

OS Aqua

Open Sea Aquaculture in the Eastern Mediterranean

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Ευρωπαϊκό Ταμείο
Περιφερειακής Ανάπτυξης



Κυπριακή Δημοκρατία



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της Ευρωπαϊκής Ένωσης στην Κύπρο

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Executive Summary

This report describes the OS-AQUA GIS, the Geographical Information System (GIS) designed and developed as the Marine Spatial Planning (MSP) tool used to identify Allocated Zones for Aquaculture (AZA) (see Deliverable D13 “Identification of AZAs and AMAs and estimation of their carrying capacity”).

The OS-AQUA GIS design and development is based on the needs and the requirements of the project, and it is built as an open-source solution, able to provide greater flexibility and easier upgrade and integration with other open systems. QGIS, a free open-source GIS software, was chosen for the data import, analysis, and management, the Marine Spatial Planning, the thematic mapping, etc., instead of other licensed GIS software.

The Database management system (DBMS) design was based on the Hydrographical and other data collected from various sources, and PostgreSQL, a powerful free open-source object-relational database system, was chosen as the DBMS software.

OS-AQUA GIS will be continuously upgraded to become a powerful decision tool. It will be able to run either locally or provide services through the web and support this project and other projects related to Cyprus maritime space.

Contents

- 1 INTRODUCTION5
 - 1.1 Geographical Information System (GIS)5
 - 1.2 Marine Spatial Planning (MSP) and GIS6
 - 1.3 OS-AQUA GIS and MSP7
- 2 OS-AQUA GIS9
 - 2.1 Introduction9
 - 2.2 GIS and Database Design9
 - 2.2.1 The needs9
 - 2.2.2 The data9
 - 2.3 Licensed or Open-Source Solution?12
 - 2.3.1 Comparison13
 - 2.3.2 GIS Software Selection14
 - 2.4 OS-AQUA GIS Development14
 - 2.4.1 Hardware14
 - 2.4.2 GIS Software & Geodatabase15
 - 2.4.3 People and Methods18
 - 2.4.4 Use18
- 3 Conclusions and Next Steps21
- 4 References22



FIGURES

Figure 1. Marine Spatial Planning Workflow (Source: SPREP 2019).....7
Figure 2. The diagram of the “os_aqua_db” geodatabase17

TABLES

Table 1. Data Collected and Imported into OS-AQUA GIS10
Table 2. Local Environment Specifications (Windows)14
Table 3. The geodatabase “os_aqua_db” and its schemas16

1 INTRODUCTION

1.1 Geographical Information System (GIS)

There are different definitions for GIS, each developed from a different perspective or disciplinary origin. Rhind (1989) defined GIS as a system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems, while Cowen (1988) stated that GIS is a decision support system involving the integration of spatially referenced data in a problem-solving environment.

GIS is comprised mainly by five components: Hardware, Software, Data, People, and Methods (Ali, 2020):

- **Hardware:** represent local or cloud resources GIS operates.
- **Software:** Tools to run and edit spatial information supporting query, edit, run and display GIS data using RDBMS (Relational Database Management System) to store the data.
- **Data:** the most important component of a GIS. Geographical data and related tabular data can be created in house using GIS software or can be purchased. A GIS will integrate spatial data with other data resources and can even use a DBMS to manage spatial data. Geographic data are divided into two main groups, vector and raster.
 - Vector: Vector data are discrete. It stores information in x, y coordinate format. There are three types of Vector data: Lines, Points and Area
 - Raster: Raster images store information in a cell-based manner. It can be an aerial photo, satellite image, Digital Elevation Model (DEM). Raster images normally store continuous data.

All data in a GIS are either spatial data or attribute data: spatial data tells us where something occurs, while attribute data tells what occurs; it tells us the nature or characteristics of the spatial data.

- **Users/People:** The users of Geographic Information System define requirements and provide feedback for the design and development of GIS. They run the GIS software and perform GIS tasks such as creating a simple map or performing advance GIS analysis.
- **Methods:** A successful GIS operates according to a well-designed plan and business rules that are defined by each organization.

The use of Geographical Information Systems provides many benefits (Ali, 2020). As the data is tied to a common referencing system, it is easy to use the same data to various applications as well as to associate diverse data sets previously unavailable for joint analysis.

Specifically, GIS can provide users with benefits such as:

- Better decision making
- Improved communication

- Better geographic information record-keeping
- Managing situations with a geographical aspect
- It adds a degree of intelligence and sophistication to a transport database that has previously been unknown.
- It is possible to perform geographic queries in a straightforward, intuitive fashion.
- The analyst can ask a series of geo-based questions and obtain the answers quickly in an easy-to-understand color-coded presentation.
- Integrates different databases into one environment
- Displays and manages spatial data in a spatial context.
- Map data is easier to search, analyze and present.
- Cost savings resulting from greater efficiency.

Finally, Laurini and Thompson (1992) have identified ten major GIS **Functions**: Automated Mapping, Thematic Mapping, Map Overlay or Composite Mapping, Spatial Querying, Spatial Browsing, Spatial Problem Solving, Analysis of Spatial Data, Creating Spatial Statistics, Analysis of Spatial Statistics and Spatial Analysis.

