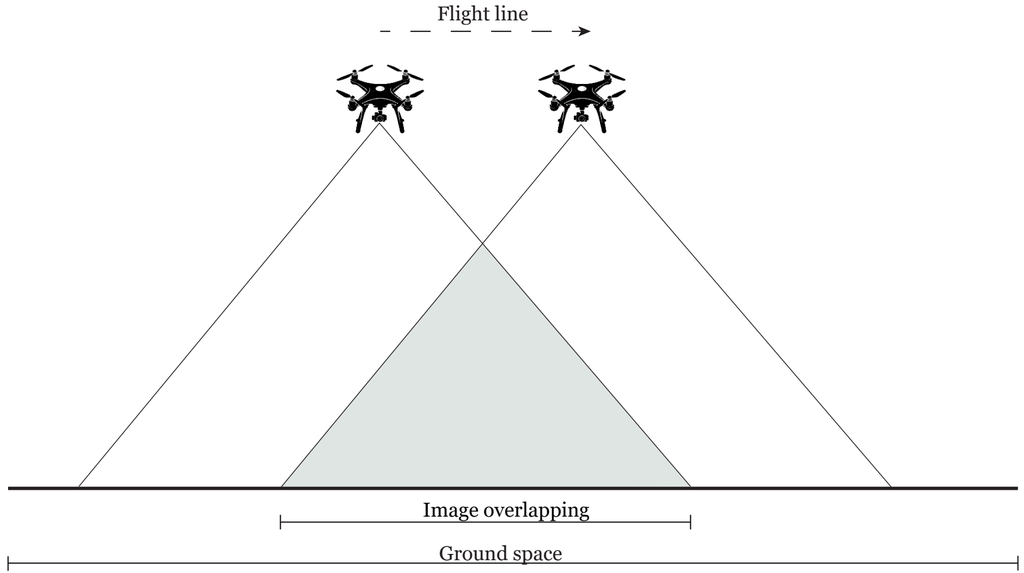
The object's depth is defined by the horizontal parallax (dx), also known as the linear parallax, which is located in the visual plane that includes the grip's base and the perceived object-point.

The relative altimetric or depth coordinate of the observed location can be obtained by measuring it.

As a result of this movement, it is intuitive to think of it as a variation of the relative distance between two object-points positioned at different distances from the hold center.

The most common instance of horizontal parallax is when someone watches the gradual relative movement of a close object in relation to a more distant point reference through the window of a moving vehicle.

Since the eye can only perceive horizontal parallaxes, it must eliminate vertical parallax (dy), also known as height parallax, which is geometrically defined as the lack of intersection between two homologous rays that are not coplanar.



Stereoscopic shooting scheme of aerial photographs or images

Looking at a high building from a distance is a typical illustration in a practical setting.

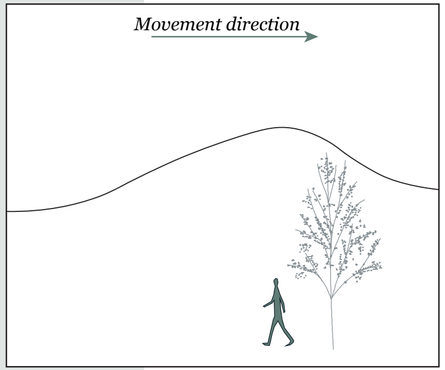
The vertical viewpoint of the structure will shift as you travel on an incline or uneven surface, and you might notice that the doors and windows are not properly aligned, which could cause visual confusion.

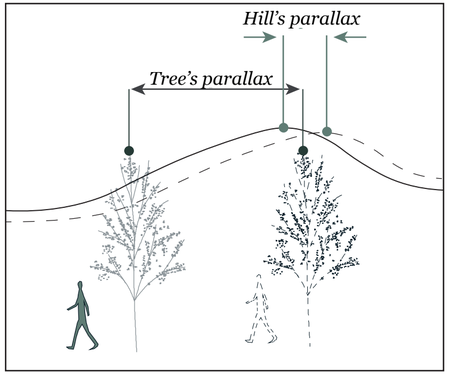
In the “stereoscopy vision” scheme is rapresented the principle of stereoscopy; since a single photograph is insufficient to precisely identify an object’s position, many photos taken from various angles are required to rebuild it in three dimensions.

To take pictures of the object from various angles, the camera moves along a grip base.

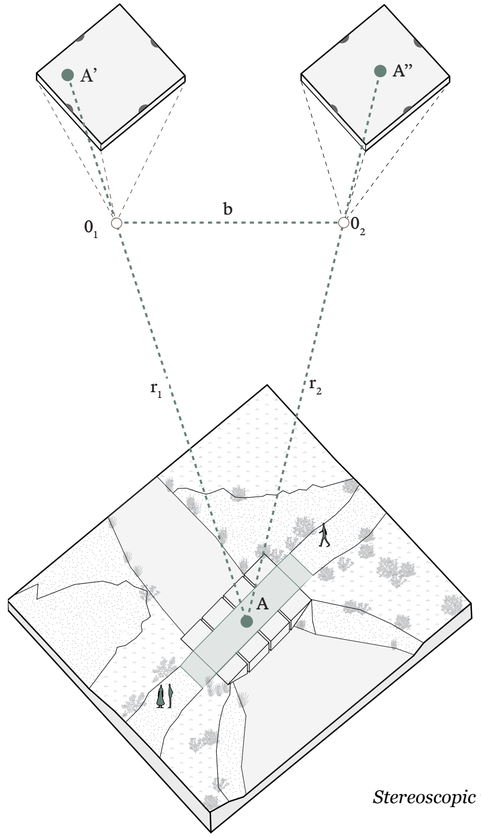
[5-6-7-8] Gomarasca, Mario A. (2004). **Elementi di Geomatica.** Roma: Associazione Italiana di Telerilevamento.

[9] Kraus, Karl. (1994). ***Fotogrammetria***. Piemonte (TO): Libreria universitaria Levrotto & Bella.





Concept of horizontal parallax



Stereoscopic vision

4.1.4 Image processing

The range of possibilities for the measurement and evaluation of photogrammetric images has been greatly expanded with the advent of digital image processing methods. Like in other areas, digital images offer us new techniques in image collecting, storage, archiving and output. But more significantly, they allow for automated image processing.

Pre-processing, segmentation (image measuring, line following, image matching), and picture acquisition (sensor technology, calibration) are the main areas in which photogrammetric image processing techniques are created and used.

"Methods appropriate to high-level image processing (object recognition) and image understanding are still under development." [10]

With the shift to digital sensing, some benefits have come to light, such as the significant improvement in image quality achieved by the lack of film grain and the additional radiometric range of digitally sensed pixels.
"Film may support a dynamic range of about eight bits per color channel whereas digital sensing may offer more than twelve bits." [11]

An essential component of image processing is the specification of the pixel coordinate system.
A standard two-dimensional picture with axes x and y defining its rectangular (Cartesian) coordinate system according to a very basic image model.

A picture is represented by the function f(x,y), which is the product of two independent functions: the illumination, which is variable, and the reflection, which is between 0 and 1 and indicates the properties of the lighted item.
The digital image is then created by dividing the continuous function into pixels, creating a matrix of rows and columns.
The number of pixels in a picture and the size of the pixel on the object are usually related to the geometric resolution of the image.
Pixel values in a greyscale image are typically quantized with an 8-bit depth, resulting in 256 grey levels that range from 0 (black) to 255 (white).

"Since human vision can only distinguish about 60 shades of grey, this pixel level depth is sufficient for a visual representation of images" [12]

A key component of image processing techniques used for image measurement is the specification of the pixel coordinate system.
The fact that film producers estimate a doubling of color film sales at the expense of black and white film since 1990 indicates that photogrammetrists have started using color film as their regular source material.

Consequently, the need to resolve the color nuances of the film sources has been a problem for photogrammetric film scanners. The same is true for digital aerial cameras, where color information is likewise important but geometric precision and detail are still prioritized.

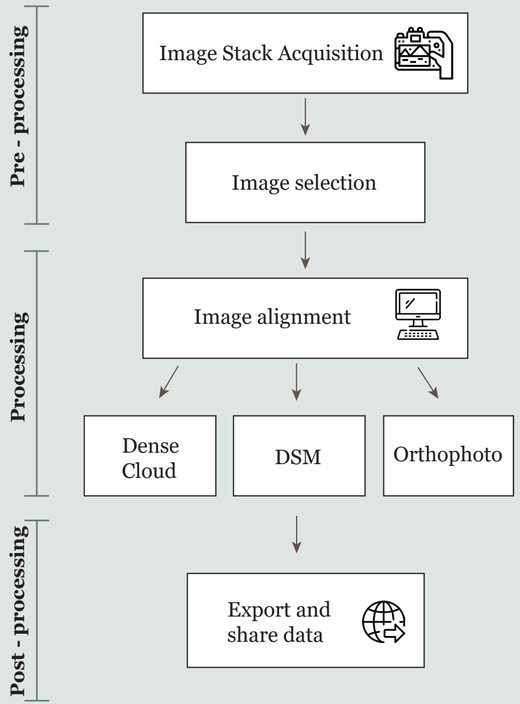


Image acquisition and processing workflow

Typically, true color images are saved using 8 bits for each of the RGB color channels and 24 bits per pixel.

Color representation is more complex. Each color pixel in a color image usually has three numbers, one for each of the colors red, green, and blue. This means that each color pixel has a total of 24 bits. When a near-infrared channel is added, each pixel has four numbers.

Only about 100 shades of gray can be distinguished by the human visual system out of hundreds of thousands of various colors and intensities. As a result, a color image may carry a lot of additional information.
There are several models that describe how color functions, but our understanding of color is still lacking. Because appropriate computer technology and memory are expensive, color has not been used extensively in digital picture processing.

The three different kinds of cones in the human retina and an object's ability to reflect electromagnetic waves with varying wavelengths and reflectivities are the sources of color. The three cone types' highest reactions occur at 440 m (blue), 545 m (green), and 580 mm (red).

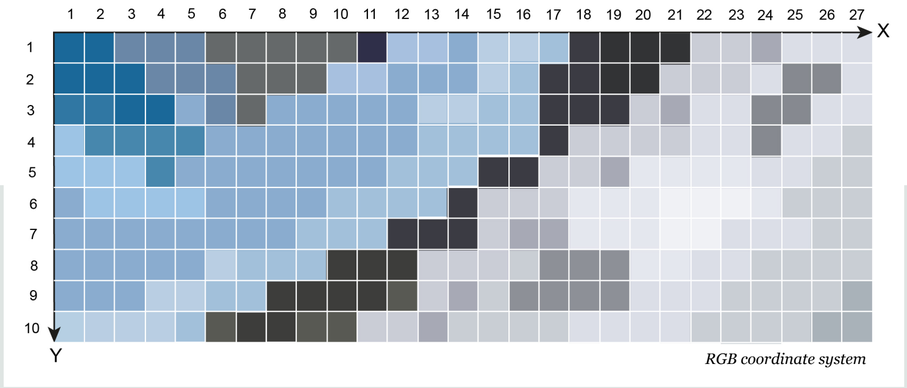
"Color is of growing interest in photogrammetry as automation of the image interpretation function evolves." [13]

The scheme refers to the RGB Pixel Coordinate System, which is related to the image next to it.

Each digital image is made up of pixels.

Every pixel has a precise location that is identified by two numbers: one that indicates how high it is (the coordinate y) and another that indicates how low it is (the coordinate x).

To determine the color of each pixel, we use a system known as RGB.



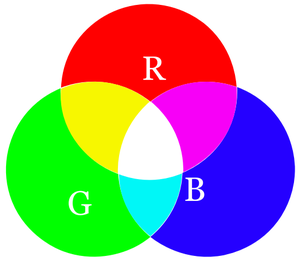
RGB coordinate system

"Color-sensitive cones are found in the fovea, the region of the eye with the highest sensitivity to color." [14]
As it turns out, these cones are not as sensitive to red, green and blue light as they are to red and green, but they are significantly less susceptible to blue light.

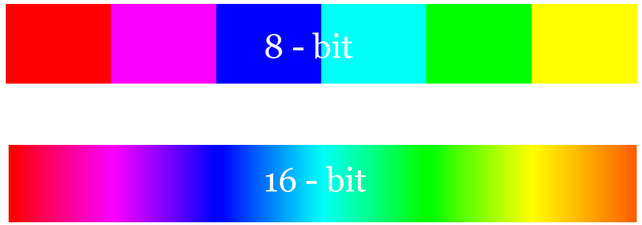
The yellow-green region is where the rods of the eye are most sensitive, and that is also where the sensitivity to brightness is highest.
According to the tristimulus theory of color perception, any color may be created by combining the three primaries: blue, green, and red. Some apparent colors cannot be matched in this manner, but almost all can.
It is possible to match one of these incompatible colors with a combination of the other two if one of the primaries is added.

By providing a 3D coordinate system and a subspace that includes all constructible colors within a specific model, color models offer a standardized method of specifying a specific color.
Every color model is tailored to either image processing software (HSI) or particular hardware (RGB, CMY, YIQ).

Porto Liscia beach June 2024 - Pixels with a distinctive color and shades (RGB)



RGB colour model



8 - BIT vs 16 - BIT depth

Three separate image planes, one in each of the fundamental colors: red, green, and blue; they make up an image in the RGB paradigm. The quantity of each of the main components that make up a certain color is provided.
The geometry of the RGB color model is used to specify color using a cartesian coordinate system.

Robust analysis requires taking into account the connectedness of pixels, particularly their neighbors, while working with images that may vary depending on variables like angle, lighting and environmental circumstances.
"In defining connectivity, neighbouring pixels are classified according to the N4 or the N8 scheme". [15]
In image processing, the term N4 connectivity refers to the relationship between pixels in a two-dimensional grid.

According to this paradigm, a pixel is related to four neighboring pixels: the ones directly above, below, left and right.
According to the N8 connectivity model, an object is a connected set of pixels that form an integral entity.

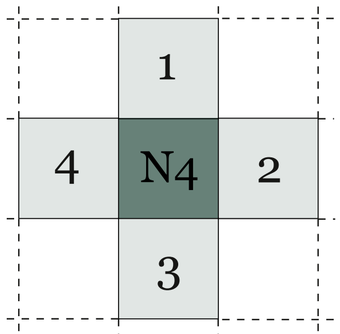
N8 connectivity encompasses all neighboring pixels, including those in the corners as well as those that share a side, unlike the N4 model.

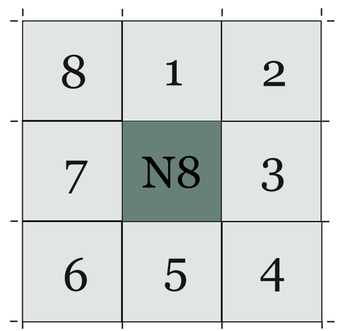
Connectivity improves accuracy and dependability in image analysis and segmentation by offering methods to overcome the difficulties caused by sudden pixel changes.

Image pyramids are data structures that represent a picture at various resolutions.

This method works very well for several applications, including multiscale analysis, object recognition, and image reduction.
So, image pyramids are powerful tools in image processing that enable efficient and versatile analysis across different resolution scales.

To sum up, image processing is an important topic that includes a variety of methods and approaches meant to improve, examine and understand visual data.
By employing sophisticated algorithms like filtering, segmentation and transformation, image processing allows us to enhance the quality of images, extract valuable information from them, and support automated decision-making.





N4 and N8 models

[10] Luhmann, Thomas. (2006). *Close Range Photogrammetry*. Dunbeath: Whittles Publishing Ltd.
[11] American Society for Photogrammetry and Remote Sensing. (2004). *Manual of Photogrammetry. 5th ed.* Bethesda (MD):J. Chris McGlone.
[12] Luhmann, Thomas. (2006). *Close Range Photogrammetry*. Dunbeath: Whittles Publishing Ltd.
[13- 14] American Society for Photogrammetry and Remote Sensing. (2004). *Manual of Photogrammetry. 5th ed.* Bethesda (MD): J. Chris McGlone.
[15] Luhmann, Thomas. (2006). *Close Range Photogrammetry*. Dunbeath: Whittles Publishing Ltd.

4.1.5 UAV

The employment of Earth observation satellites has long been linked to the idea of remote sensing, which is the gathering of data about an item without direct touch.
Recent articles about novel approaches to remote sensing from much closer distances have proliferated with the advent of unmanned aerial vehicles (UAVs), which are capable of carrying sensors and navigating using a global positioning system (GNSS).

UAVs' capacity to position themselves in the air at pre-programmed coordinate points, trace flight paths and record the coordinates of the sensor position at the time of shooting, has created the interesting subject of UAV photogrammetry.
The following duties are included in designing the photogrammetric project: create the image's geometry, the flight schedule, plan for the flight mission and determine the ground control requirements.

