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MAES_GR: A Web-Based, Spatially Enabled Field Survey Platform for the MAES Implementation in Greece

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Abstract: This study presents a standardized approach to collecting, registering, and reporting field-survey data for baseline MAES (Mapping and Assessment of Ecosystems and their Services) information in Greece. This is accomplished through a web-based platform (MAES_GR) exclusively developed under the relevant, nation-wide LIFE-IP 4 NATURA project. Based on the European Commission's guidance for ecosystem condition (EC) and ecosystem services (ES) MAES studies, we conceptualized and structured an online platform to support EC and ES assessments, integrating all relevant fields of information needed for registering EC and ES parameters. A novel algorithm calculating EC was also developed and it is available as an integral part of the platform. The use of the MAES_GR platform was evaluated during nationwide field surveys efforts, increasing time efficiency and reducing costs. Field recording of EC and ES pinpoint spatial priorities for ecosystem restoration, conservation and sustainable development. This work highlights that MAES implementation can be favored by the use of technology tools such as mobile survey platforms, developed according to scientific needs and policy guidelines. Such tools, apart from the data inventory phase, can be used for data analysis, synthesis and extraction, providing timely, standardized information suitable for reporting at the local, regional, national and European Union scale.

Keywords: data collection; decision making; ecosystem condition; ecosystem services; environmental monitoring; GIS; IT; mapping; search and analytics engine; web application

1. Introduction

Mapping and assessment of ecosystems and their services (MAES) has attracted the interest of the scientific community since the introduction of the ecosystem services (ES) term and concept in the 1990s (e.g., [1–3]). Thereafter, a significant, increasing amount of effort has been given on MAES studies at the local, regional, national and international/global scale. Characteristic examples are the Millennium Ecosystem assessment [4], presented in 2005, the recent Global Assessment of Biodiversity and Ecosystem Services, under the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) initiative [5], and for the European context, the provisions of the EU biodiversity Strategy [6] for ecosystem condition (EC) and ES assessments across the Member States, supported with the relevant guidance documents (e.g., [7,8]) and the targets of the EU Green Deal [9]. Subsequently, a variety of methods and supporting platforms have been

developed and tested to serve the research needs in the field of ES [10]. Many countries work on their national delineation and standardization of MAES studies (e.g., [11–16]). An ongoing assessment for natural capital accounting tries to mainstream national accounts for ecosystems and ecosystem services in the EU [17] following the prerequisites of SEEA Experimental Ecosystem Accounting and the Central Framework [18]. However, a standardized approach for assessing and reporting EC and ES status across all scales (local, regional, national, European/global) is missing. Moreover, ES mapping is not a trivial task, since direct assessment of ES is challenging as ES are intermediates of ecosystems' supplies to the society, while most mapping methods rely on indicators and questions exist on scale-related issues and on popular extrapolation and interpolation schemes [19].

Since 2015, Greece has been developing methodologies, actions, and capacity building workshops and projects to integrate MAES into management practices and decision-making processes (e.g., [20–23]). These efforts, conducted under the requirements of the EU Biodiversity Strategy, are mainly supported by the Action A.3 of the Life Integrated Project “LIFE-IP 4 NATURA” [24], led by the Hellenic Ministry of Environment and Energy, which aims to implement the MAES approach at the national, regional and local (case-study) level. However, the relevant preparatory actions and literature review revealed significant data gaps across the Greek territory, especially for ES identification and ecosystem type documentation, including their condition, outside the Natura 2000 protected areas network [20,22]. Within the LIFE-IP 4 NATURA project, there is an ongoing effort for homogenizing existing and generating new spatial datasets, which are essential for the MAES implementation. Yet, it is evident that up-to-date, precise and content-rich field data are urgently needed to support various aspects of the implementation process.

Many studies in the past employed field data alone or along with remote sensing measurements for direct ES assessment [25]. Based on a comprehensive needs' assessment, similar to earlier studies, we further identified that field surveys are also considered essential for providing timely data for assessing the accuracy of remote sensing-based efforts for ecosystem type mapping [23]. They are also essential for ground validation of EC and ES availability and flows [20,22] estimated through spatial analysis.