1.2 Marine Spatial Planning (MSP) and GIS

As a management tool, Marine Spatial Planning (or Maritime Spatial Planning; MSP) allocates space for upcoming activities such as aquaculture at sites with both favorable operational characteristics as well as lower potential for conflict with other sectors (Christie et al., 2014; Guerry et al., 2012; Stelzenmüller et al., 2017). In other words, MSP aims at minimizing the conflicts among different marine uses and their negative effects by allocating space and applying zoning between uses.

In practical terms, MSP provides a public policy process for society to better determine how the ocean and coasts are sustainably used and protected - now and for future generations." (SPREP 2019).

GIS can be applied in several ways in the process, As Snickars and Pitkänen (2017) note:

1. GIS tools can be used for the delineation of features. The state of features (bio-geophysical, socio-economical, and governance) in a marine area is essential knowledge in an informative MSP process, and GIS can be an efficient tool for identifying, locating, and visualizing the cover and spatial distribution of resources and uses in the form of maps.
2. GIS tools can be used as indicators for assessing management performance throughout the whole MSP cycle, concerning efficiency and effects both during the planning process and the implementation phase. For example, GIS can be used for state comparison either between different areas or over time in the same area.
3. GIS tools can combine several types of spatial data. The process of the Pressure Evaluation Matrix (PEM), relates all uses and their effects in a marine area to the sensitivity of the habitats and species of that area. GIS can be

combined with the PEM to visualize the relationship, i.e. by overlaying the spatial distribution of pressure factors and sensitive habitats. Hence, the applications of GIS in marine management are tightly interconnected and can be used synergistically.

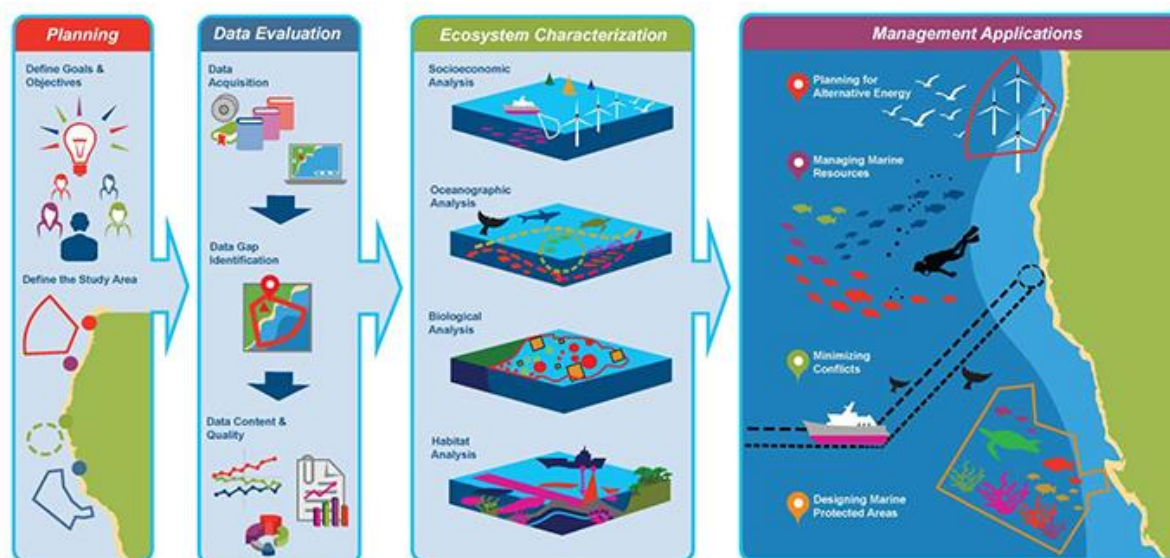


Figure 1. Marine Spatial Planning Workflow (Source: SPREP 2019)

Multi-Criteria Evaluation (MCE), is a method that is used to create area use plans. MCE or MCDA (or multi-criterion decision analysis) evaluates a set of alternatives based on multiple criteria that are quantifiable to create an outcome where each criterion is taken into consideration. When utilizing MCE with spatial data in a GIS environment, there can be better integration of social, political, environmental, and economic factors in the output than the traditional suitability analysis. MCE can also better manage the stakeholder criteria and importance of these criteria by applying weights. (Wood & Dragicevic 2007)

1.3 OS-AQUA GIS and MSP

OS-AQUA GIS is the Geographical Information System developed for the purposes of the project. Its primary objective is to be the tool for the development of the National Marine Spatial Planning (MSP) for the designation of zones of Open Sea aquaculture areas, while its secondary objective is to support in any gi-related task and procedure within the context of this project, from its start till its completion (data manipulation, spatial analysis, map creation, etc.).

However, it is built as an open architecture system allowing greater flexibility and easier integration with other open systems, supporting any future development of the system itself (for example, the incorporation of innovative algorithms) and any other maritime-related project.

OS-AQUA GIS as the responsible MSP tool

- a. exploited data collected from various sources (open & licensed data) as well as the model output from WP3
- b. while reducing conflicts and environmental impacts through the application of a Multi-Criteria Evaluation
- c. mapped the nearshore regions suitable for aquaculture.