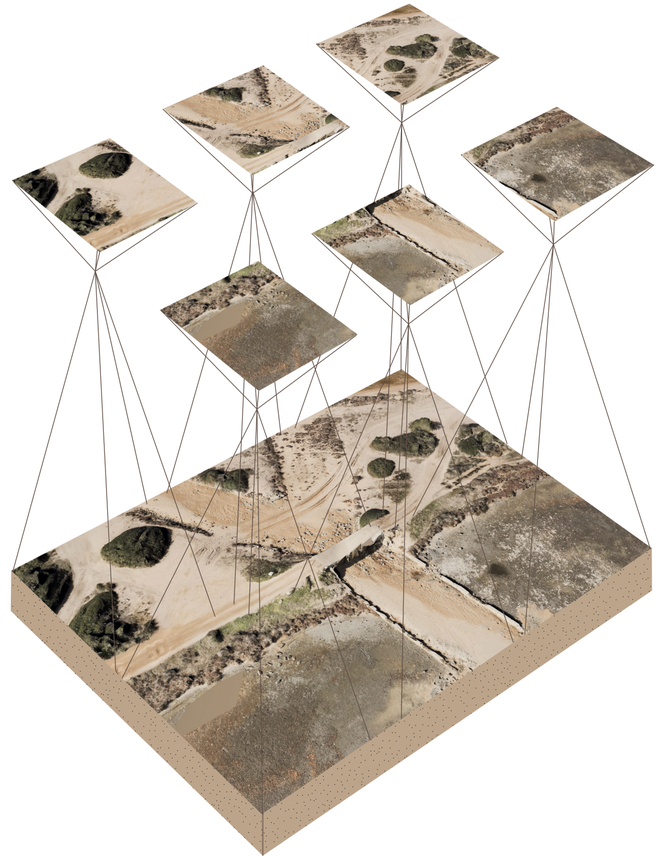
Talking about flight plan, a stereoscopic coverage of the entire mapping region is necessary, which means that each section of the landscape must be imaged from a minimum of two distinct camera locations. This is accomplished by flying in a straight line and separating the exposure stations so that each image has a common overlap.
Photograms that are adjacent longitudinally (along a strip) must overlap by 70–80%, while those that are adjacent transversally (between strips) must overlap by 60–70%.
As UAVs with integrated global navigation satellite system–real-time kinematic (GNSS RTK) become more widely available, georeferencing without GCPs is emerging as a viable substitute.

"At present, the use of UAVs equipped with an onboard global navigation satellite system–real-time kinematic (GNSS RTK) receiver is on the rise." [16]

"The easiness of flying COTS (Commercial Off-the-Shelf) UAVs and the quasi-automatic flight plan generation are currently key features for monitoring environmental risks in mid hazardous environments". [17]

To sum up, the application of unmanned aerial vehicles, or UAVs, has transformed the fields of photogrammetry and remote sensing.
UAVs provide a precise and efficient way to collect geospatial data because of their low operating altitude and simplicity of interaction with GNSS and other technologies.

[16] Carvajal-Ramirez, Aguera-Vega, Martinez-Carricondo. (2021). *UAV Photogrammetry and Remote Sensing.* Basel: MDPI.
[17] Calantropio, Chiabrando, Spanò, (2018). *UAV photogrammetry and thematic maps for environmental risk assessment in construction safety.*



Surveying with a drone

4.2 GNSS survey

The global navigation satellite system, or GNSS, is a type of system that uses active satellites to determine position.

Satellite positioning systems are employed in air, sea and land navigation as well as topographic-geodetic surveys.

The primary global positioning systems are the GLONASS (Russia), the proposed GALILEO (Europe) and the widely utilized NAVSTAR (USA).
Both self-determination (back intersection), where known points are observed from an unknown point, and direct intersection (forward intersection), where the point to be determined is observed from known points, are the conventional methods used in topography to determine the position of points.
Typically, measurements of angles and distances are carried out in both situations.

Utilizing a constellation of operational artificial satellites, the NAVSTAR GPS is the American satellite global positioning system. Supported by the US Department of Defense, it was first implemented in 1973 as a system for military ships to use during navigation.
It gives real-time position based on the WGS84 (World Global System 1984) geodetic reference system, which is applicable to the entire planet.

Through time, distance, and position data, passive self-determination enables the user to determine their three-dimensional location in relation to a geocentric reference system.

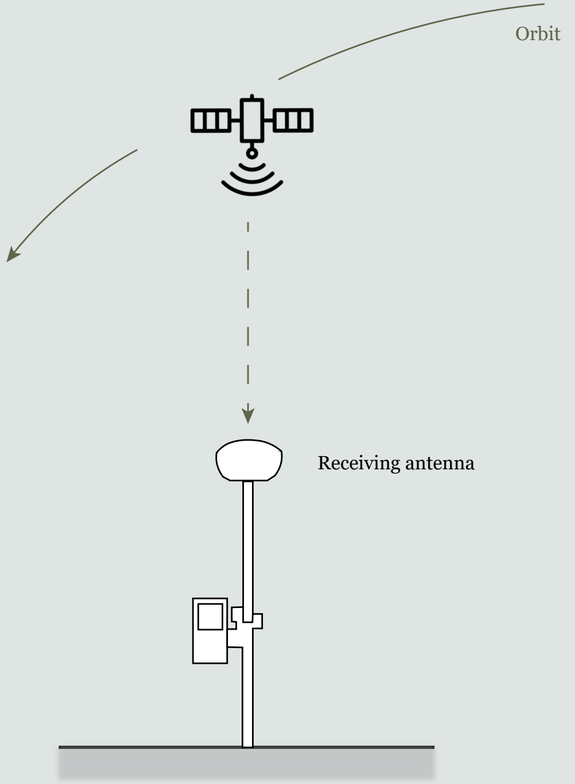
"The acquisition and processing of data occur in real time, with high precision, continuously, in any weather conditions and at any point on the globe." [18]

GNSS limitation is that it requires simultaneous vision of many satellites from the station point, which is challenging in populated regions, wooded areas and tunnels.
However, the GNSS system's connection with inertial navigation devices enables it to continue operating even in the event that satellite emissions are momentarily unavailable.

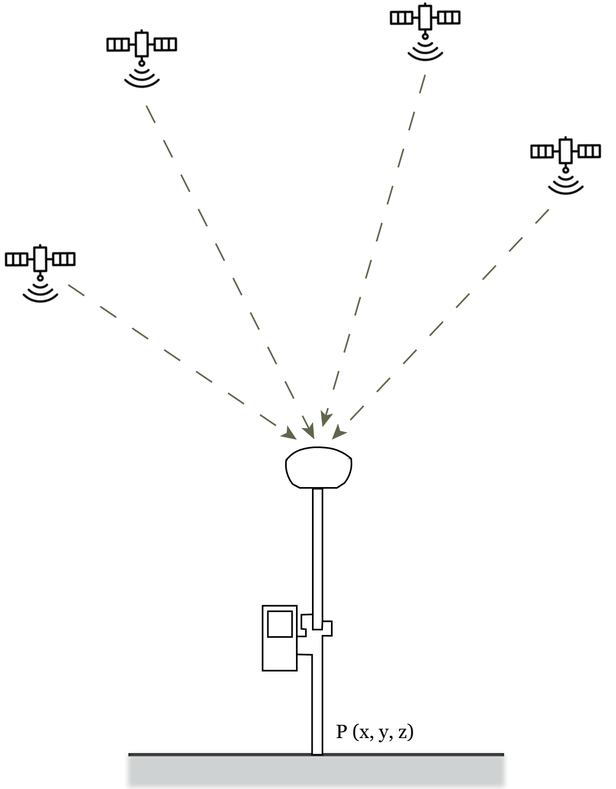
The GNSS system consists of three parts:
- The constellation of 24–32 satellites (four are reserve) makes up the space component. As they orbit the planet, the satellites continuously send out signals that include the base frequency, the satellite's identification and position, the time, which is determined by accurate on-board atomic clocks, as well as additional information.

- Five tracking, three transmitting, and one master ground station make up the control component.
These stations monitor the satellites' orbital behavior, make the required adjustments, oversee their operation, and enable the space element to always provide accurate space-time information.

- The ground receivers serve as a representation of the user component, interpreting (decoding) and processing the signals that the space element transmits.



Measurement of the receiving station-satellite distance



Global positioning stystem: at least four satellite are used to compute the spatial coordinates

Natural GCP (V24)

Natural GCP point measured with the rover

GCP marker measured with the rover

The GNSS receiver self-determines distance measurements by using satellites as trigonometric points.

The distance between the receiver and a specific number (≥4) of satellites at a specific time must ultimately be calculated.

The constant series of constantly shifting positions is caused by errors of many kinds, including processing, systematic or model, instrumental and observational errors.

The application of a combined set of techniques that can eliminate or minimize the impact of these inaccuracies on location measurements has made it feasible to utilize GNSS for geodetic applications.

By monitoring the flight duration of the electromagnetic pulses that the satellites emit, which contain their position and the time t, of departure, the satellite-receiver distance is determined.

By monitoring the phase difference between the code generated locally by the GNSS receiver using the same procedure and the code that arrives from the satellite, the time is determined.
The clocks of the satellite and the receiver are not synchronized.
All of the factors that go into determining the receiver location have an impact on how accurate the result is.
Final positioning mistakes in the receiver are caused by their imprecise measurement.
An estimate can minimize some of these inaccuracies, while proper operational detection processes can eliminate others.

Improving accurancy with GCPs from MetaShape

It is crucial to place the antenna as far away from the receiver as possible in open spaces since the location precision that GNSS measurements provide increases as more satellites communicate with the receiver at once.
GNSS measurement errors can be systematic or unintentional.

About 1 ms is the synchronism error, or receiver fundamental scales, which results in a measurement inaccuracy of roughly 30cm, which is quite little.

The GNSS system is susceptible to several types of mistakes, which can be eliminated entirely or in part by implementing certain safety measures and technological fixes.
The operator's measurements may contain inaccuracies, which could be systematic or caused by the system management (SA).

The US Department of Defense implemented the Selective Availability (SA) program to purposefully add clock noise to GPS satellite signals, reducing its accuracy for civilian users.
This results in a 100-meter circular inaccuracy, which affects the ground measurements.

The accuracy was increased by developing the differential GPS (DGPS) and adding a local ground station to assist the satellite-based stations in order to get around this restriction.

The differential mode (DGPS), which requires at least two receivers, one on a known point (master instrument) and the other on the point to be determined (rover instrument), was employed in the surveys conducted during our team direct experience.
If the rover and master are sufficiently close, the coordinate discrepancies that are discovered on the known point as a result of system errors enable the data obtained from the instrument positioned on the point to be evaluated to be corrected.
Specifically, the relative mode produces high-precision measurements by using two instruments at the same time, one of which is on a known location.

Nowadays, the Real Time Kinematic (RTK) mode, which is based on processing code and phase observations in real time, is where the relative survey is primarily utilized.
GNSS receivers have been permanently installed on some of these locations to create a network of permanent stations connected to a computing center.

The mistake of the data sent by the GNSS satellites is promptly detected by a network of ground stations, which then model the data in the form of a grid in relation to the system coverage area.
The orthogonal Cartesian coordinates X, Y, and Z, which correspond to the WGS84 geocentric axes trio, make up the GNSS measurement result.

As previously mentioned, the GPS system can be effectively utilized for terrestrial, aerial, and maritime navigation as well as geodetic-topographic surveys.

[18] Amadio, GianFranco. (2012). *Introduzione alla Geomatica*. Palermo: Dario Flaccovio Editore.

4.3 GIS Geographic Information System

Today, the information system (e.g. computer or software) has replaced maps, tables and other media that were used as a means of presenting geographical information.
The replacement of paper media by digital media has led to an overhaul of the methods of capturing, storing, using and presenting geographical information and has ushered in a new era of access and dissemination.
All data stored on magnetic disks or CD-ROMs is stored in the information system.

"The real revolution took place when the computer tool allowed us to perform spatial analysis on real objects by examining a computer model of them." [19]

The data-rich computer system is called a Geographic Information System (GIS).
"It is a computerized geographic information system that processes information from geographic data and enables its collection, recording, display, sharing and presentation". [20]

For our initial analysis, we used the software Qgis, which contains a database of geo-referenced data representing their geographic position in one of the reference systems present in it.
This allowed an initial analysis and knowledge of the area to then proceed with more specific detailed analyzes on different topics.
"GIS can process a huge amount of data describing the environment in an advanced mode both during ordinary and extraordinary situations" [21]

Geographic information system enables the computer-aided organization of geographic data relating to objects and phenomena on the surface of the earth.

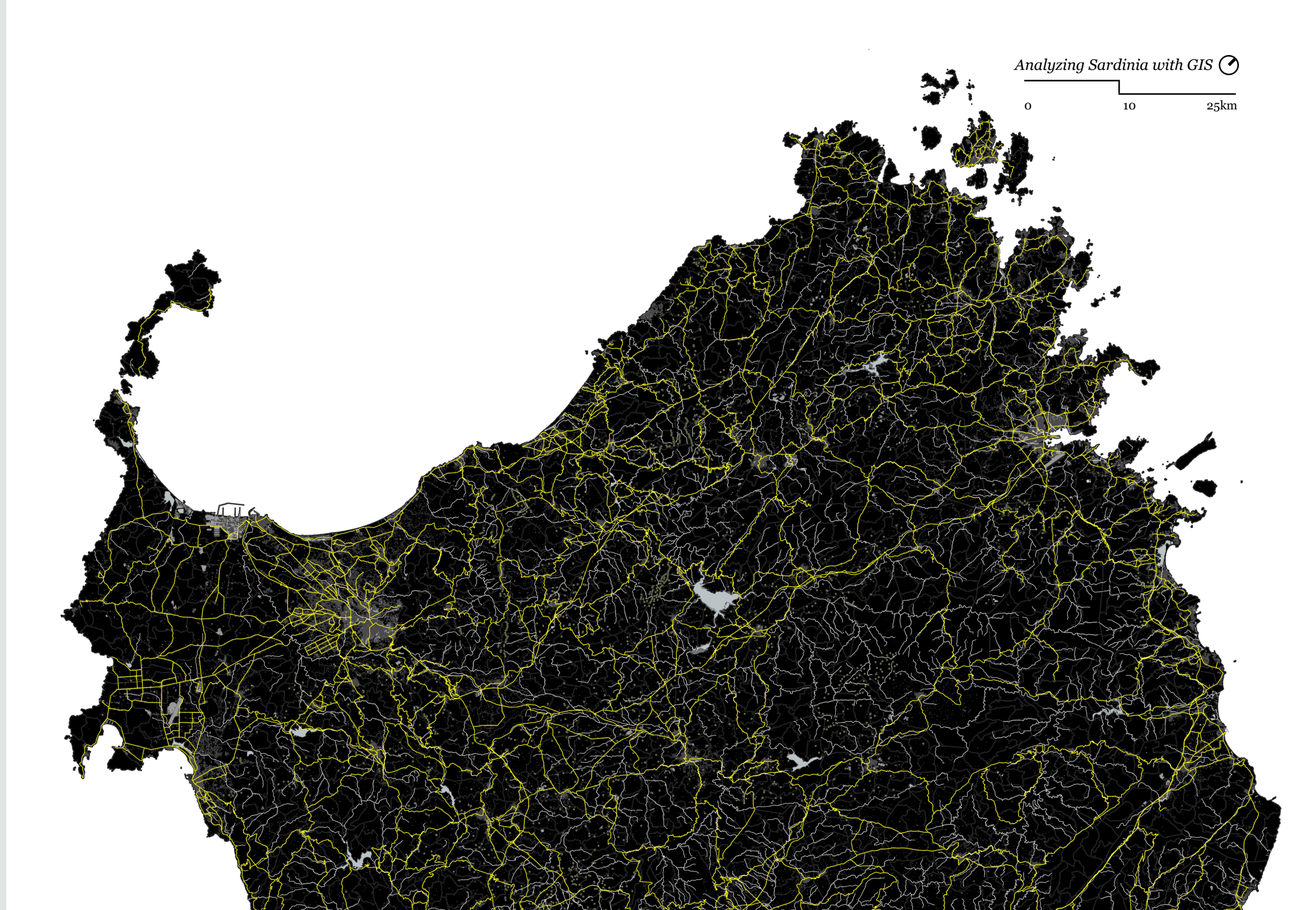
"These objects with their characteristics and properties are described by spatial and alphanumeric attributes" [22]

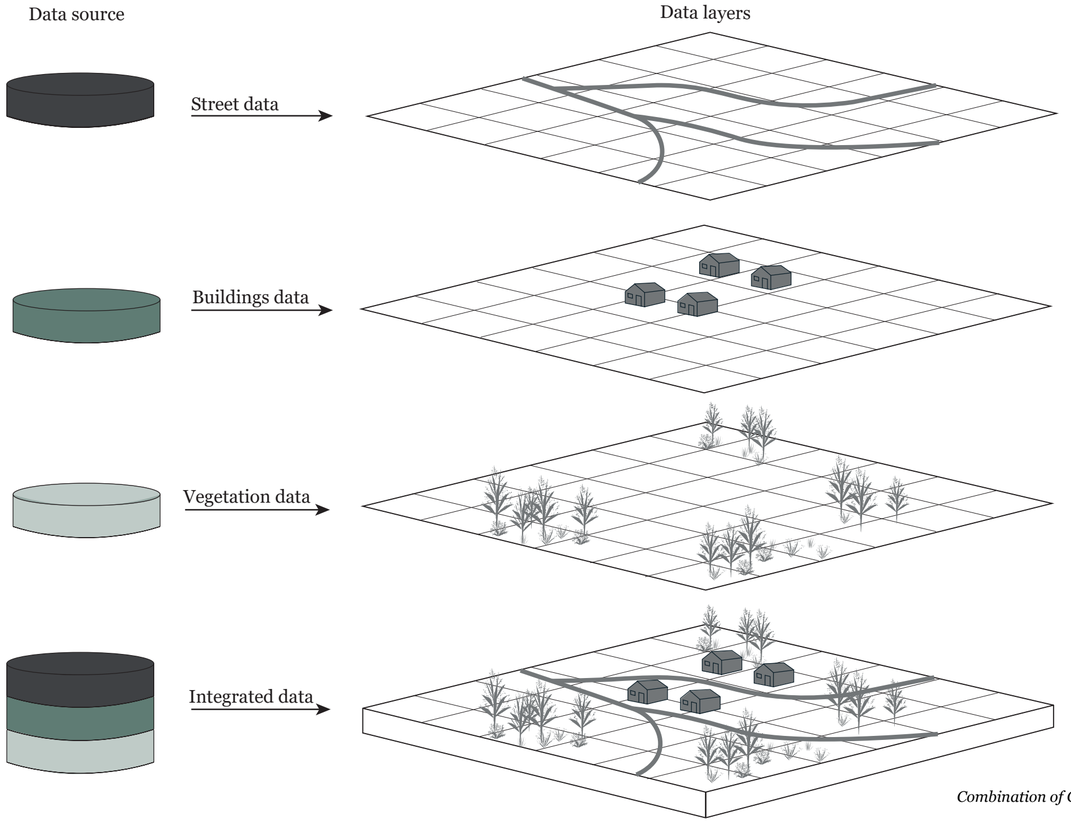
The characteristic of these objects in computer systems is that they contain information about their properties, such as shape and position; therefore, GIS represent objects that are georeferenced with respect to a cartographic reference.