While ground data from other European or national biodiversity relevant monitoring schemes have the potential to provide certain ES parameters, in general they are of limited use due to the missing cross-reference between the original data-recording scheme and MAES implementation needs [26]. In addition, such monitoring schemes with coarse update intervals present discrepancies and outdatedness in comparison to the actual landscape structure [23].

Relevant ecological field surveys (e.g., Habitat Directive's monitoring and habitat type mapping projects) revealed that one of the major problems was the data collection method and registration; thousands of paper-based reports had to be edited and indexed in order to properly register all information in a homogenized database. This time-consuming and, subsequently, economically inefficient method is found to be inappropriate, error-prone and obsolete for these type of studies (especially when conducted at the national scale and in fine detail) considering the technological progress on field data collectors (e.g., built in Global Navigation Satellite Systems (GNSS) receivers), relevant software availability or development ease (e.g., open source platforms) and remote access to the internet (e.g., Wi-Fi networks, Bluetooth and GPRS protocols) [27].

Earlier comparative studies in other domains have identified that electronic-based, mobile field surveys, compared to traditional paper-based, in-situ surveys, generate more complete data with higher accuracy as well as time and cost efficiency [28,29].

Trying to fulfil the aforementioned needs and cope with the cost-effective, efficiently functioning relation for future, large-scale ecological field assessments, this study provides an electronic-based mobile survey approach to recording, registering and presenting field data and relevant results. More specifically, the herein presented web-platform aims to: (a) provide pre-defined responses for ecological parameters' registration, (b) calculate relevant information based on location and the registered data, (c) minimize post-processing

effort, (d) be user-friendly and (e) be compatible with a variety of devices and operating systems. Finally, this work provides an extensive review of trial runs and field testing of the platform, acting as a guide for standardized data collection and registration for the MAES implementation among EU Member States, for reporting at the local, regional, national and EU (10x10 EEA reference grid) [30] level.

2. Materials and Methods

The design and development of the MAES_GR web-based platform consists of two distinct but interdependent parts:

1. The MAES conceptual approach for data collection and analysis for both ecosystem condition and ecosystem services.
2. The technical development of the platform.

To fulfil the process, we designed and followed a conceptual framework of inputs and outputs needed for the assessment and assigned it with the implementation (technical) process (Figure 1). This framework consists of steps, with each one supporting a different need (responds to specific scientific query) and their synthesis provides guidance for decision making:

- Step 1: Conceptualization
- Step 2: Ecosystem type identification (includes ecosystem type classification scheme) (input)
- Step 3: Design of the ecosystem condition assessment approach (includes ecosystem condition assessment parameters) (input)
- Step 4: Design of the ecosystem services assessment approach (includes ecosystem services categories, classification scheme and rating scheme) (input)
- Step 5: Development of the web-based platform (includes pilot testing and evaluation)
- Step 6: Outputs to support decision making