These GIS results, in combination with existing work commissioned by DFMR and the dialogue realized with the other stakeholders, had as an outcome the four candidate Allocated Zones for Aquaculture (AZAs) (see Deliverable D13 “Identification of AZAs and AMAs and estimation of their carrying capacity”):

1. Xylofagou West (point 2)
2. Larnaka (point 3)
3. Governor’s Beach (Center & East) (point 6)
4. Aphrodite Hills (point 7)

In this deliverable, the OS-AQUA GIS will be described by presenting:

- The Design of the GIS and the Spatial Database.
- The Platform of OS-AQUA as a result of the review of the various open-source solutions, both for GIS and spatial databases,
- The Development of OS-AQUA GIS in the chosen source technology.
- How the system was used and exploited
- What are the next steps in OS-AQUA GIS integration

2 OS-AQUA GIS

2.1 Introduction

Briefly, the phases of the OS-AQUA GIS development included the establishment of information needs, the collection of data, the system implementation and the system delivery and evaluation. Options of hardware and software, GIS database design, and specifications needed to be appraised to assure a quality system. Thus, any of the five components of OS-AQUA GIS (Hardware, Software, Data, People, and Methods) needed to be carefully identified and implemented.

2.2 GIS and Database Design

2.2.1 The needs

OS-AQUA GIS needs to be a system that would be able to fulfill mainly the following requirements:

- Be able to perform all the GIS functions required, such as Spatial Planning, Spatial Analysis, Thematic Mapping, Composite Mapping, Spatial Querying, etc
- Be able to run locally, but as it progresses to an end-product to be able to provide services through the web as well
- Both the above use carefully selected hardware and software in order to be able to run efficiently and effectively
- Have the right amount of storage for all the data collected in vector and raster format (which take more space)
- Be able to accept any of the most commonly used types of spatial data
- Have an open architecture in order to accept new data, new functions, new algorithms, and processes at any stage of implementation and operation

2.2.2 The data

The usefulness of any geospatial system depends on how accurately the data were collected, stored, manipulated, and analyzed. GIS design involves organizing geographic information into a series of data themes (layers) that can be integrated using geographic location and geodatabase design initiates by identifying the data themes to be used and then by specifying the contents and representations of each thematic layer.

This involves defining:

- How the geographic features should be represented for each theme/layer (points, lines, polygons, or raster) along with their tabular attributes.

- How the data will be organized into datasets
- What additional spatial and database features will be required for integrity rules, for implementing rich GIS behavior (e.g. topologies, networks), and for defining spatial and attribute relationships between datasets.

As the main objective is to zones of Open Sea aquaculture areas in the island of Cyprus, data required, first and foremost, can be categorized in the following sets. i.e. the first level data themes:

- Administrative data
- Hydrographic / maritime data
- Oceanographic data
- Environmental data
- Other Related Spatial data

A fundamental condition to build a spatial system working on heterogeneous data (where cartographic data have a basic role) as the above, with a high level of integration and interoperability with other systems, is to have data that are not only correct but also a) correctly structured according to the rules of database design and implementation, and be b) referenced in a common coordinate system, or if otherwise to apply the appropriate coordinate transformations between the involved coordinate systems.

Table 1 shows all the data collected, divided into the aforementioned data themes.

Table 1. Data Collected and Imported into OS-AQUA GIS

A/A	DATA THEMES	NAME	TYPE	CRS	SOURCE
1	Administrative	The Island of Cyprus	POLYGON	CGRS93 (LTM)	Geomatic Technologies
2	Administrative	Exclusive Economic Zone	POLYGON	WGS 1984	Geomatic Technologies
3	Administrative	British Sovereign Bases	POLYGON	CGRS93 (LTM)	Sovereign Base Areas Administration
4	Administrative	Municipalities/Communities (Polygon)	POLYGON	CGRS93 (LTM)	Geomatic Technologies
5	Administrative	Centre of Settlements	POINT	CGRS93 (LTM)	Geomatic Technologies
6	Hydrographic	Anchorage	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
7	Hydrographic	Maritime Geographical Names	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
8	Hydrographic	Undersea Volcanoes	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
9	Hydrographic	Tides meters	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
10	Hydrographic	Ports	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
11	Hydrographic	Port Works (Licensed-License Stage)	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
12	Hydrographic	Shipwrecks	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)