In our analyzes, we have used geometric information by creating shapes such as polygons, lines or points; topological information such as the distances between one point and another, necessary to calculate the distance, especially with regard to the new proposal on the "Cammino delle 100 torri"; informative information, which in our case includes textual data such as the addition of the names of the places in the area in question.

The spatial data can be vector data, raster data or mixed data.

Collecting data has a significant impact on the final cost (between 70 and 80%) as it is also closely linked to the cost of software and hardware. Metadata is very important as each file must contain information about the data quality, accuracy, completeness and updating of the data it refers to.





Combination of GIS data

Since the 1960s, GIS has been able to manage vector data.
In the geometric vector model, primitive elements are used, such as: points, each containing a pair of coordinates, surfaces or closed polylines and nodes, which are points representing the position of an element.

"The relationships existing among the geometrical primitives (nodes, areas and polygons) are called topological relationships." [23]

The vector format has several advantages, including: it does not involve a large use of memory space, and the level of accuracy and quality of the data is always high (for example, the quality does not decrease if you zoom).

Since the 1970s, however, it has been possible to use raster data in GIS.
The raster model consists of dividing spaces into a network made of rows and columns, creating a grid. Each cell defines a portion of land in space.
Each cell hosts an attribute of the soil in that geographic position. So, if we have multiple attributes, these will have to be positioned in different rows of the grid.

Unlike vector data, raster requires the use of a large amount of memory to be stored because the accuracy depends on the size of the cell on the ground and this influences the size of the file.

The main objective of GIS is to compare multiple layers of different data, superimpose them, and thus create new information thanks to intersection and union operations.

"This does not just produce a graphical effect but generates new information at both the geometry and the attribute level." [24]

When using GIS, errors may arise; they may have different origins. The most obvious is the positioning error, but there are many others that are less obvious.

These conceptual or logical errors can compromise the accuracy of the attribute position. Some errors can be avoided because they are caused by lack of attention or superficiality.

There are also propagation errors; they are caused by the transformation of data into digital format, which can create various errors.
The use of incorrect data thus creates new errors.

So, when propagation errors are transferred and used as a basis multiple times, in that case we have cascade errors.
Being able to access and download GIS data is now simple and fast; we only need a good network connection and a good browser. In GIS data distribution, security is essential, as the original data must not be affected by unauthorized access.

[19] Amadio, GianFranco. (2012). *Introduzione alla Geomatica*. Palermo: Dario Flaccovio Editore.
[20] ebw.it/cose-un-software-gis-e-a-cosa-serve/
[21] Gomarasca, Mario A. (2009). *Basics of Geomatics*. Heidelberg: Springer.
[22] Amadio, GianFranco. (2012). *Introduzione alla Geomatica*. Palermo: Dario Flaccovio Editore.
[23-24] Gomarasca, Mario A. (2009). *Basics of Geomatics*. Heidelberg: Springer.

4.4 Team DIRECT's experience

4.4.1 Mission June 2024

During the month of June 2024 we were able to approach for the first time the work of Team DIRECT (disaster recovery team), a working group of the Polytechnic of Turin that deals with geomatics for the management of catastrophic events.

The objective of this mission was to deepen and complete the work of surveying and exploring the seabed carried out on the Island of Culuccia, directly dealing with both the island and the wetland adjacent to it.

This allowed us to experiment with the use of cutting-edge instruments, deepen our knowledge of the area and help us identify the problems present.

The realization of the survey started from the identification of points in natural elements, used as GCPs (ground control points), that are, reference points defined and measured with precision on the ground that have known geographical coordinates.

It was essential to find natural points that are easily identifiable in the images acquired by drones, such as stones or anthropic elements, which will then be inserted into the photogrammetric software 'Metashape'.

These points were detected using the Stonex S 990 as a rover, equipped with an advanced GNSS card capable of supporting multiple satellite constellations.

The receiver is equipped with an Android Handheld GNSS RTK system that allowed us to detect data and photos quickly and easily.

Before flying the drone, it is necessary to check the weather conditions that were favorable during that day, since there was little wind and the sky was cloudy allowing an almost total absence of direct solar radiation.

We then carried out the flight plan, with an area of 830,000 square meters, a height of 100m, a duration of about an hour and an overlapping of longitudinal overlapping of 80% and the transversal one of 65%.

We used the latest generation DJI Matrice 300 RTK drone, widely used in various contexts such as mapping, search and rescue; the Playload DJI Zenmuse P1 camera was mounted on it, capable of taking high-resolution images that were essential during post-processing and creation of by-products such as orthophotos.

DJI Matrice 300 RTK with Playload DJI Zenmuse P1 camera

4.4.2 Data processing

The flight produced about 2014 shots in the wetland that, once processed on 'Metashape', allowed the creation of the various documents that we will examine in more detail later.

All these images were inserted into the 'Agisoft Metashape' software, commonly used in the architecture and survey sectors, which allowed, as a first step, the alignment of them to create a reconstruction of the 3D model.

To obtain a good alignment it was necessary to import the GCPs taken during the survey, with the WGS84 – UTMzone32N (EPSG::32632) reference system.

Therefore, we collimated each GCPS with every natural point in every picture, placing a green flag. However, because some of them were inaccurate because of low visibility, we turned off four of them to achieve a good accuracy, resulting in a 5cm error for control points.

This alignment then produced a medium-quality dense cloud, which processed 738,778,813 points in about two hours.
"A point cloud may consist of millions of points for a high-quality representation of a real-world 3D scene." [25]

In order to accurately describe 3D areas, 3D point cloud data is essential.
A variety of multi-platform/multi-resolution tools have been created as a result of technological advancements, making it easier to obtain point cloud large data.

Even though the processing step is extremely complicated due to the large number of points, it is carried out by specialized software to create dense image point clouds with color information.
The result of the point cloud creation process was then the basis for the creation of the DSM (Digital Surface Model), describes the earth's surface, including objects placed on it, such as buildings, vegetation, using known geometric primitives.

By interpolating between the points, a continuous surface is created, representing the topography of the area, including all the objects on the surface. This process ensures that the DSM captures even the smallest details, providing a true representation of the surface.
The data processing required 14 minutes.

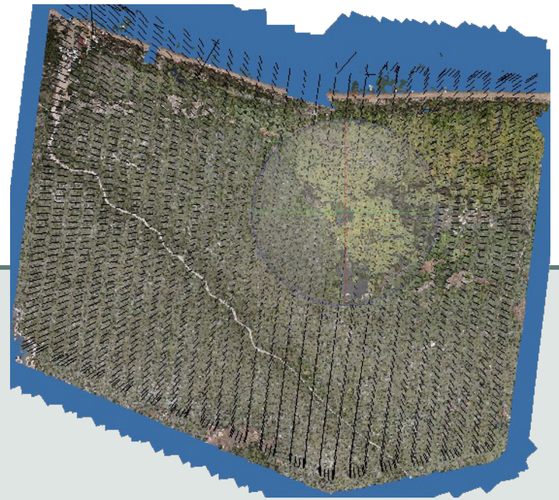
As a final photogrammetric product we generated the orthomosaic, consisting of photographic shots, aerial or satellite, geometrized on which we can measure and define the position and size of visible objects. Each orthomosaic preserves the real proportions and dimensions thanks to its geometric correction to have an accurate representation of the area concerned.

We generated the orthomosaic with the acquisition from June 2024, with a quality of 2 cm/px; it was related to the new area, from the main parking lot all along the 'Sciumara' street.
This was then combined with the orthomosaic created in 2023 to have a complete overview of the wetland and the beach area of Porto Liscia, also including the work previously carried out on the island of Culuccia.

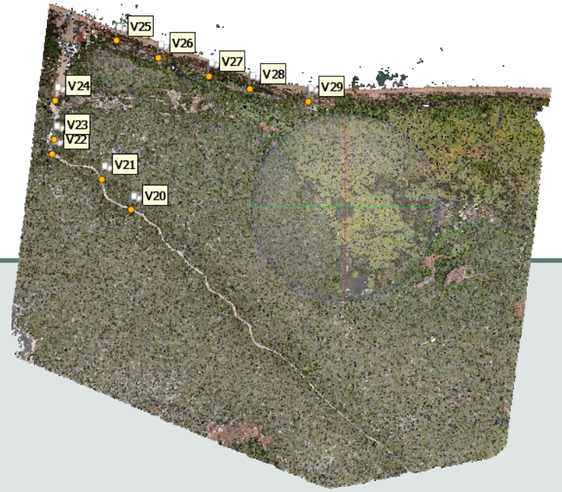
Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Yaw (°)
DJI_20240620154846_0001						
DJI_20240620154848_0002						
DJI_20240620154849_0003						
DJI_20240620154851_0004						
DJI_20240620154853_0005						
DJI_20240620154855_0006						
DJI_20240620154856_0007						
DJI_20240620154858_0008						

Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
V25	524906.169000	4560044.919000	1.491000	0.005000			
V27	525097.248000	4559969.796000	0.825000	0.005000			
V28	525181.903000	4559945.188000	0.711000	0.005000			
V24	524777.903000	4559920.797000	1.818000	0.005000	0.010366	5	0.758
V22	524773.133000	4559809.141000	5.401000	0.005000	0.027395	10	0.655
V20	524937.769000	4559693.871000	10.061000	0.005000	0.039262	13	0.883
V29	525302.997000	4559918.817000	1.138000	0.005000	0.048786	3	5.745
V21	524876.088000	4559755.406000	7.501000	0.005000	0.058993	6	4.670
V23	524777.379000	4559838.761000	6.308000	**0.005000**	0.088164	5	6.572
Total Error							
Control points					0.051692		3.321
Check points							

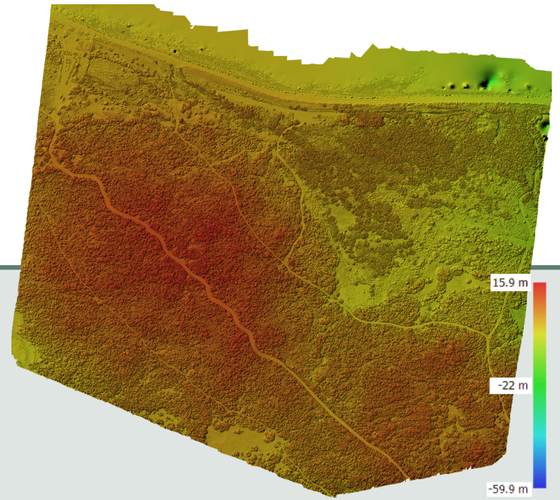
GCPs Error check



Dense cloud with frame alignment



Dense cloud with GCPs pointsts



DSM (Digital Surface Model)

Orthophoto survey June 2024

0 100 200 500m

Ortophoto joining 2023 and 2024 survey

0 100 200 500m

The survey conducted on June 2024 is referred from the main parking lot till 'la Sciumara' road, taken into consideration in our thesis work.
To have a full overview of the wetland and beach area, the survey of February 2023 and the one of 2024 are joined together, but we still can see the differences based on the different weather conditions during the surveys.
Both ortophotos are generated with a quality of 2cm/px.

In conclusion, the technology and tools employed during this survey were essential to the investigation and survey of Culuccia Island and the nearby wetlands. Ground control points (GCPs), which are essential to the photogrammetric procedure, could be precisely identified and measured thanks to the employment of high-precision equipment like the Stonex GS18 GNSS receiver.
The Zenmuse P1 high-resolution camera on the DJI Matrice 300 RTK drone made possible to take complete aerial photos over a vast area. Together with careful planning and good weather, these instruments made sure that the data collected was precise and reliable, which made it easier to create orthophotos and improved our understanding of the site as a whole.

In our opinion, this experience was quite beneficial since it allowed us to work with modern technology and improved our practical comprehension of procedures linked to geomatics.
\
We were able to handle practical scenarios where theory was applied in reality, which enhanced our ability to work with specialized equipment like drones and GNSS systems.

[25] Li, Gao, Gao. (2024). *Point Cloud Compression*. Springer.

05

Critical nodes

We discovered three crucial aspects about Culuccia's accessibility that lead to a number of challenges when trying to get there.
These points were the starting point for reflections on the territory, purely of a naturalistic and functional nature for those who often visit this area.

Our objective was to identify, evaluate, and deconstruct the issues in order to provide solutions that would enhance the current state of conditions.

La sciumara' street June 2024

5.1 Accessibility problems:
low visibility in 'la Sciumara' street

The risk of "la Sciumara road", which must be navigated in order to reach the island and the beach of Porto Liscia, was an issue we ran into during our two inspections of the area surrounding the Island of Culuccia.

The asphalt road SS133 bis continues as the La Sciumara road, which has a narrow and irregular pavement and goes through uncultivated vegetation. Its surfaces are characterized by holes and extremely sharp turns that seriously compromise vision for crossing animals as well as for cars traveling in the other way.

Animals in their natural habitat are seriously endangered when fast-moving vehicles pass on a road with limited vision.
Actually, drivers might have to deal with unforeseen circumstances, which could have fatal repercussions.
Furthermore, pollution and noise can stress them out and make it harder for them to locate food and shelter. Therefore, it's critical to create a safe habitat for local wildlife as well as drivers.
We observe a total lack of signs, which makes it challenging for pedestrians and vehicles to find their way about, particularly in new places. Route delays and confusion may result from this.
In addition, the roads can be particularly dangerous at night or in low visibility due to a lack of reflective signage.
All of this makes accidents more likely.

To sum up, the "la Sciumara" road requires maintenance.
Enhancing this infrastructure would help maintain the appealing qualities of this special location in addition to increasing traveler safety.

Podarcis tiliguerta
Photo Lorenzo Rivella

Parking lot June 2024

5.2 Main flora risk:

principal parking lot

The parking lot in front of Porto Liscia's beach is the second issue we will examine in this thesis.

We are in the area known as "Costa Smeralda", which is a wealthy and popular tourist destination in northern Sardinia.
Furthemore, because the weather is ideal for surfing most days of the year, surfers are quite familiar with the Porto Liscia beach.
As a result, in addition to the large number of visitors who visit the beach during the summer, athletes from all over the world enjoy going to it during the cooler months.

However, the facilities available near this beach do not correspond to the volume of visitors, which has led to the partial extinction of the local wildlife.
Since more people and cars have resulted in more invasive parking inside the natural habitats, the rise in car traffic has therefore contributed to the retreat of vegetation in this area.

Additionally, even the protected areas have been impacted by the creation of additional sites near the main parking lot that were formerly entirely covered by vegetation.

As was previously mentioned, there are a number of restrictions surrounding this area because of the substantial wildlife value that exists there.
As a result, it is imperative that special attention be given to protecting this environment.

In this context, it's worth mentioning the Culuccia Island Naturalistic Observatory's annual program that involves spending a day with kids in the Porto Liscia wetland to clean up items that are typically left behind by tourists or washed back by the sea.

Summarizing, the subject of parking in front of the Porto Liscia beach is a complicated one that touches on both sustainable tourism management and environmental preservation.

The biodiversity of this priceless area of the Costa Smeralda is under danger due to the harmful effects of increased vehicle traffic and inadequate services on local flora and wildlife.

However, programs like the Culuccia Island Naturalistic Observatory show that community participation in environmental conservation is feasible and can educate the next generation about the need of preserving ecosystems.

It is essential to keep coming up with solutions that strike a compromise between the requirements of tourists and environmental preservation, like regulated parking, the usage of alternate ways of transportation and awareness-raising initiatives.

The beauty and natural wealth of Porto Liscia can only be preserved for future generations by taking an integrated and sustainable strategy, which also ensures that tourists have a good time and that the environment is respected.

Bridge June 2024

5.3 Accessibility problems

Bridge collapse

The only direct access by land to the wetland and adjacent Culuccia island was represented by this small reinforced concrete bridge, used mostly by locals or from the workers of the Island.