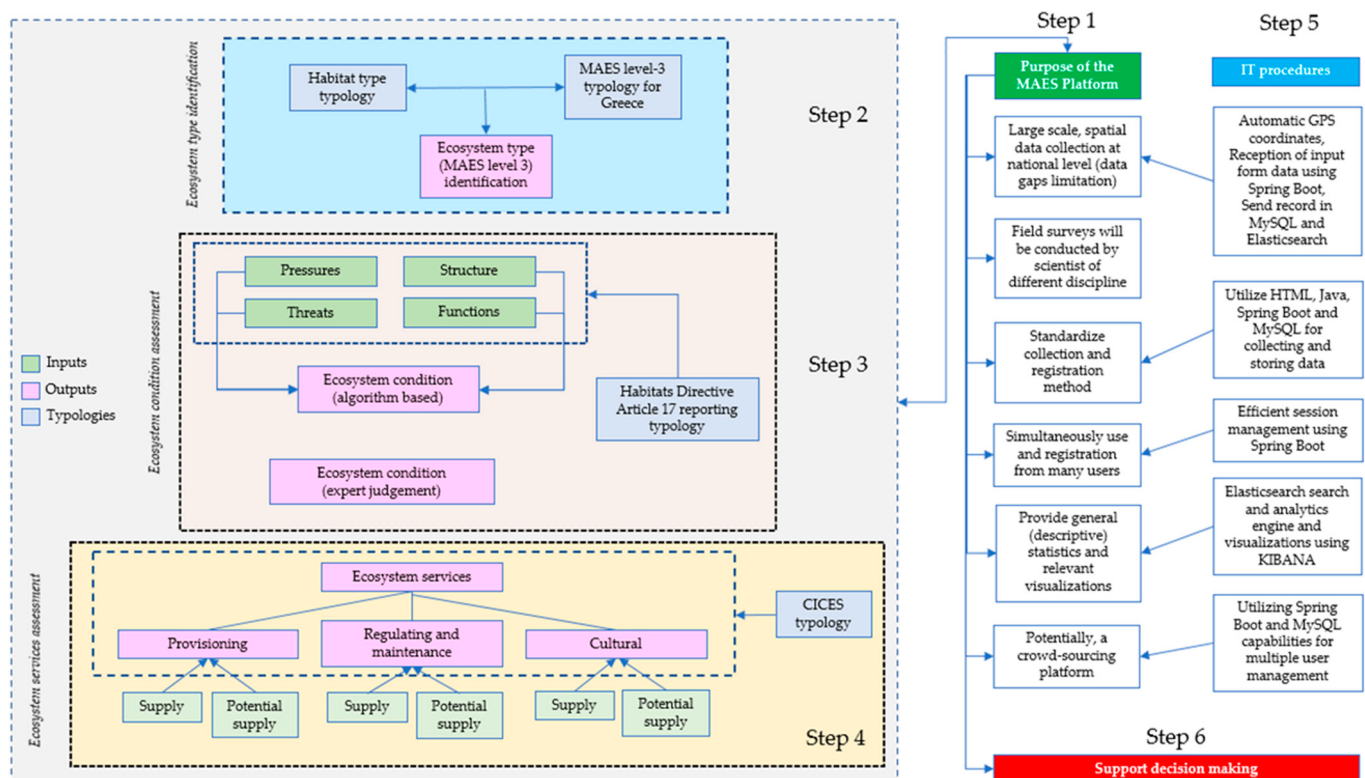


Figure 1. Methodological flow-chart for the platform development.

The methodological procedure is described in detail, as follows.

2.1. Conceptualization

The requirements for the platform were specified according to the LIFE-IP 4 NATURA project needs and the available resources. The implementation workflow was motivated based on the following principles:

1. Use of open-source, reusable, software both for the front-end (graphical user interface) and the back-end
2. Ability to geospatially visualize the ES-relevant data, using up-to-date satellite and GIS base-maps, providing informative context to users
3. Ability to implement a variety of visualizations (i.e., pie charts, heat-maps) and spatial/aspatial queries
4. Ability to automatically update the central database as new survey data become available without modifying the software code, supporting monitoring and ES spatio-temporal changes detection
5. Disaggregation and aggregation of the survey data. Calculation of the respective statistics at various scales and units (e.g., EEA reference grid cell, regional unit, national)
6. Ability to extract information using task-specific algorithm
7. Ability to survey data relevant to ecosystem types, ecosystem services and ecosystem condition
8. Ability to complement concurrent activities and tasks within the project (i.e., providing reliable, accurate reference data for spatial explicit mapping of ecosystem types and services using Earth Observation data)
9. Compatibility with a variety of mobile devices and operating systems for data entry

2.2. Ecosystem Type Identification

The initial step to begin the assessment is to select the relevant ecosystem type at the most detailed level that can be identified by the surveyor at the plot, i.e., MAES level 1, 2, 3 or at the habitat type level (most detailed). For the delineation of the ecosystem type classification scheme, we followed the typology proposed by previous studies for Greece, which allows the correspondence of all terrestrial habitat types to the MAES Level 1, 2, 3 ecosystem type classes [21–23,31]. Table 1 presents an example of the typology for wetland classes, while the detailed typology for all terrestrial ecosystems is included in Table S1.

Table 1. Typology example of the correspondence among mapping and assessment of ecosystems and their services (MAES) ecosystem type classes (level 1, 2 and 3) and habitat types, for the wetlands.