13	Hydrographic	Buoy	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
14	Hydrographic	Sewage disposal points	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
15	Hydrographic	Desalination Stations	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
16	Hydrographic	Artificial Reefs	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
17	Hydrographic	Aquacultures	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
18	Hydrographic	Lighthouses	POINT	CGRS93 (LTM)	Department of Land and Surveys (DLS)
19	Hydrographic	Pipelines	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
20	Hydrographic	Coastline	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
21	Hydrographic	Coastline - Constructions	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
22	Hydrographic	Coastline - Mean Sea Level	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
23	Hydrographic	Ship Routes	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
24	Hydrographic	Isodepths	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
25	Hydrographic	Port Areas (Lines)	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
26	Hydrographic	Swimming Areas (Lines)	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
27	Hydrographic	Restricted Use Areas	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
28	Hydrographic	Coastal Zone Suggested Limit	LINE	CGRS93 (LTM)	Department of Land and Surveys (DLS)
29	Hydrographic	Anchorage (Polygon)	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
30	Hydrographic	Sandy Areas	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
31	Hydrographic	Fuel Warehouses	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
32	Hydrographic	Rocky Areas	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
33	Hydrographic	Coast Erosion	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
34	Hydrographic	"Natura 2000" Network	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
35	Hydrographic	Energy Centers	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
36	Hydrographic	Suggested Maritime Works	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
37	Hydrographic	Sea Shooting Ranges	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
38	Hydrographic	Posidonia Oceanica Meadows	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
39	Hydrographic	Port facilities	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
40	Hydrographic	Port facilities (Polygon)	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
41	Hydrographic	Maximum Winter Water (Line)	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
42	Hydrographic	Island Area from Lower Low Water	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
43	Hydrographic	Military Material Depot Areas	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
44	Hydrographic	Brine Disposal Areas	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)

45	Hydrographic	Areas of Geological Interest	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
46	Hydrographic	Dredging Areas	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
47	Hydrographic	Areas Vulnerable to Nitrate Pollution	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
48	Hydrographic	Swimming Areas (Polygons)	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
49	Hydrographic	Areas Affected by Tsunami	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
50	Hydrographic	Dredging Material Deposition Area	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
51	Hydrographic	Spatial Fishery Restrictions	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
52	Hydrographic	Suggested Aquaculture Zones	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
53	Hydrographic	Aquacultures (Polygon)	POLYGON	CGRS93 (LTM)	Department of Land and Surveys (DLS)
54	Oceangraphic	Mean 5m temperature 2010-2015	RASTER	WGS 1984	Copernicus Marine Service
55	Oceangraphic	Mean current speed 2010-2015 (vertical max)	RASTER	WGS 1984	Copernicus Marine Service
56	Oceangraphic	Mean wave period 2010-2017	RASTER	WGS 1984	Copernicus Marine Service
57	Oceangraphic	Mean 5m salinity 2010-2015	RASTER	WGS 1984	Copernicus Marine Service
58	Oceangraphic	Mediterranean Sea	POLYGON	CGRS93 (LTM)	Geomatic Technologies
59	Oceangraphic	Bathymetry	Raster	WGS 1984	EMODnet
60	Environmental	Protected Areas (WPA and WD-OECM) May2021	POLYGON	WGS 1984	www.protectedplanet.net
61	Environmental	Special Protected Areas (2019)	POLYGON	WGS 1984	Game Fund
62	Environmental	Migratory bird crossing areas	POLYGON	WGS 1984	Game Fund
63	Other	Airports	POINT	CGRS93 (LTM)	Geomatic Technologies
64	Other	Coastal Points of Interest	POINT	CGRS93 (LTM)	Geomatic Technologies

2.3 Licensed or Open-Source Solution?

The software selected will define more or less the hardware needed securing that the deployment is satisfying the three criteria of Reliability, Availability, and Performance.

To date, there is a huge collection of GIS software that can be categorized by license, source, and operating system support. A comparison can be viewed in the link https://en.wikipedia.org/wiki/Comparison_of_geographic_information_systems_software.

GIS software also can be divided into:

- Desktop Application / Full Package (ArcGIS, QGIS)
- Web GIS / Mapping / Feature Server / Server GIS: (OpenStreetMap, Geoserver, etc.)
- Web Browser with GIS Tools / Thick Client

- Apps, Mashups, APIs – Distributed GIS

OS-AQUA GIS should be able to run locally and on the cloud.

For this project one licensed and one open-source solution were compared and evaluated:

- Licensed Platform Solution: **ArcGIS** by Esri (<https://www.arcgis.com/>)

ArcGIS is a suite of client software, server software, and online geographic information system (GIS) services developed and maintained by Esri. ArcGIS was first released in 1999 and originally was released as ARC/INFO, a command-line based GIS system for manipulating data. ARC/INFO was later merged into ArcGIS Desktop, which was eventually superseded by ArcGIS Pro in 2015. ArcGIS Pro works in 2D and 3D for cartography and visualization, and includes Artificial Intelligence (AI). Furthermore, Esri provides also server side ArcGIS software for web maps, known as "ArcGIS Server".

- Open Source Platform Solution: **QGIS** (<https://www.qgis.org/>)

QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application. It functions as complete GIS software, allowing users to analyze and edit spatial information, composing and exporting graphical maps. It supports both raster and vector layers. In terms of file formats, it supports shapefiles, coverages, personal geodatabases, dxf, MapInfo, PostGIS, etc. It also supports Web services, including Web Map Service and Web Feature Service, to allow the use of data from external sources

QGIS integrates with other open-source GIS packages, including PostGIS, GRASS GIS, and MapServer and Plugins written in Python or C++ to extend QGIS's capabilities.

2.3.1 Comparison

A brief comparison of the two GIS software can be found in <https://www.trustradius.com/compare-products/arcgis-vs-qgis>. The main points of this comparison are:

- Features

ArcGIS and QGIS are both used for mapping spatial data, but they have a few important differences.