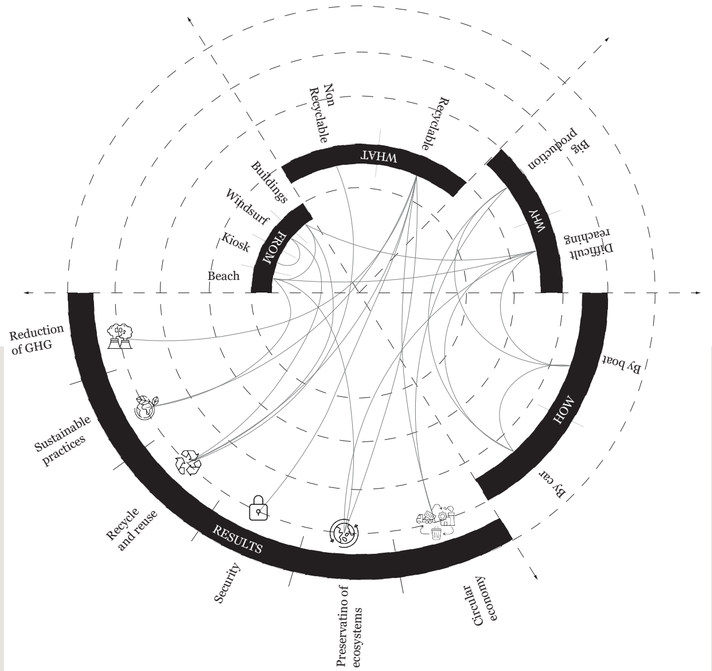
Because using the bridge is neither restricted or supervised, it has resulted that the vehicles stops in a protected area such as the wetland, which daily disrupts the natural habitats and disturbs migratory species such as birds, which seek a quiet spot in this area after their long journey.

In particular, during the survey in June, we noticed how the presence of animals such as dogs, brought by people, encourages the movement of birds present in the area, which are frightened by them.
On one hand, the bridge's collapse during spring caused inconveniences, particularly for staff arriving by land or for the transportation of garbage to Santa Teresa's ecological center;
on the other hand, this guaranteed a less frequent use by cars that usually park near the bridge and go by foot near "la Peschiera".

In June we were able to notice the presence of a new path adjacent to the bridge that causes the passage over a protected area, causing more damage for the nature than having a new bridge.

The streaks of the machines, like the John Dears of the island, leave marks on the ground, a sign of an obvious issue to be addressed.

Bridge February 2023



Waste management in the Island

Transport to the island is necessary for example for the transport of waste but also of equipment or heavy materials, which cannot be transported by sea.
The bridge's collapse make us to understand the extent to which this situation could cause inconvenience for those who need to access the island on a daily basis, particularly in the area of waste disposal. We conducted an interview with Nilas, a worker of the agricultural company Culuccia, in May 2024.

Question 1: ***How often is the waste taken to the landfill?***
Answer: Our waste must be divided into two categories: produced on the island and which we collect from the beaches.
If we focus on the waste we produce on the island, these are more frequent rounds. It is necessary to make a pass every week to take everything to the landfill as they also have to deal with organic waste which, if left lying around, could cause a smell problem and attract wild animals. So once a week we take care of visiting the interesting places of interest on the island like the houses, the general infrastructure where we create the electricity and the pier.
As far as the waste on the beach that arrives by sea is concerned, we usually take time once a month to collect and dispose of it.
In the winter months we clean more frequently, while in the summer months we mainly clean the areas where most people pass by.

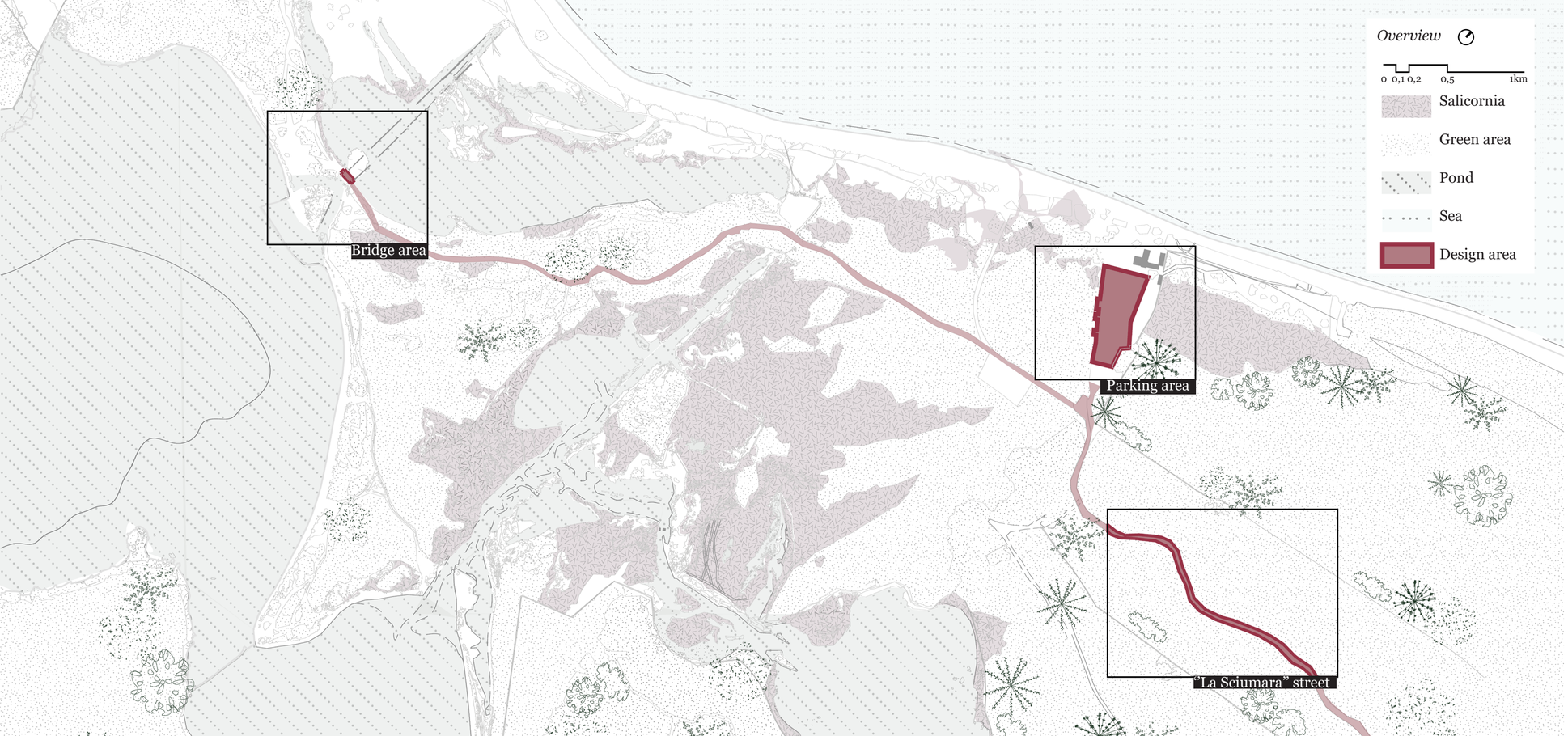
Question 2: ***Is waste separation practised?***
Answer: Yes, what we produce is automatically sorted and then taken to Santa Teresa, where the eco-island is located. In recent years, they have taken great care to ensure that waste is separated as much as possible, otherwise it will not be accepted at all.
So on this eco-island there are containers for disposal.
In Santa Teresa they go from door to door to collect the waste, but although we belong to the municipality of Santa Teresa and would have the right for them to come and collect our waste, this does not happen because it is too inconvenient for them to come to the island.
In addition, we produce larger quantities than a house and so of course the quantities have to be disposed of, one garbage can would not be enough.

Question 3: ***Is the waste on the island disposed of in any way?***
Answer: Even the wet waste is taken to Santa Teresa, as it is organic material it attracts a lot of wild animals.
There was an idea to put compost garbage cans, but as we said, that would attract animals and make them tame and even dangerous for humans.

Question 4: ***How have you managed garbage collection since the bridge collapsed?***
Answer: The bridge has collapsed, but it is still possible to cross it on foot in one part. It is risky, but if we carry the vehicle loaded with waste on one part of the bridge and wait for another vehicle on the other side of the bridge, we can pass the bags by hand.
Otherwise, we use one of our boats, which docks at the landing stage and is loaded and transported from there, but we only do this if we have very large quantities of waste.
Of course, this situation is unpleasant for us and much more unpleasant than before the bridge collapsed, but we must adapt.

06

Design solutions



6.1 Interested portions

As illustrated by the overview, our thesis's proposals for design are organized into three primary interventions: the bridge, the main parking lot, and the intervention in "la Sciumara" street.

One of the most important components of this field is accessibility; we found out that the bridge that linked the surrouding to the Island of Culuccia collapsed a week after our initial visit.
The necessity of taking action to address the access issue was further highlighted by this incident.

The road "la Sciumara" is another major issue. The only way to get to the island of Culuccia and the Porto Liscia beach region is over this tiny, uneven and rough road.
Its risky condition presents a danger to both travelers and the local wildlife because the route is extremely narrow and poorly visible, offering little protection for users.

Last but not least, we saw that Porto Liscia beach is a popular location, particularly for surfers and tourists, with an increasing number of visitors all year long.

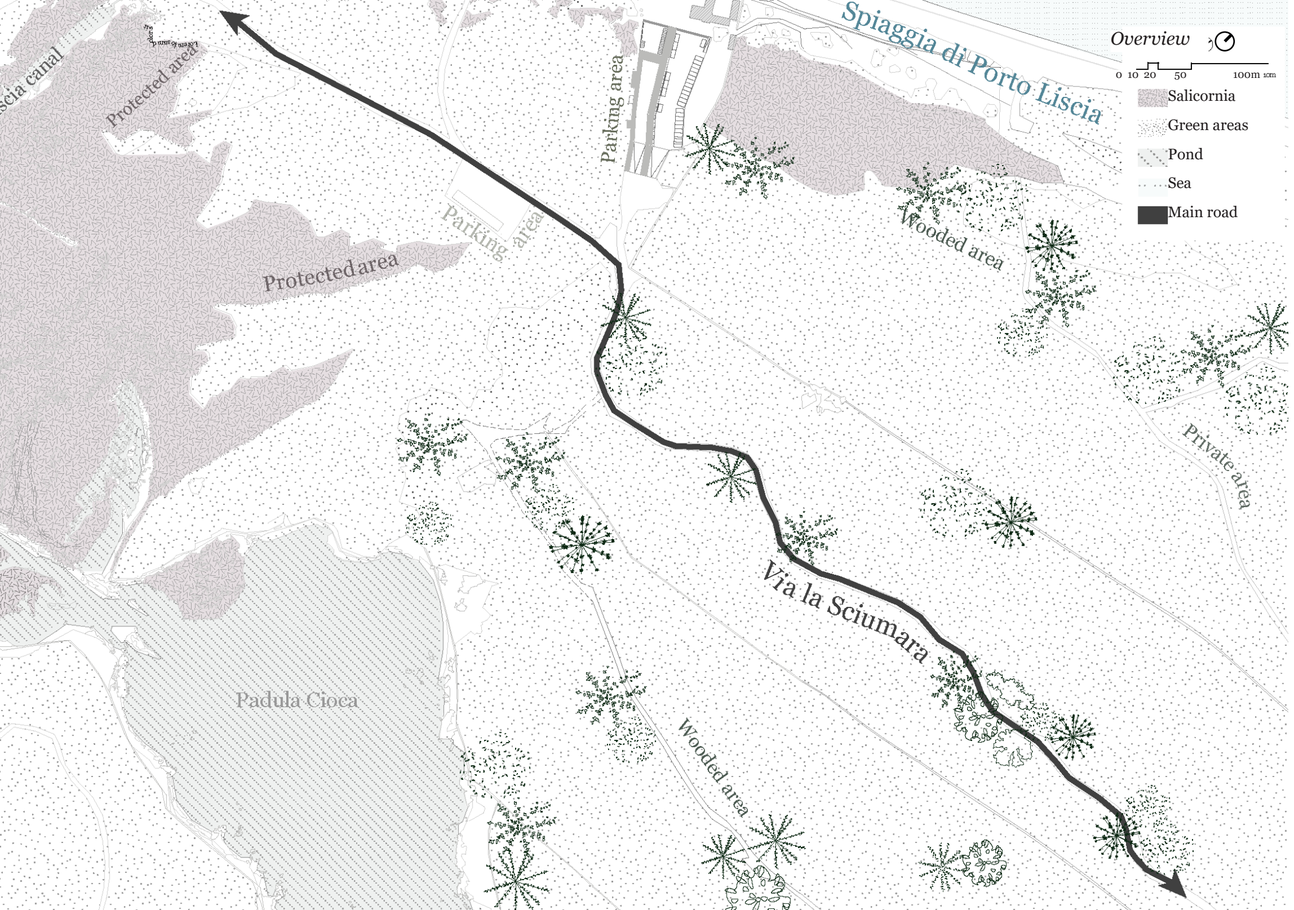
As a result, there is a high need for services specifically, sufficient parking, that can satisfy visitors' needs without compromising the area's sensitive and distinctive character.
Additionally, because it is a restricted location, it is crucial that the interventions respect and preserve the ecosystem, taking into consideration all environmental and landscape preservation laws.

Without sacrificing the environmental integrity of such a sensitive and constrained site, our design proposals try to deal with the primary issues of accessibility and area use in a detailed way.

6.2 ‘La Sciumara’ street

Point cloud

Texturized point cloud



The first problem addressed in the thesis was the resolution of the limited visibility of the road known as "La Sciumara".

The local word "sciumara," which translates to "mouth of the stream," is the source of the name of this old route in the Gallura region of northern Sardinia.

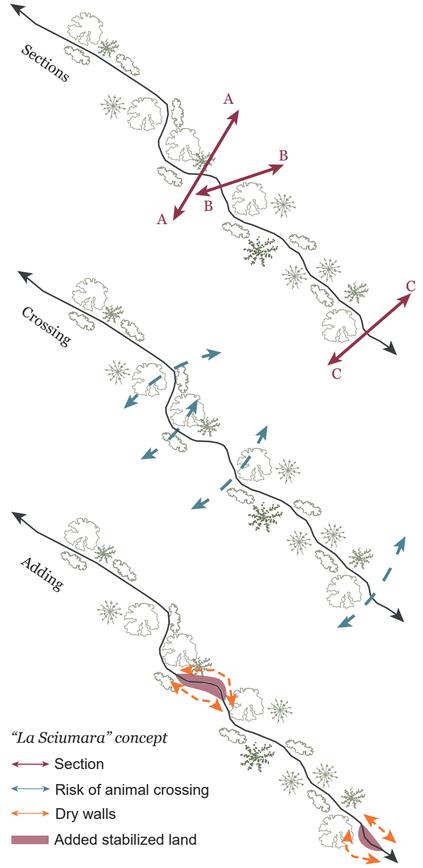
The route is especially congested in the summer, which highlights several serious problems during its passage.
Travelers' safety is seriously at danger due to the decreased isibility, which is made worse by the road's low width and the uncultivated grass along its sides.

The large number of visitors, many of whom were from abroad, requires the improvement of the road infrastructure in order to guarantee increased safety, according to an inspection conducted in June.

Therefore, a series of interventions to widen the roadway have become indispensable, aimed not only at improving visibility but also at preserving the passage of wild fauna, which often crosses Sardinian roads and represents a potential risk for vehicles.

Only three sections were chosen for the intervention, specifically those that we determined to be the least visible and to have the highest driving risk conditions during the inspection.

Attention to the coexistence between road safety and environmental protection was therefore central to the project to improve the "Sciumara street".



Sus scrofa meridionalis
Photo Lorenzo Rivella

6.2.1 Vertebrates

As was already established, the “Sciumara street” holds a number of important features, such as being extremely narrow and having poor vision close to the curves.
There are many wild species that could be dangerous or harmful because the area is surrounded by uncontaminated environment.

We are aware of the abundance of many mammal species in Culuccia and the surrounding area.
Both the animals, who could suffer serious injuries or possibly die, and the drivers, who could experience injuries or have their vehicles damaged, are at risk from these crashes.

Road crossings rise as a result of wild boars and animals moving more frequently in search of food or mates during breeding seasons or seasonal migration.

Animals may become confused and follow hazardous paths as a result of noise pollution.
They may be disturbed by cars and continuous noise, which may lead them to step onto roadways they might have otherwise avoided.

Serious accidents can result from collisions between cars and wild animals, especially if the driver is not prepared to brake or avoid the contact.

The Sardinian wild boar, or “Sus scrofa meridionalis,” is a subspecies of the wild boar that is indigenous to Sardinia.
It is one of the animals that can be found in these surroundings.

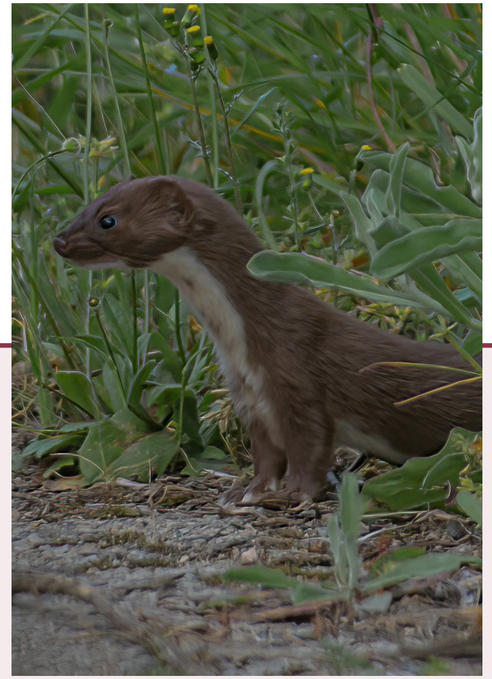
Additionally, deer, foxes and turtles frequently live in places close to roads, like woods, forests or agricultural fields, and this species has successfully adapted to the Sardinian habitat.
They frequently cross roadways due to their eating and mobility patterns, which raises the possibility of accidents.

“Weasels and pine martens (Mustela nivolis boccamela and Martes martes latinorum) may occasionally cross rapids on exposed terrain.” [1]

In addition to their unpredictable behavior, wild boars are especially dangerous when crossing roads.
They frequently cross the roads without warning and are more active at night or in the morning, making it challenging for vehicles to react in time.