ArcGIS has been in use since 1999, and since then, it has evolved to a very robust, full-featured program with a steep learning curve for end-users. Data sharing and exporting options make it possible to use ArcGIS for many different types of projects, and ArcGIS provides excellent support for its users, including training.

QGIS is simpler than ArcGIS, it is perfect for small projects which use less data, and since it is free, it's ideal for organizations with leaner budgets. It is compatible with ArcGIS, however, so QGIS users can still accept and work with

ArcGIS-specific files. Like many open-source projects, it has lots of plugins and extensions to accomplish that expand its capabilities.

- Limitations

ArcGIS is complex and fully-featured, so it needs a lot of computer processing power to use properly, the program loads slowly upon opening, and large files take a very long time to save. It is too complex for simple tasks for the end-user, and this complexity is reflected in the price as well. Advanced analytical tools not included in the original software cost extra money.

The limitations of QGIS are typical of open-source software. Plugins and extensions for tasks QGIS itself cannot do are abundant, but they are not centrally located and can be difficult to find. QGIS is easier to use than ArcGIS, but it lacks the official training resources and dedicated support

- Pricing

As QGIS is open-source software, it is free to use while ArcGIS is licensed, and it is quite costly.

2.3.2 GIS Software Selection

ArcGIS is considered the most complete and advanced GIS application, however, issues with ArcGIS include perceived high prices for the products, proprietary formats, and difficulties of porting data between Esri and other GIS software. QGIS is compatible and can accept and work with ArcGIS-specific files. This fact was crucial in terms of database design and implementation. Thus, it was decided OS-AQUA GIS development to be completed with an open-source technology.

2.4 OS-AQUA GIS Development

2.4.1 Hardware

OS-AQUA GIS is currently deployed in local desktop environment and will be provided as a web application by the end of the project. The Environment Specifications are provided in Table 2:

Table 2. Environment Specifications (Windows)

	Minimum	Recommended
Processor - CPU	Core i3 2.7Ghz	Core i7 3.5Ghz
Memory RAM	2Gb	8Gb or more
Hard Disk	500 Gb	128Gb or 500Gb
Graphic card	1Gb RAM	2Gb RAM (NVIDIA Geforce)

Operating System	Windows 7-10 / Linux	Windows 7-10 / Linux
System type	64-bit operating system, x64-based processor	64-bit operating system, x64-based processor

2.4.2 GIS Software & Geodatabase

GIS software

The selected GIS software is the QGIS (latest version used 3.22), with all the advantages/disadvantages noted in previous sections.

- Latest version used: 3.22

Spatial Database (Geodatabase)

A spatial database is a database optimized for storing and querying data that represent spatial objects.

In order to proceed in a sound way in the making of a GIS, particular care must be paid to the design of the database (Carrion et al, 2009). For the structure of the database is based on the rules of database design (Atzeni et al. 1999). In designing a database, one out of several different models may be chosen; however, the one that is nowadays most commonly used in the GIS field is the *relational model* of data (Codd 1970; Chen 1976). The relational model allows for a remarkable flexibility from the point of view of the database users while providing “a means of describing data with its natural structure only—that is without superimposing any additional structure for machine representation purposes” (Codd, 1970).

Relational databases also offer multi-user functionality so that multiple users can connect to a database and edit the data at the same time. Having a centralized data repository means that all users in an organization can work with the same data, which will always be the most up-to-date version of it. In terms of data management, this will save everyone a lot of time and force people to adhere to the data structure or data schema.

PostgreSQL is a powerful and robust, free open source object-relational database system with over 30 years of active development. PostGIS is a database extension that is run alongside PostgreSQL and allows you to do spatial operations, store data, geometries, build spatial indexes, and more.

While working with folders full of spatial data files is a valid way of managing spatial data, it has limitations. For example, a file format as the shapefile has its own limitations in terms of file size, and column names are limited to a maximum of ten characters. A spatial database, like PostgreSQL, is a natural progression in this regard. Another great advantage of a PostgreSQL geodatabase is that it can be built either locally or on a server but still be accessible by QGIS.

All data mentioned in section 2.2.2 where imported in a PostgreSQL Geodatabase, named “os_aqua_db” (Table 3). Five schemas have been initially created based on the corresponding 1st level data themes aforementioned. In addition, two extra schemas called “msp” and “cage_design” were created which contained the results of the Marine Spatial Planning, as described in D13 (Identification of AZAs and AMAs and estimation of their carrying capacity), and the designs of the cages per technology and cages (see D11- Identification of sites with less sensitive/important/rare habitats where the impact of the aquaculture at the environment can be minimized).

All other data that will be required or generated until the end of the project will be allocated accordingly to the created schemas, or if it necessary, new schemas will be created:

Table 3. The geodatabase “os_aqua_db” and its schemas

1st Level Data Themes	Schemas
Administrative data	admin_data
Hydrographic / maritime data	hydrographic_data
Oceanographic data	oceanographic_data
Environmental data	environmental_data
Other Related Spatial data	other_data
Marine Spatial Planning	msp
Cage Design	cage_design

The diagram of the geodatabase is shown in Figure 2.

The PostgreSQL database of OS-AQUA GIS is currently deployed on a local desktop environment and will be moved to the cloud by the end of the project for open access.

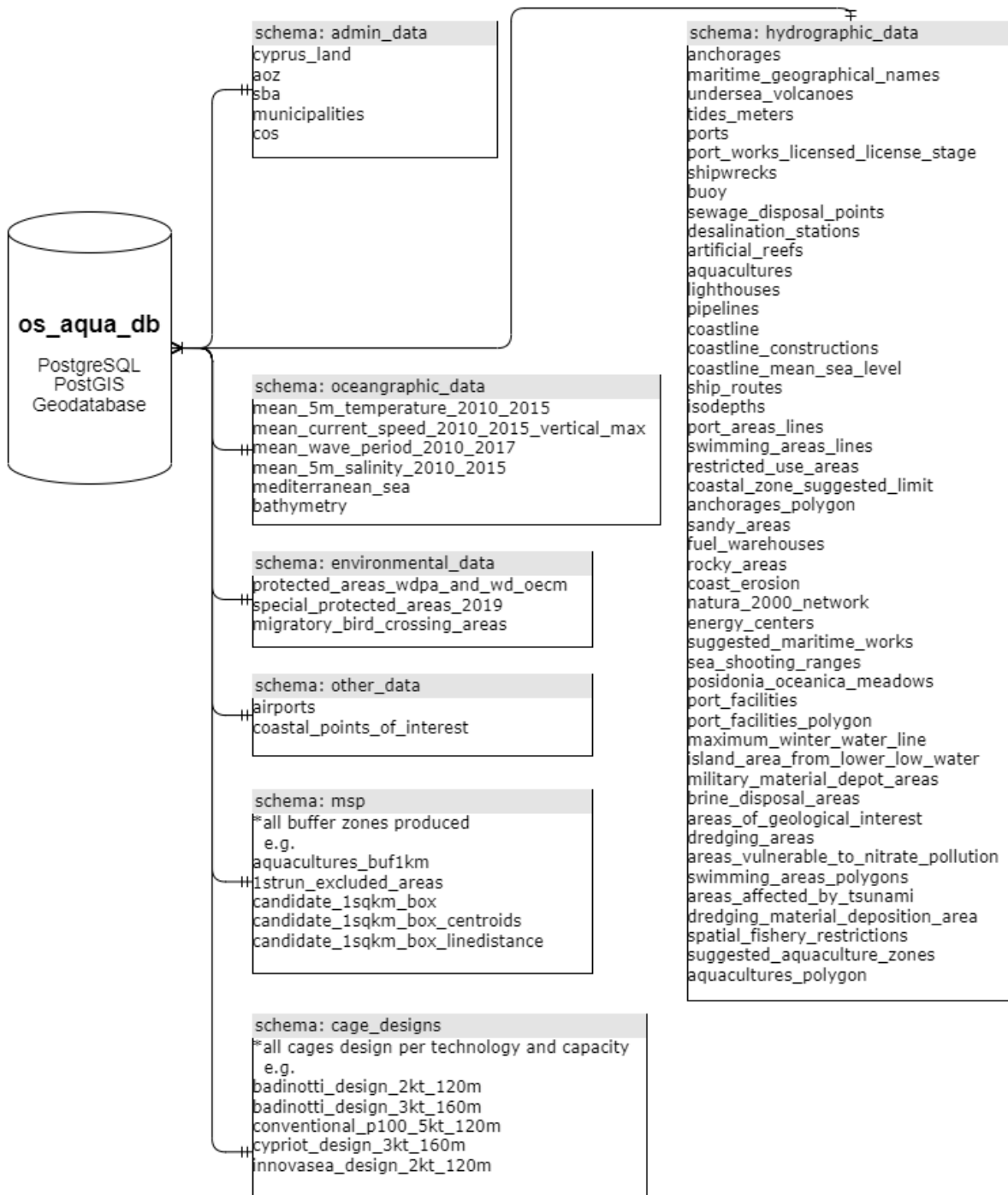


Figure 2. The diagram of the "os_aqua_db" geodatabase

2.4.3 People and Methods

The GIS software, i.e. QGIS, the creation, management, and the maintenance of the geodatabase of OS-AQUA GIS were handled by GEOMATIC, the responsible partner for the GIS-related development and management.

The main GIS Functions and Methods required until month18 were:

- Data Import (e.g. import data acquired into the database)
- Data Management (e.g. create and split cage designs per technology and capacity)
- Data Analysis (e.g. calculate the distance of candidate AZAs from nearest port facilities)
- Thematic Mapping & Map Overlay (e.g. Candidate AZAs Area Maps, Land Use Maps, MSP Criteria Maps, etc.)
- Spatial Analysis (e.g. MSP – buffer zones creation, layers overlay/union)
- Spatial Querying (e.g. what existing aquacultures exist within a distance from the candidate AZAs?)

2.4.4 Use

OS-AQUA GIS, once it was designed and developed, has been used intensively throughout the whole progress of the project (see previous section, 2.4.3.) until month 18. The system will be constantly upgraded and improved until the end of the project.