These features got us to thinking about how important it is to make wild animals and people who meet wild species safer.

[1] Rossi, S. (2022). *l’Approdu, n. 02.* Sardegna: Osservatorio dell’isola di Culuccia



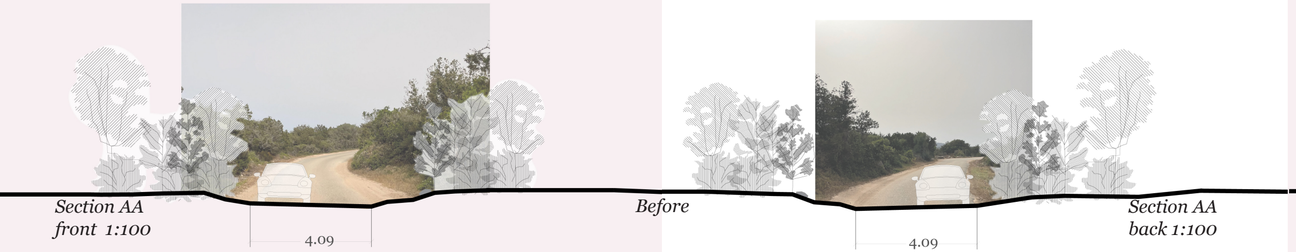
Mustela nivalis boccamela
Photo Lorenzo Rivella

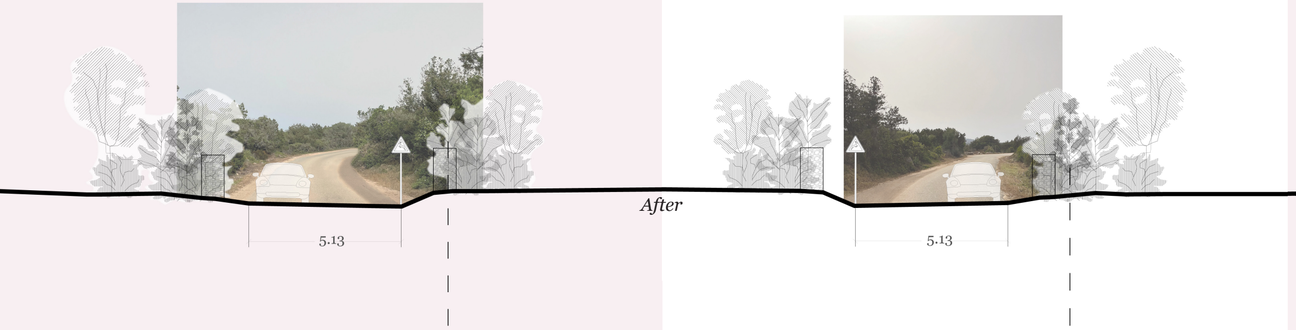
Biacco
Photo Lorenzo Rivella

Testudo marginata
Photo Lorenzo Rivella

Vulpes ichnusae
Photo Lorenzo Rivella

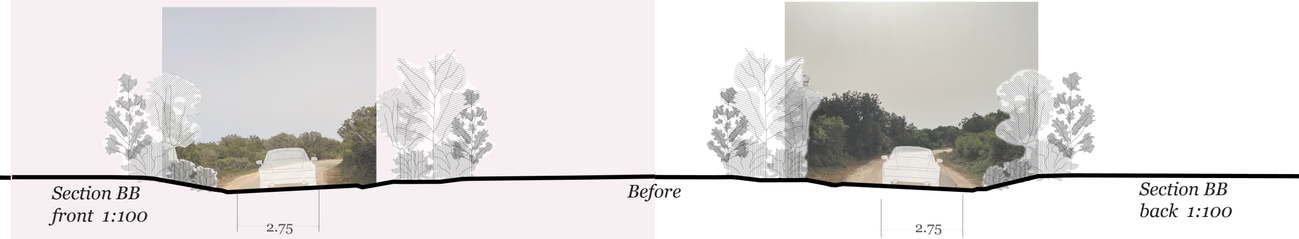
6.2.2 Design





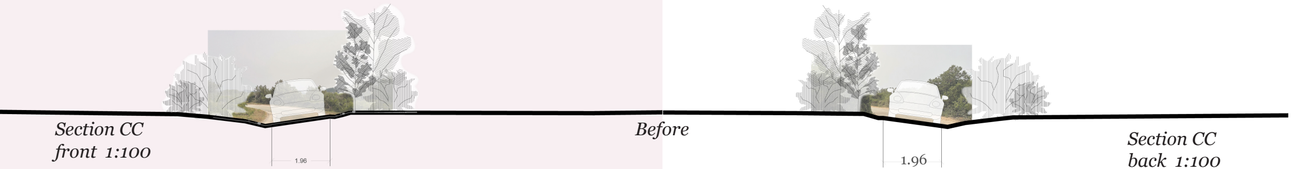
Increasing driveway space on the road to improve visibility and avoid accidents

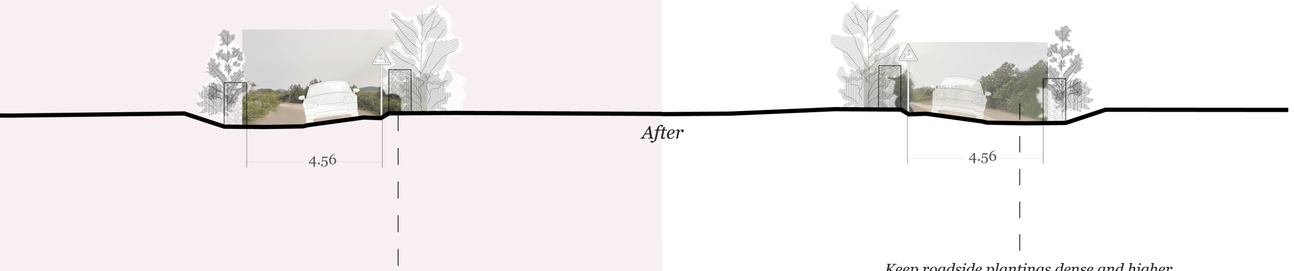
Use of stabilized land to level the ground creating a reversible intervention



Standard warning sign

Gentle slope (<45 degrees) to provide easy to climb surfaces





High stone walls on both sides to keep wildlife from accessing and crossing where the visblity is low

Keep roadside plantings dense and higher than the height of traffic to discourage animals to cross and encourage birds to fly above it

The three sections were examined for their proximity to curves as well as the carriageway's narrow width, which prevents two cars from passing each other at the same time without expanding on the roadside vegetation, which may have small, vulnerable invertebrate and vertebrate species.

Therefore, the planned interventions are intended to ensure both the safety of drivers and the preservation of plant and animal species.
Every portion was thoroughly examined from the front and the back, enabling significant improvement in the regions considered most vulnerable throughout the examination.
For every case study, the following solutions were adopted.

The first significant intervention was to widen the carriageway to a width that would permit two cars to pass safely while maintaining the trees along the borders to prevent deforestation.

In order to provide a stable and safe surface without using asphalt, a layer of stabilized earth that ensures a reversible and environmentally responsible intervention was used to level the ground with the rest of the road in order to accommodate the extra width.

The expansion also brought to light additional issues with "la Sciumara" route, such as the movement of wild animals, which is a risk that is especially prevalent in Sardinian regions with abundant uncultivated flora.

Given the volume of tourists passing through, the first idea was to put warning signs to alert people to the hazard.

To allow small animals and invertebrates to safely go towards the plants, additional research recommended combining this technique with the construction of a modest slope (<45%).
In order to finish this intervention, a dry stone wall was constructed in the same style as the island of Culuccia's traditional walls, which are presently undergoing restoration.

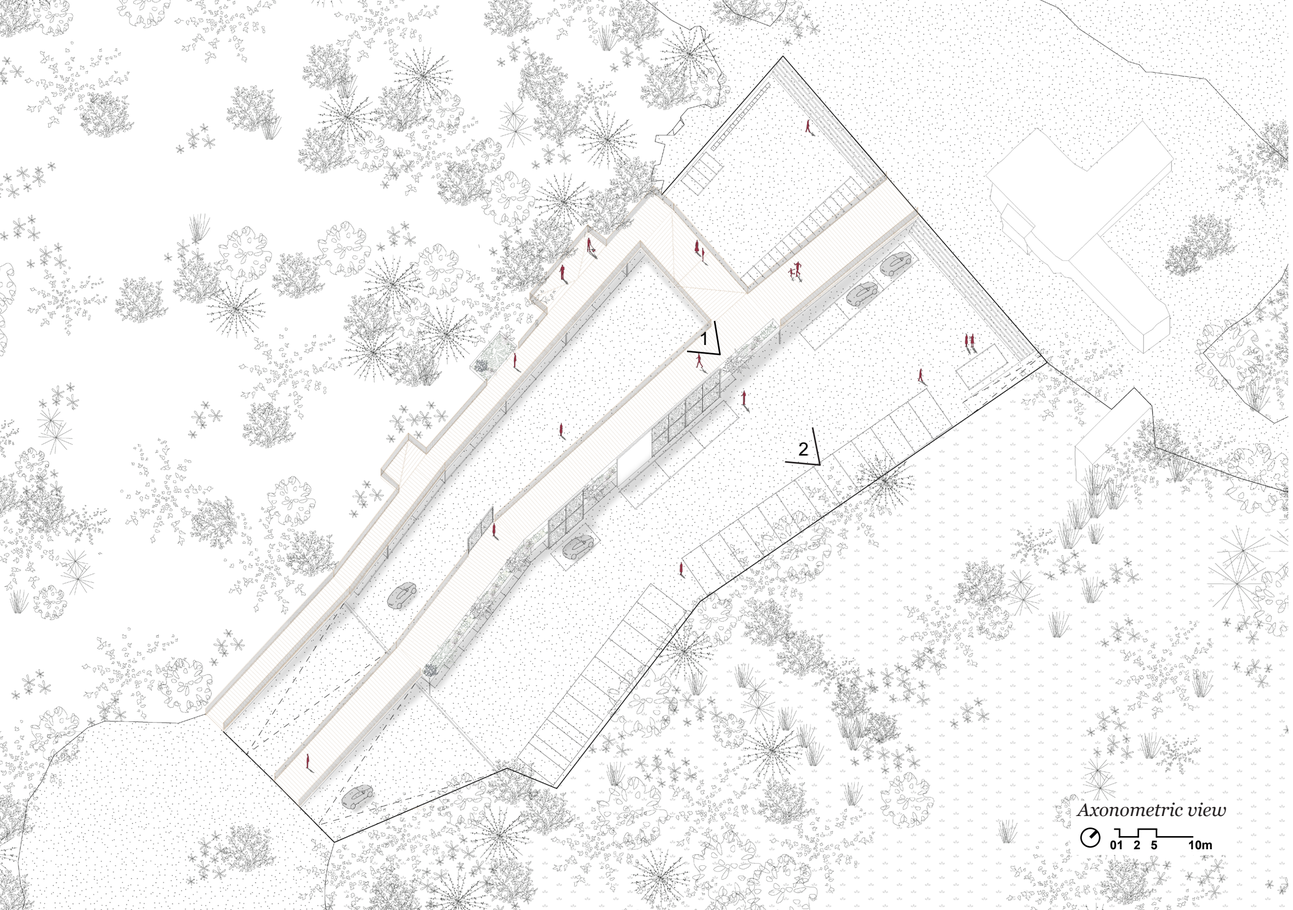
Additionally, this construction lowers the chance of accidents by discouraging larger animals, like wild boars, from jumping into the road at low visibility spots.

Lastly, we made an effort to keep the roadside tree vegetation in a healthy state.
Because of the thick foliage cover, animals are prevented from approaching the driveway by having less visual access to the road.

6.3 Parking area

Point cloud

Texturized point cloud

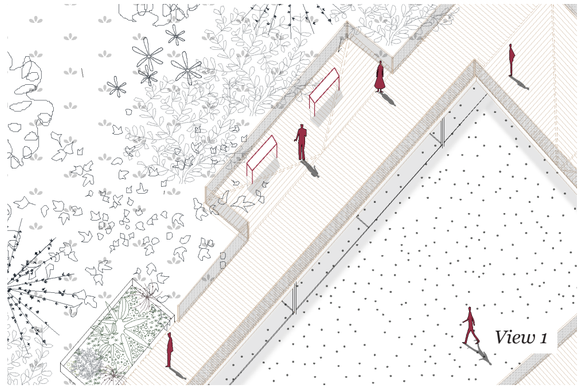


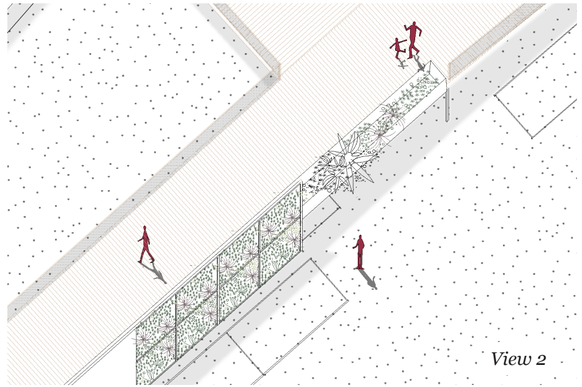
The initial parking area intervention involved excavating 80 cm to clearly define the project area.
This was done to prevent cars from parking in the adjacent vegetation, which is a common practice nowadays in the area, particularly in the summer.
The vehicle parking lots will be located at the foot of the excavation; some will be in areas with shade, while others will be exposed to the sun, guaranteeing an ideal distribution of spaces.

The gravel roads which connect the beaches to the parking lots that are already there in the area, served as the inspiration for the design concept, which emphasizes the visitor's arrival at Porto Liscia beach by arranging the spaces in a straight line and supporting them on a visual journey that faces the sea.

Two wooden walkways were erected to further enhance the sense of access to the sea.
The secondary walkway, on the left, is distinguished by a few extension areas that provide a privileged view of the wetland and the surrounding beach, enabling visitors to appreciate its beauty from an elevated perspective.
The central walkway acts as a panoramic point directly towards the sea.

Grid walls, which are positioned along the road towards the sea, enhance the whole area and produce evocative light and shadow plays. These components offer the project a visual rhythm that blends in with the surrounding landscape and strengthens the link between the beach and the parking lot.





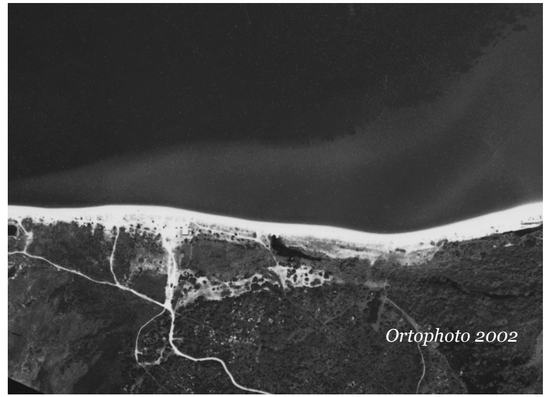
Wetland of Porto Liscia
Photo Lorenzo Rivella

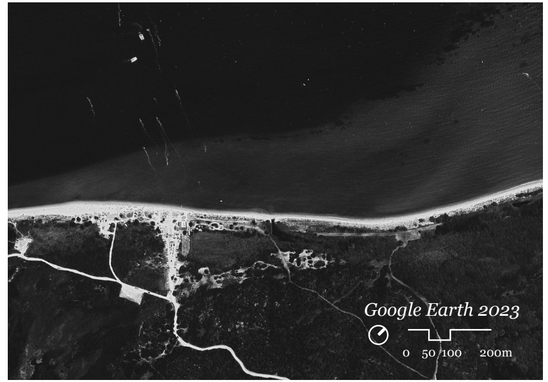
6.3.1 Vegetation

Like in many other habitats where vehicles and people frequently pass by, the vegetation in the Culuccia area is vulnerable to serious damage from human disturbance.
Crossing sensitive or accessible areas by cars and people, particularly close to unprotected routes or roads, can harm vegetation in a number of ways and have long-term consequences for the ecosystem.
We have observed, in particular,x that as tourism has increased over the years, the parking space next to the Porto Liscia beach has become larger as a result of cars expanding on the flora and affecting the natural ecology there.

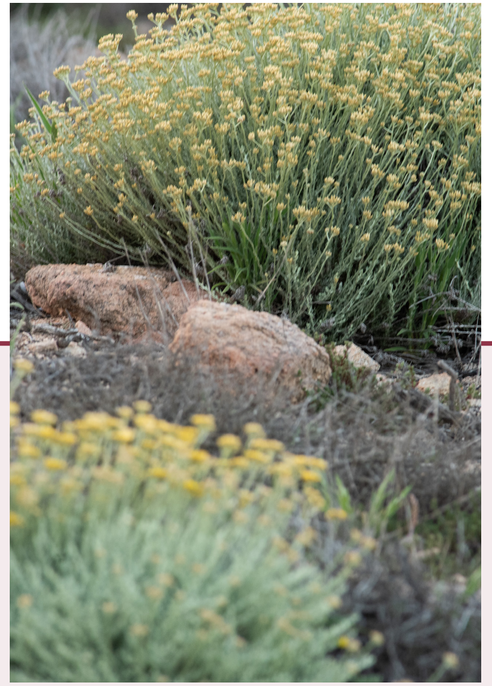
In some places, the constant movement of cars and humans compresses the earth. Because compacted soil is less able to absorb water, there are less resources available for plants.
This may retard the development of new seedlings and damage the roots of already-existing plants, reducing or even killing the vegetation before its time. Damaged vegetation puts the ecosystem out of balance by reducing wildlife's access to food and shelter.