Examples of the exploitation of OS-AQUA GIS are shown in the following maps.

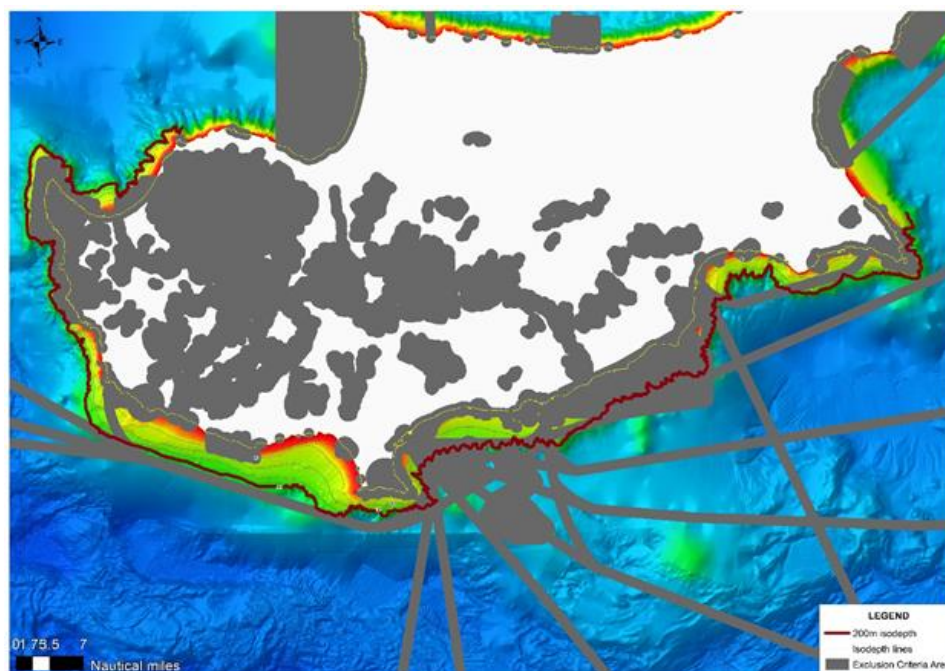


Figure 3. Areas excluded during Phase 1 of Marine Spatial Planning (see D13).

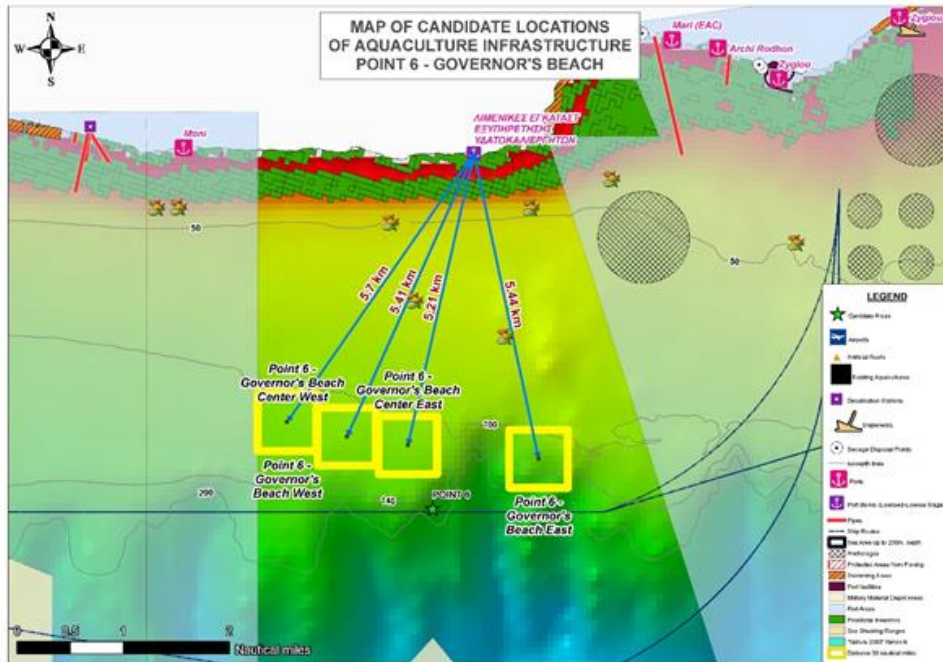


Figure 4. Governor's beach Candidate AZA and its 4 AMAs (see D13).