Helichrysum, glasswort and rushes, typical plants of salty wet environments, are the most prevalent types of plants that are adapted to the primarily saline soil.
In conclusion, our investigation indicates that the Porto Liscia wetland, which is around eight hectares in size, has a wide range of plant species that vary depending on the type of terrain they grow in: humid, sandy and dune.
In order to protect these plants from potential harm caused by cars, a project proposal was required.





Yellow Cistus
Photo Lorenzo Rivella



Helicrysum italicum
Photo Lorenzo Rivella

Artocnemeto
Photo Lorenzo Rivella

Salicornia fruticosa
Photo Lorenzo Rivella

6.3.2 Design

As was already indicated, a key component of the project's initial phase was the goal of establishing direct link paths towards the sea, which were modeled after the dirt roads that typically travel to the seaside.
Wooden walkways and a ramp were created for this reason; they serve different purposes but function as linear connectors.

The most direct link axis is the major walkway, which runs through the middle, beginning at the parking lot entrance and ending at the beach.
Diverse entry points are provided by a second path on the left that grows to create lateral rest places before flowing into the main pathway.
The ramp, however, is only placed strategically in one location of the project, which corresponds to a service area, where it helps to provide easy accessibility.

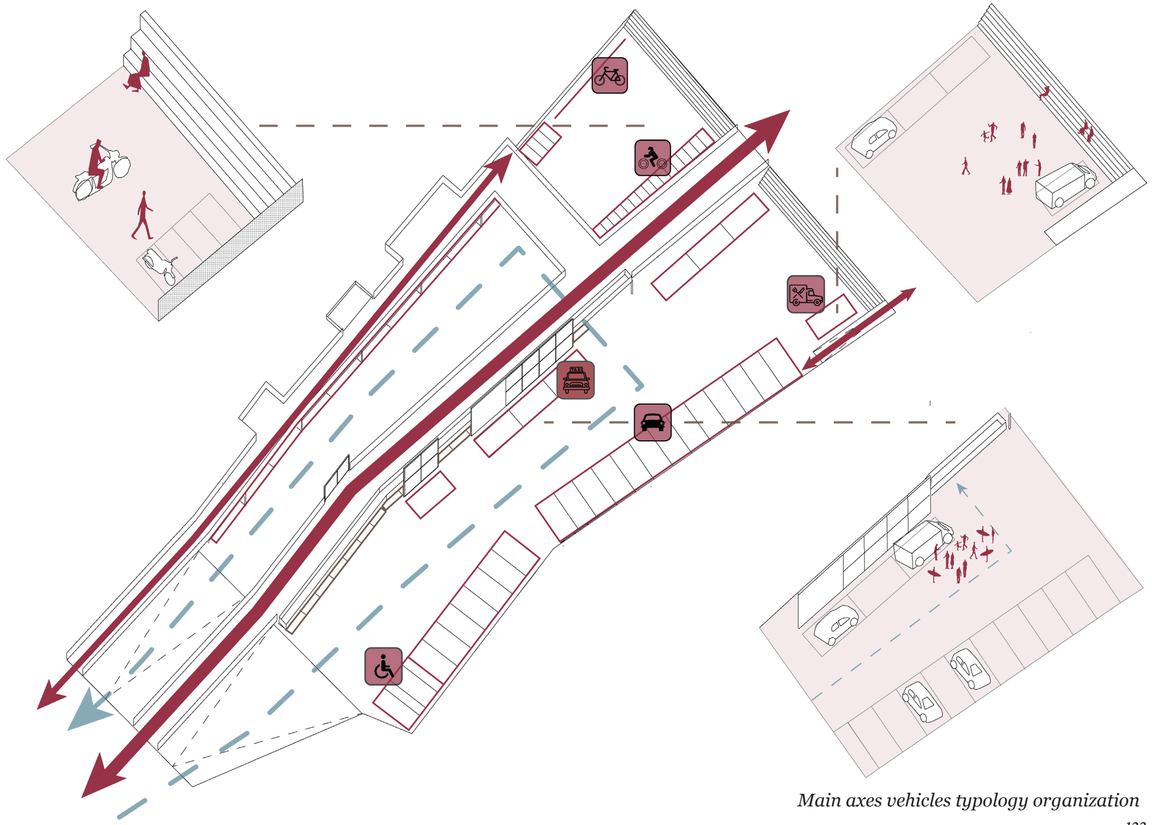
In order to guarantee a smooth and orderly flow, the parking lot's internal traffic flow was organized.
Four-wheeled vehicles can be parked in several designated zones and are accessed from the right side of the parking lot.

After passing under the main elevated walkway, the car lane continues past more parking areas until it reaches the exit.

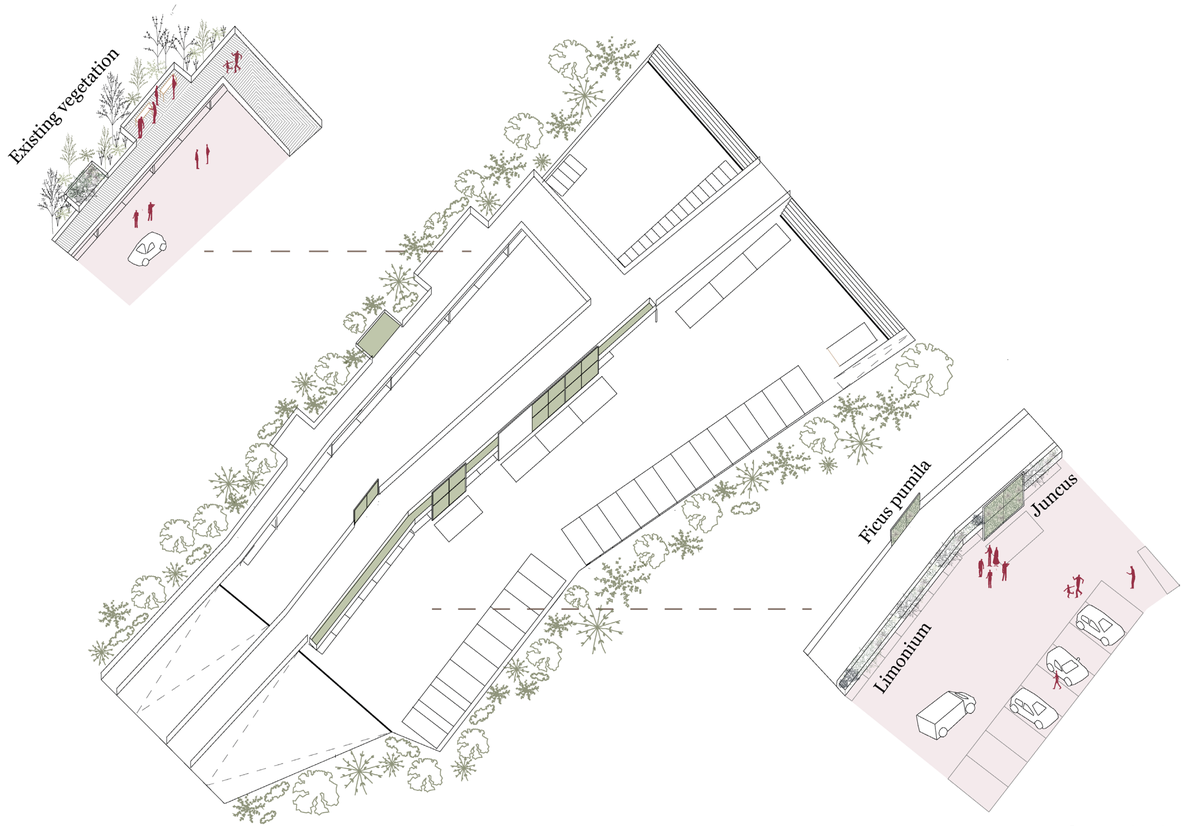
However, in order to maximize the region's safety and order, motorcycles, bicycles and other two-wheeled vehicles are assigned a specific area in the northwest, away from other cars.

With special attention to the layout of the disabled parking spaces, which are positioned in a privileged position at the entrance to ensure easy access, the parking lot's sections designated for various vehicle types can be clearly distinguished from one another.
The car section features shaded spaces underneath the walkway and spaces exposed to the sun.

Last but not least, a food truck-themed area has been created in the northeast corner, creating a meeting spot and refreshment area with a small square where people may have a break or have lunch.
This area enhances the services offered and encourages visitors to have a full experience.



Main axes vehicles typology organization



Green areas and organization

We have identified a few plants that we believe are appropriate for inclusion in the area project: Juncus Maritimus, Juncus Acutus and Limonium because they prosper in sandy soils and high-salinity environments, which are typical of this region.
These plants are perfect for a low-maintenance project that offers a vibrant, green appearance without requiring constant intervention. Most of the plants will be positioned in pots along the elevated walkways for pedestrians.

The installation of panels composed of various materials along the central walkway's path is another unique feature of the project. The steel net on the majority of these panels is intended to promote the growth of Ficus Pumila.

The panels' primary function is to shade the pathway, which is especially helpful during the summer when temperatures can rise. Because the panels are positioned strategically, they provide shade at different times of the day.

A large pot that merges well with the surrounding vegetation is also planned for the left pathway, further solidifying the connection between the parking lot and the surrounding landscape.

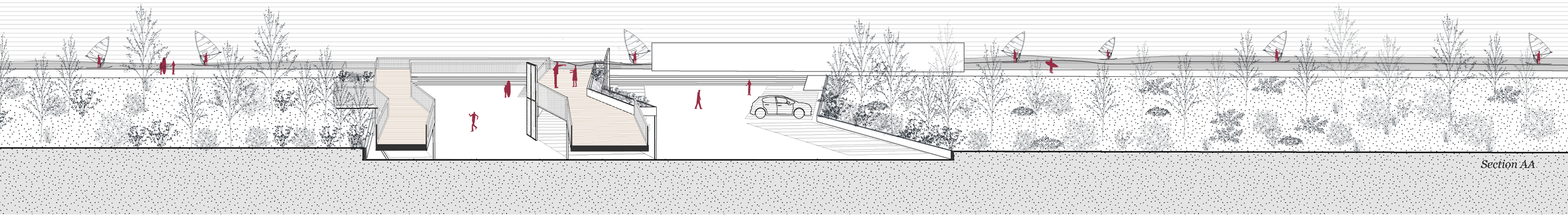
Next to this, there are two proposed panoramic terraces where guests can pause and take in the scenery. These areas are intended to serve as observation points that provide a sense of being in nature, in addition to being places to relax.

Information panels on the primary plant species that populate the region will be located on one of these terraces, providing guests with an opportunity to learn about and become more conscious of the environment.

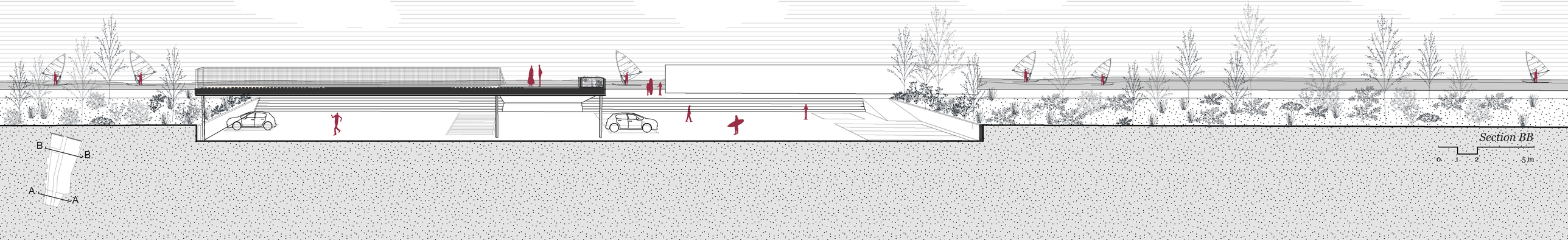
Juncus
Photo Lorenzo Rivella

Limonium contortirameum
Photo Lorenzo Rivella

Ficus pumila

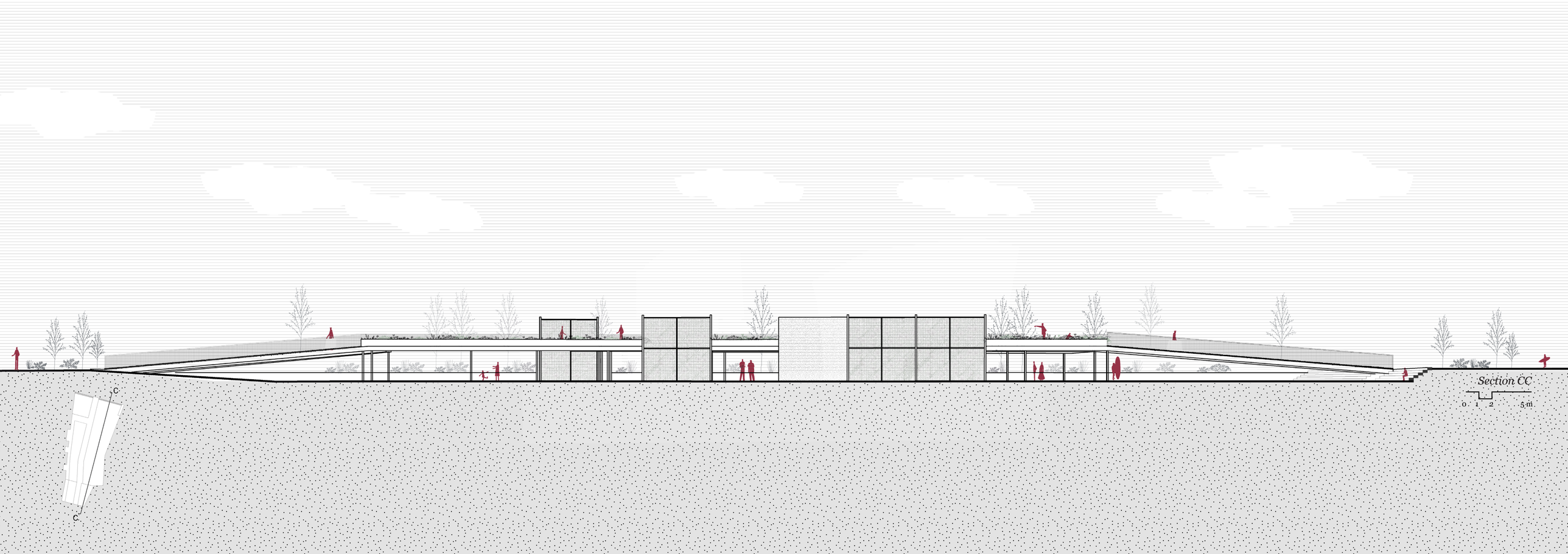


Section AA

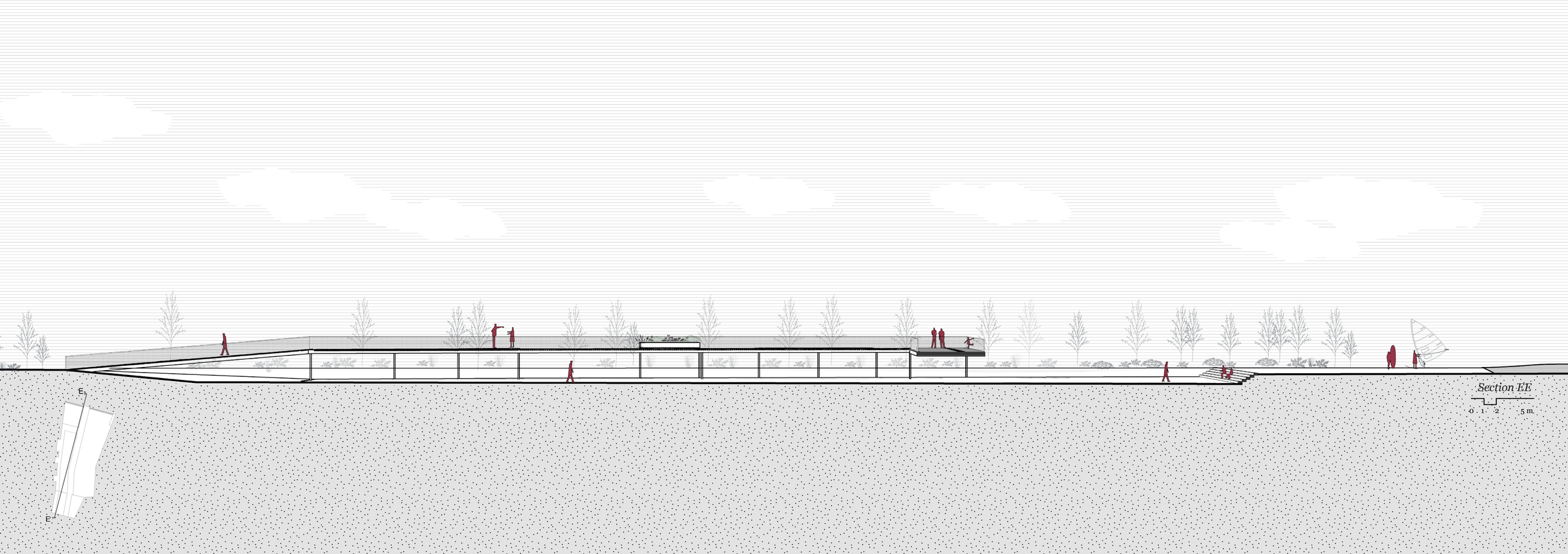


Section BB

0 1 2 5 m


C
C
Section CC
0 1 2 5 m


D
D'
Section DD
0 1 2 5 m


E
E
Section EE
0 1 2 5 m

Section AA shows the features of the wooden walkways as it passes the first section of the path parallel to the coast.

To provide sufficient permeability and visual continuity with the surrounding natural environment, these walkways are constructed from 10 cm wide pine slats spaced 5 cm apart.
The parapet provides hidden protection and is composed of a light steel grid structure that resists corrosion caused by the maritime environment.

Vertical closures consisting of a steel structure containing a grid intended for climbing plants are located in the center walkway.
This element facilitates a healthy relationship between the architectural intervention and the current environment by visually integrating the walkway with the surrounding landscape and establishing a direct connection with the indigenous plants.

There are 50 cm high planters on the right side of the central walkway that are intended to hold native flora. As previously said, these planters evoke the characteristic flora of the region, contributing to the place's landscape identity and visual coherence with the natural vegetation.

In contrast, the BB section displays a cut of the elevated portion that opens onto a square-shaped area orthogonal to the two major walkways.

This spot, which offers a unique perspective of the sea, was intended as a place for rest and reflection.
Visitors can take in the view of the horizon and the maritime atmosphere from this little belvedere.

The corten barrier adds depth to the composition and breaks up the apparent continuity by introducing a more substantial and enclosed feature.
With its distinctive rust color, corten blends in perfectly with the surroundings.

The vertical divisions that alternate in this section are intended to produce a rhythmic visual and functional design for the path.
The partitions alternate between components with steel structure and grid, which are perfect for supporting climbing plants and one with a corten panel, which offers a unique material and visual note.
The metal-gridded partitions are intended to promote the development of vertical vegetation, enabling climbing plants to interconnect themselves with the project.
In addition to giving the walkway a more organic feel, this approach produces a transparent and light appearance that preserves an unobstructed view of the surroundings.
Also, to adding to the overall aesthetic, the switching between green grids and corten panels serves a functional purpose: the climbing plant-adorned grids encourage visual permeability and a closer relationship with nature, while the corten panels offer visual breaks and partial shade from the sun, providing shade and a private area along the walkway.

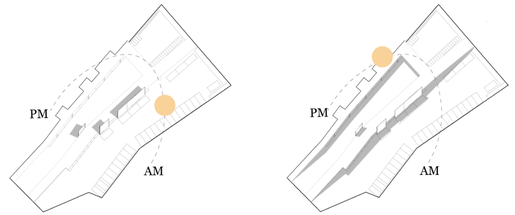
Large clearings in the left part are designed as rest and observation spots alternate here, giving guests a chance to pause and take in the scenery.
These open areas provide a chance to become fully immersed in the local flora, promoting quiet times of reflection and leisure in a setting enhanced by the presence of indigenous species.

These open areas provide a chance to become fully immersed in the local flora, promoting quiet times of reflection and leisure in a setting enhanced by the presence of indigenous species.

To maintain visual and practical coherence throughout the project, a planter that is comparable in size and design to the one along the central walkway is positioned in between each clearing.
By accommodating native plants, these planters enhance the connection between the path and the surrounding environment.
Selecting native plants respects the ecological aspect of the intervention by lowering care requirements and enhancing landscape integration.
There's a stairway on the right side of the part that leads up to the beach.
This multipurpose projectct acts as a gathering place and an informal rest spot in addition to connecting the walkway and the beach.

In the morning, the shadows are primarily concentrated on the central walkway, as referenced by the summer solstice.
However, in the afternoon, they become more apparent in the uncovered area of the car parks. This arrangement promotes thermal well-being during the second part of the day, when the shadows in the open areas of the car parks offer relief from the heat. At the same time, the central walkway provides a partially shaded passage in the morning, ensuring thermal comfort for pedestrians wishing to reach the beach.

The reorganization of the car parks has allowed vehicles to be distributed in a more organized way and divided by type without reducing the number of existing car parks.



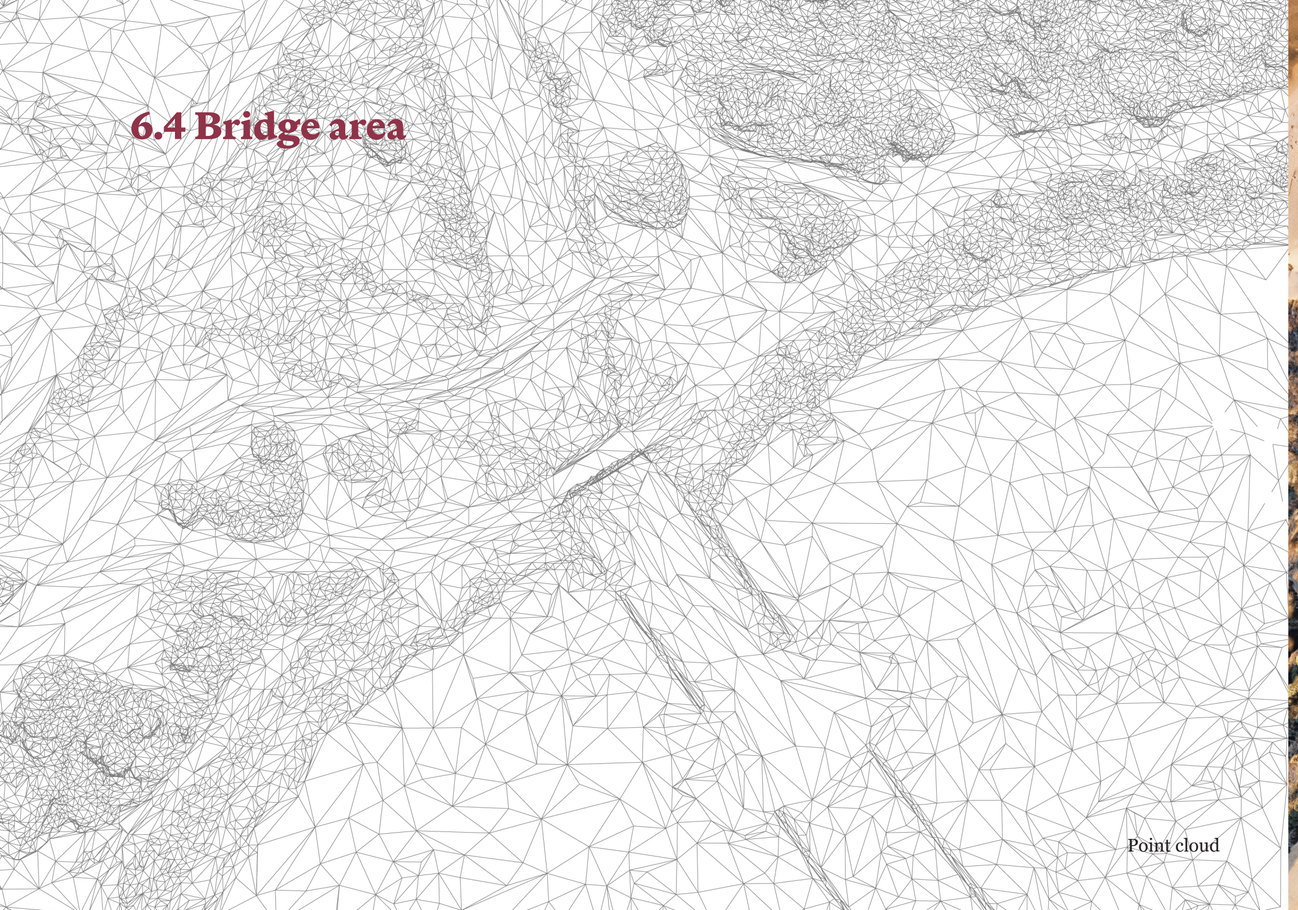
Summer solstice

Parking organization

Rendered aerial view

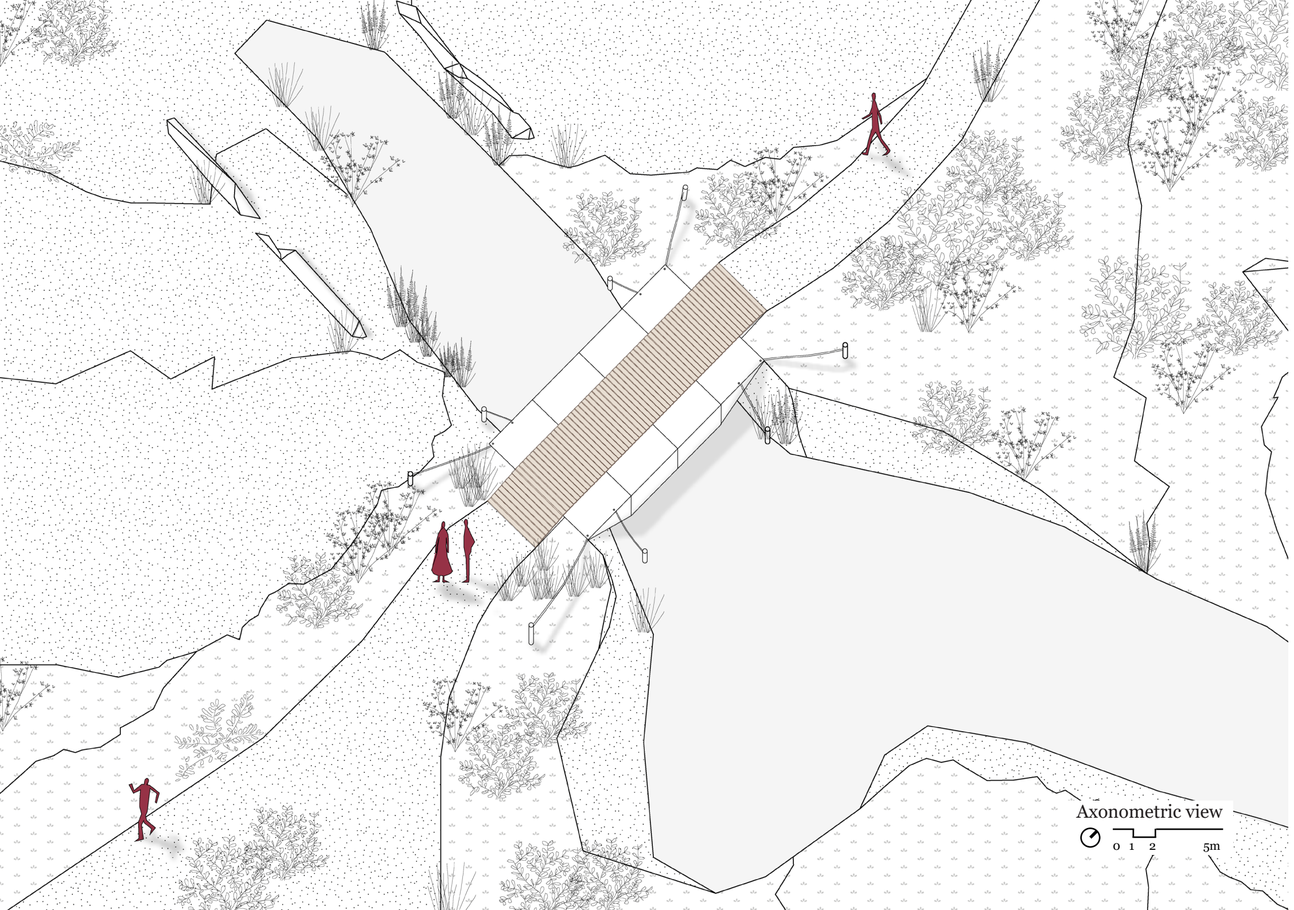
Wooden walkways and parking view

6.4 Bridge area



Point cloud

Texturized Point cloud

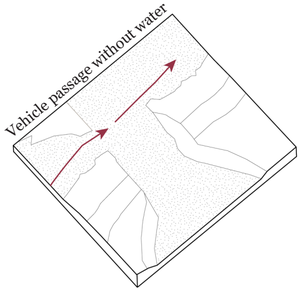


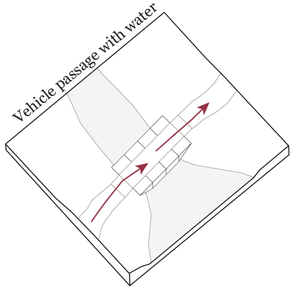
After the existing bridge that connected the two banks collapsed, the intervention on the bridge was planned to provide safe and functional access to the island of Culuccia and its wetland.
The bridge is intended to be a temporary and flexible solution that can be put together and taken down when access is required or during the most important times of the year, such the cold and rainy seasons.
Because it is reversible, it can be used in a variety of ways without harming the environment.
The goal is to practically connect the two places while minimizing effect and removing them as circumstances permit, maintaining the area's functionality and landscape.
Steel was selected for the bridge's base construction in order to guarantee stability and longevity. A layer of pine wood is placed on top of this metal base to serve as a "floor," offering a secure and impervious surface for travel.
Five separate modules make up the structure: the pine cladding covering the upper surface and four steel modules, that are made to be easily managed and adjusted to seasonal conditions, which enables effective management all year long.

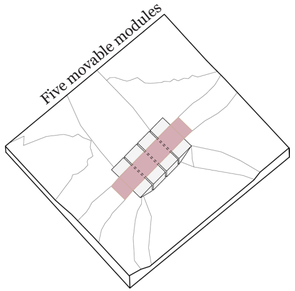
This bridge's flexibility in responding to seasonal shifts and water level fluctuations is one of its unique features.
When it's dry, the modules stay stable by resting directly on the ground.
However, a hinge mechanism between the fixed and detachable pieces allows the bridge to lift and dynamically adjust to water conditions during rainy seasons or when the water level rises in the watercourse, guaranteeing its functionality even in high flow situations.

Four strong hardwood poles, that are securely fastened to the ground, support the structure for further stability and safety.
Even when there are heavy winds or other unfavorable weather conditions, these poles help prevent collapses by allowing for a better distribution of the structure's weight.

In this approach, the bridge serves as a temporary but stable and useful structure for the time of its requirement, not only connecting people but also doing so in a way that respects and is safe for the environment.







Little egret
Photo Lorenzo Riwella

6.4.1 Birds

The flora and fauna that make up the wetland of Culuccia environment play a decisive role in its composition. The basins of this area have different depths, salinities, temperatures and water exchanges with the sea, resulting in a very high biodiversity in this area.

Before starting the design phase, we analyzed the flora and fauna to understand which species characterize the area and to become more aware of this richness, respecting the existing living beings and trying to increase biodiversity without affecting them.
The Porto Liscia wetland is home to a large number of migratory birds that come here to feed or nest.

"The islands are essential for migratory birds because they have a better climate, are therefore rich in food and flower in spring and are rich in nectar, which many reeds feed on (especially).
Wetlands are also important because they are rich in food and water: they are "unique" resting places for many species." [1]

"The most common species in this area are herons such as: the heron, the little egret (Egretta garzetta), the squacco heron (Ardeola ralloides), the night heron (Nycticorax nycticorax)." [2]

For several reasons relating to the direct and indirect disruption that human activities create to birds and their habitats, birds are especially vulnerable to the movement of people and cars.
These elements have the potential to harm their reproduction as well as survival, which would be damaging to their biodiversity and general well-being. Vehicles have the risk to hit birds that are crossing roads or other communication routes.

This risk is especially significant for migrating birds that cross roadways unaware of the dangers caused by automobiles or for low-flying species.

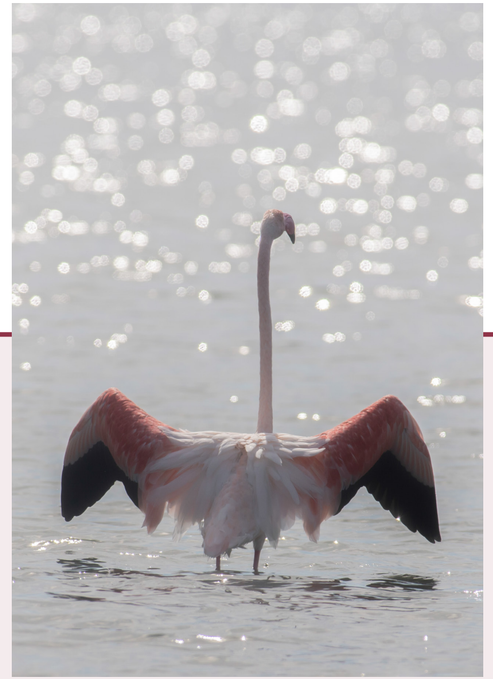
People may cause damage to the plants that the birds eat when they explore. The development of vegetation that offers food and shelter might also be affected by walking on sandy or wet soil.
Additionally, human activity (such as the presence of hunters, hikers or industry) and traffic noise might change how birds fly.
Additionally, birds may be forced to leave ideal nesting places due to human presence and noise.

The exhaust gases and other pollutants released by cars can contaminate the environment and harm the insects and plants that birds eat. Furthermore, wetlands where birds reproduce or feed might be damaged by toxins dissolved in water.

The foundation of our design strategy was to use a temporary passage which, removable when necessary, could make it possible for vehicles to pass through or to isolate part of the wetland and the Culuccia island.

[1] medseafoundation.org/index.php/it/news-int-ita/237-la-rotta-italiana-e-sarda-degli-uccelli-migratori-2
[2] Rossi, S. (2022). *l'Approdu, n. 02.* Sardegna: Osservatorio dell'isola di Culuccia

Birds in wetland
Photo Lorenzo Rivella



Pink flamingo
Photo Lorenzo Rivella

Nycticorax
Photo Lorenzo Rivella

6.4.2 Design

Five detachable components, comprising four high-density polyethylene (HDPE) modules and a hardwood upper cladding piece, make up the 12-meter-long bridge.

The project makes reference to the modules created by the company "flexifloat."