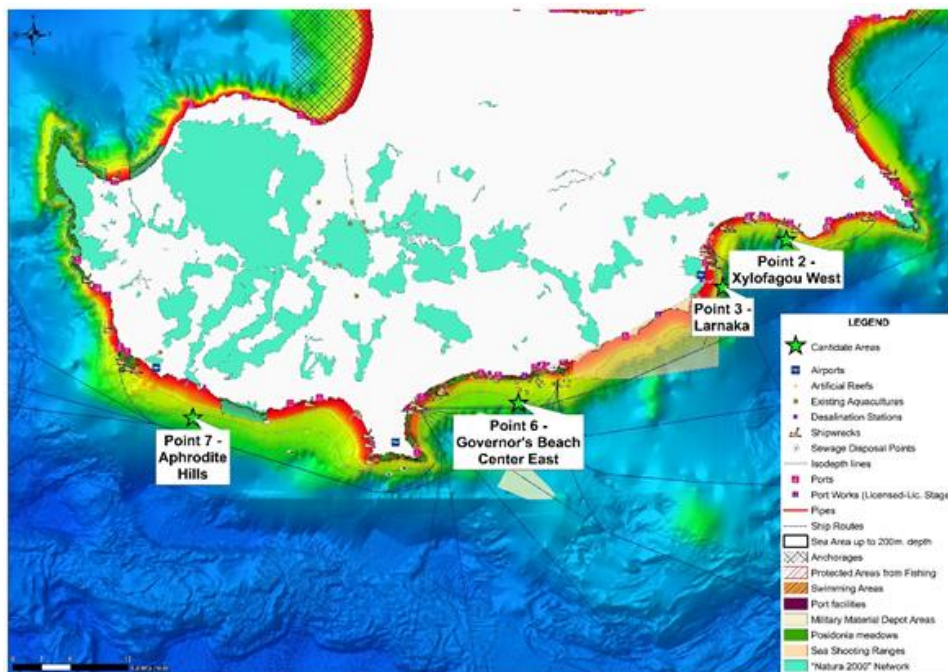


Figure 5. The result of the MSP application: 4 selected Allocated Zones for Aquaculture (see D13).

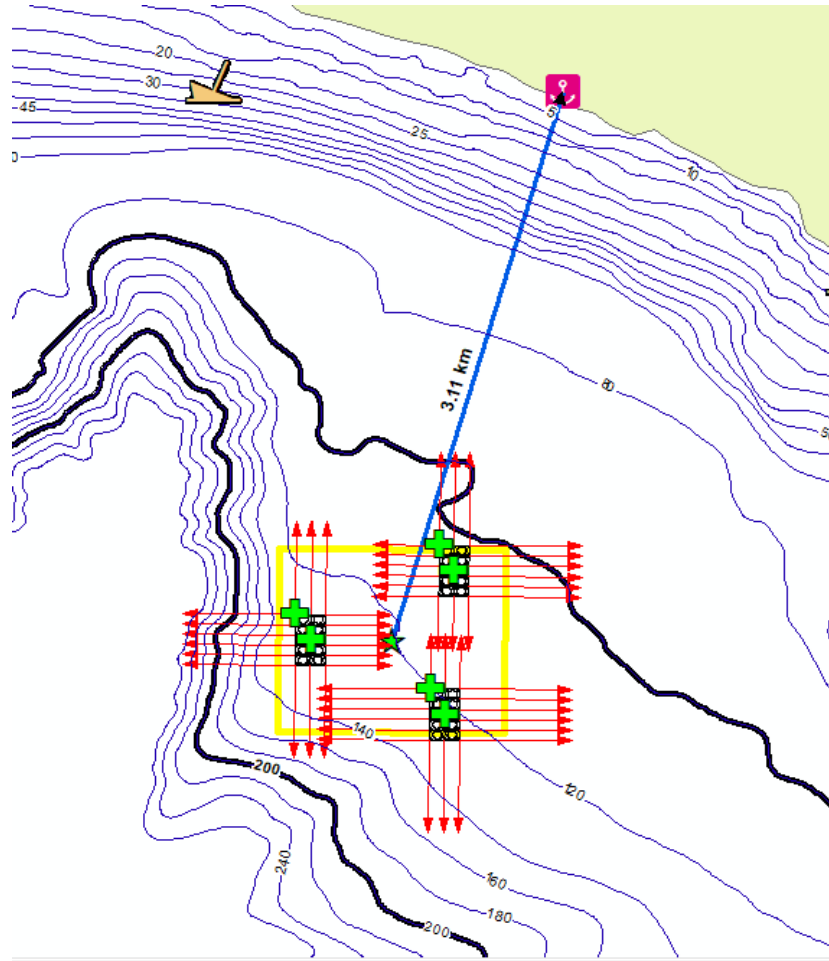


Figure 6. Deployment at Point 2 -Xylofagou West - Badinotti Technology – 2,000 tonnes per year (see D11).

3 Conclusions and Next Steps

OS-AQUA GIS is the Geographical Information System developed for the project using free open source technology. It was used as the Marine Spatial Planning (MSP) tool for the identification of Allocated Zones of Aquaculture areas and for other gi-related tasks and procedures within the context of this project (data manipulation, spatial analysis, map creation, etc.).

OS-AQUA GIS will continue to grow, until it will take the form of a decision tool. It will be deployed on a server environment and will incorporate innovative algorithms. This will increase the **impact** of OS Aqua GIS, making a step beyond the scope of this project that to support other endeavors and be linked to other systems developed, for example in the MARI-Sense project, <https://www.marisenseproject.net/>.

Furthermore, OS-AQUA GIS will be continuously demonstrated and assessed by various partners and stakeholders in the quadruple helix, such as the Department of Fisheries and Marine Research and the Cyprus Marine and Maritime Institute. It will serve applications related not only to aquaculture and existing industries, but also new ones such as offshore renewable energy production.

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