"Flexifloat® modular barges and drive-on/drive-off ramp attachments are commonly used to construct floating bridges, piers and docks for moving or supporting heavy equipment." [1]

The dimensions of each module are 3×6×1.5 meters, or "duofloats. "In order to accommodate the surrounding topography, two of them are rectangular in design, while the other two are diagonal. A "locking system" is used to secure each module to the others: "opposing "male" and "female" locks connect modules." [2]

Simple hand tools can be used to assemble these.
Two more, smaller, high-density polyethylene modules continue to be positioned on the mainland even after the bridge is dismantled.

The "flexifloat hinge connection" adds additional support to the bridge by joining the two smaller modules to the larger ones.

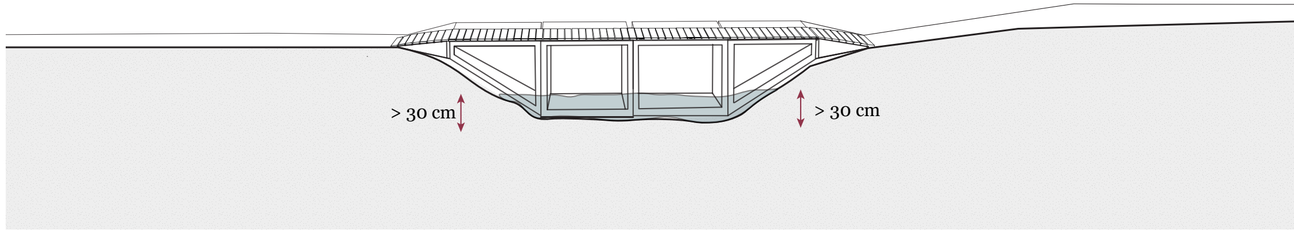
A "mobile cargo truck crane" is required for the assembly and disassembly process in order to move the roughly three-ton modules.
To remove or put the modules together, employees are required in addition to the crane.

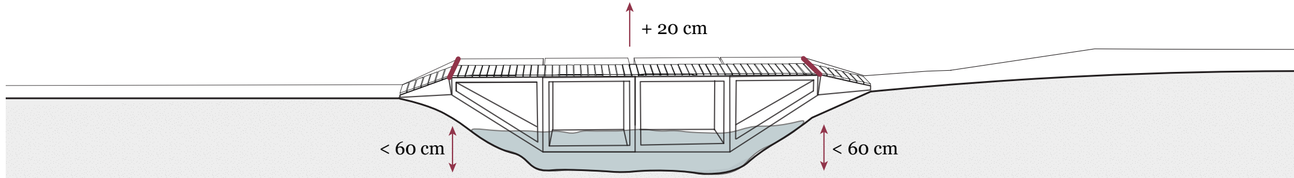
The modules will be disassembled and placed on the mainland, close to the canal, during times of need brought on by unexpectedly high rainfall that exceeds the yearly normal.

Instead, it can be disassembled periodically throughout the year based on the needs of the connection.

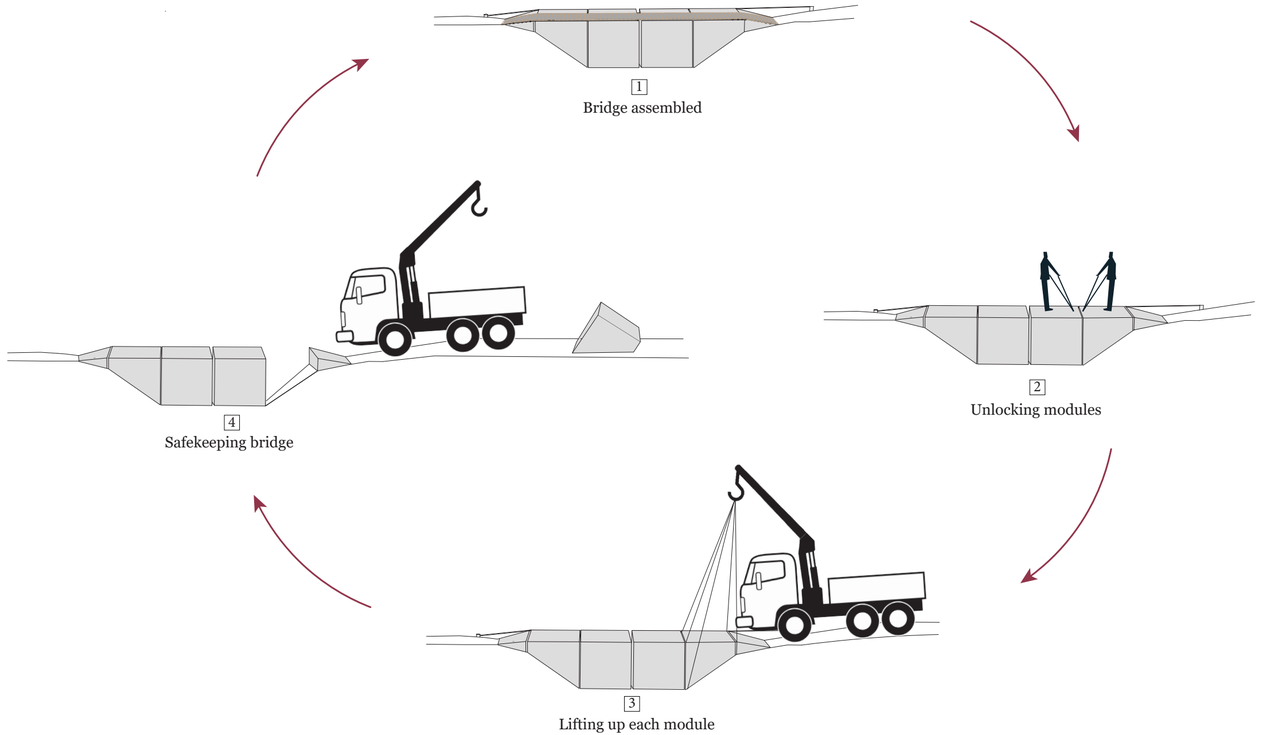
As previously stated, when the water around the bridge is no higher than one meter, the bridge sits on the ground; if it does, the hinges on its sides enable it to be elevated by no more than 20cm. Therefore, the bridge would have to be taken down if the water level rose above one meter.

However, it must be considered that these are rare events, given that taking the years 2022-23 as an example: "the cumulative precipitation in Sardinia from October 2022 to September 2023 was 60-70 cm". [3]





Bridge section with 30 and 60 cm of water



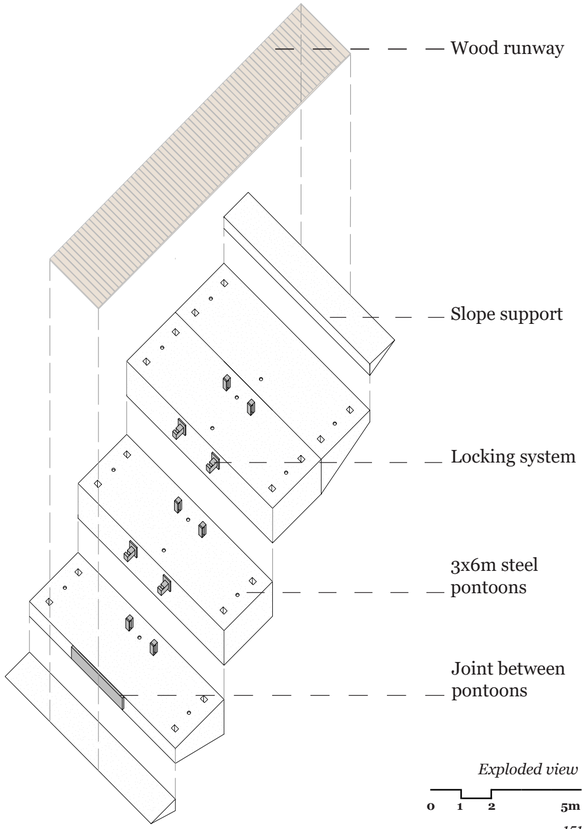
Dismantling bridge phases

The first essential step in dismantling the bridge is to ensure that you have the means to transport the modules to a safe area, which, in our case, could be a specially designated area adjacent to the canal, normally used for vehicle parking.
The dismantling process begins with the detachment of the modules, which is done thanks to the "male-female" hooking system that connects the various components.
This step requires the intervention of at least two people, but does not involve the use of specialized tools or particular technical skills, making the operation relatively simple and quick.
Then, they are loaded onto the mobile cargo truck crane, the essential means of transport, capable of lifting and moving each module weighing approximately 3 tons.

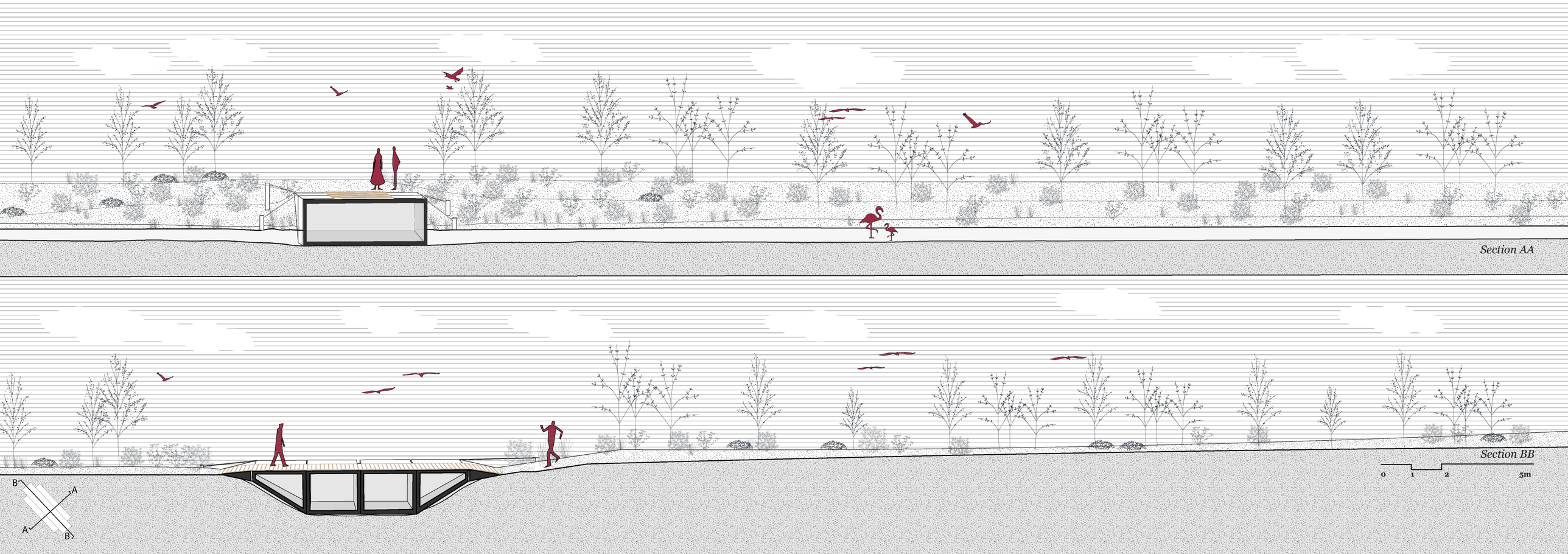
Once the transport is completed, the crane can also be used for other logistics operations on the island, such as the transport of materials or other maintenance activities.
The crane, in the event of rare catastrophic events, can be used to quickly dismantle the bridge. This is particularly useful when weather forecasts do not allow the need to dismantle the bridge quickly enough, thus ensuring a rapid and effective response.
The last step of the process involves positioning the modules in safe areas. These areas will always be located near the wetland or on Culuccia Island, where logistics allow the modules to be stored safely and securely.

The process of dismantling and reassembling the bridge has been designed to be as simple, fast and efficient as possible.

[1-2] flexifloat.com/locking-system/
[3] Rossi, S. (2022). *l'Approdu, n. 02.* Sardegna: Osservatorio dell'isola di Culuccia



Exploded view


Section AA
Section BB
B
A
A
B
0
1
2
5m

The sections highlight the internal structure of the individual components by providing a detailed view of the cutting of the steel modules in both directions.

When each module is sectioned, the thickness of the steel utilized to guarantee solidity and resistance is shown, along with the upper covering made of pine wood, which was selected for its natural appearance and practical qualities including resistance to atmospheric agents.

The section that examines the bridge in the direction parallel to the modules contains the most important details. The distribution of the modules that form the complete structure and the various altimetric levels are best understood in this view.

The bridge's main support and stable base are provided by the four detachable steel modules, each of which is rectangular in shape and the same size (3 by 6 meters). These modules offer the flexibility required to adjust to various seasons and climatic circumstances because they are made to be easily removed or replaced.
The two lateral modules, which are made of steel as well, are permanently positioned on the ground.

The upper layer of wood, a symbolic component of the project itself, is directly supported by these lateral modules and is still visible as a representation of the temporary nature of the connection between the two sides.
Seasons determine whether the bridge is there or not, but the project as a whole is always visible through the signs present in the ground.

Rendered aerial view

Bridge into the environment

6.5 Conclusions

Located in the center of northern Sardinia, the region between “la Sciumara” road and Culuccia Island’s wetlands represents a natural and ecological legacy of exceptional worth.
This region has a rich and delicate ecology because of its scenic splendor, which is defined by an alternation of rural and natural areas, from wetland ecosystem to the characteristic vegetation of the beaches.

The ecological importance of this area is also confirmed by its role as a fundamental stop for bird migrations, but its fragility requires a careful balance between development and environmental protection.

Without sacrificing the landscape’s natural integrity, our thesis work aimed to address the accessibility issues in this location.
In order to increase access without substantially changing the surrounding environment, the design concepts included interventions on the bridge, “la Sciumara” road and the parking lot close to the Porto Liscia beach.
Specifically, using temporary and reversible solutions, like the bridge, allows for functionality to be guaranteed without having an irreversible effect on the environment.

The main objective of these proposals is to make the area more accessible to both residents and tourists, responding to the growing demand of services and infrastructure, such as parking, but always with an eye on sustainability.
Respecting environmental standards and encouraging tourism that is aware of and considerate of natural resources are components of managing visitor flows and protecting the environment.

The proposed remedies seek to guarantee a fair and environmentally friendly use of this land, preserving its remarkable biodiversity and beauty while ensuring that it may remain a resource for future generations.

Our intervention aims to be a development model that prioritizes the preservation of nature over its degradation, while simultaneously meeting the demands of accessibility and service enhancement.

We want to finish up the thesis by emphasizing that, as the image on the left illustrates, the bridge’s collapse has caused a rethinking of it, not because more people or cars can now cross these protected areas, but rather because of a greater desire for responsibility and control over it.
Possessing an option for transportation does not suggest abusing the environment; rather, it indicates a desire to address the issues brought on by the collapse and, more importantly, to prevent further damage to the area, since, as you may know, people always find a way to get where they want, even if it means harming the environment.

The regulation of access has certainly been a key step in our reading of the territory concerned, respecting the nature present in all three proposals in the thesis.

07

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08 Acknowledgments

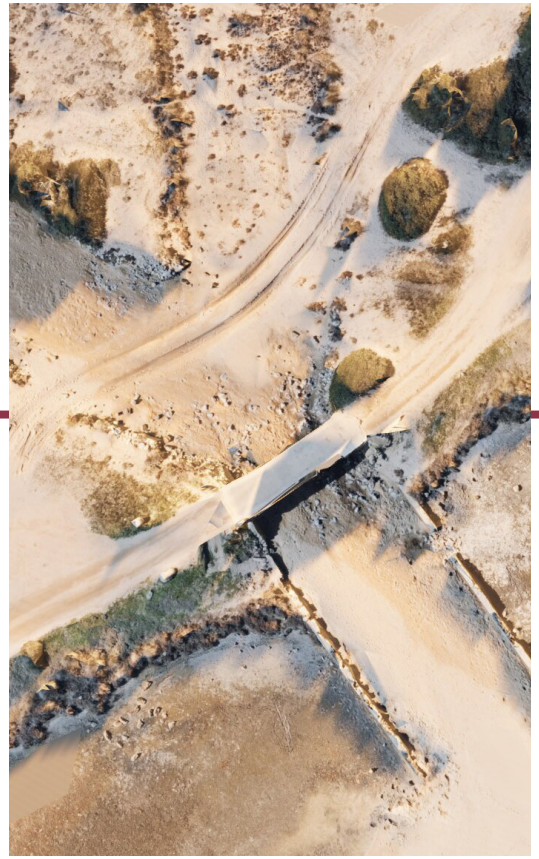
We would like to express our sincere gratitude to our supervisor, Francesca Frassoldati, a key figure in the writing of our thesis. We thank her for the extraordinary opportunity that allowed us to analyze a unique territory.
We are deeply grateful for her constant presence during the months of work.

A heartfelt thanks also goes to Professor Filiberto Chiabrando, who accompanied us with great dedication throughout the thesis and internship.
Thank you for having supported us in the knowledge of the island and the surrounding area, and for having introduced us to the reality of the DIRECT Team.
The training experience that he allowed us to live has significantly enriched our skills in the field, further sensitizing us to the topics covered in the thesis.

We are also deeply thankful to Sabrina Rossi, for guiding us during our stay on the island, and for her constant availability to provide clarifications and materials useful for our work.

We would also like to thank the Team DIRECT and all the Culuccia staff for treating us with kindness and for their availability.

Finally, we express our sincere gratitude to Mr. Marco Boglione and Mrs. Stella Lin Hung, for their collaboration with the Politecnico di Torino, which made this experience possible.



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