MAES Level 1	MAES Level 2	MAES Level 3	Habitat Type Name	Habitat Type Code
Terrestrial	Wetlands	Inland freshwater marshes	Humid dune slacks	2190
			Euro-Siberian annual communities of muddy riverbanks	32B0
			Reed thickets	72A0
			Rush communities	72B0
			Salicornia and other annuals colonizing mud and sand	1310
		Inland saline marshes	Mediterranean salt meadows (<i>Juncetalia maritimi</i>)	1410
			Mediterranean and thermo-Atlantic halophilous scrubs (<i>Sarcocornietea fruticosi</i>)	1420
			Halo-nitrophilus scrubs (<i>Pegano-Salsoletea</i>)	1430
			Salt pans	1440
			Mediterranean salt steppes (<i>Limonietalia</i>)	1510
		Peat bogs	Transition mires and quaking bogs	7140
			Calcareous fens with <i>Cladium mariscus</i> and species of the <i>Caricion davallianae</i>	7210
			Petrifying springs with tufa formation (<i>Cratoneurion</i>)	7220
			Alkaline fens	7230

2.3. Ecosystem Condition

To assess the ecosystem condition, we chose to integrate both the experts' opinion and as well as the output of an algorithm, exclusively developed for the MAES_GR platform, which calculates the ecosystem condition from the various inputs registered in the platform.

2.3.1. Expert Based Assessment

Although much effort has been made in recent decades to assess the state of the environment with quantitative and qualitative methods, it has been shown that in many cases, expert-based approaches are necessary for management reasons. In addition, the deviation from the results of the aforementioned methods is relatively small [32]. By this, we provide in the MAES_GR platform a relevant field for ecosystem condition assessment based on the evaluator's expert elicitation at each plot, with a predefined selection from a five-level Likert scale (i.e. Excellent, Good, Moderate, Bad, Very Bad), representing the ecosystem condition at the plot. All evaluators/field scientists have extensive previous experience in field assessments and monitoring projects for Dir. 92/43/EEC and Water Framework Directive monitoring. Moreover, a two-day training course has been conducted, including field testing of the platform; a user manual is also produced to support possible at-the-field operating issues.

2.3.2. Ecosystem Condition Calculation Algorithm

Following the guidance provided by the analytical framework for mapping and assessment of the ecosystem condition in EU [8] we developed an ecosystem condition calculation algorithm based on data collected and registered via the online platform. The algorithm includes as parameters (ecosystem condition indicators): (a) "key" and "other" pressures of high, medium and low importance and (b) ecosystem attributes, corresponding to "key" and "other" structural and functional ecosystem attributes, at each sampling plot. "Key" indicators are selected based on policy relevance and data availability (for details see [8]). Table S2 of the Supplement provide the lists of "key" and "other", pressures, structures and functions, as delineated for this study.

More precisely, pressure selection is made from a predefined, drop-down list that includes all pressures previously recorded for the habitat types in Greece during the last monitoring project [33]. Pressure typology follows the one provided from the reference portal for reporting under Article 17 of the Habitats Directive [34]. Each pressure can be rated as high, medium or low (importance). Ecosystem attributes delineation is made by the selection at the plot of the recorded structures and functions from a predefined drop-down list that includes all structures and functions per ecosystem/habitat type as presented in the "Methodology for monitoring and conservation status assessment of the habitat types in Greece" [35]. By this, the ecosystem condition (EC_i) at each sampling plot (i) is structured and calculated as follows:

$$EC_i = aP_i + bEA_i$$

where:

EC_i = Ecosystem Condition
 P_i = Pressures index
 EA_i = Ecosystem Attributes index
 a, b = weights
 a = −1
 b = 0.5
 i = Ecosystem type i

P_i and EA_i are calculated as follows:

$P_i = a_iPI_{key} + b_iPI_{other}$
 P_i = Pressures index for ecosystem type i
 PI_{key} = key pressure indicator
 PI_{other} = other pressure indicator

a = weight for key pressures indicator = 2

b = weight for other pressures indicator = 1

$$PI_{key} = 3 * \frac{\text{No of key pressures of High importance at plot}}{\text{No of key structures of high importance at MAES level 3}} + 2 * \frac{\text{No of key pressures of medium importance at plot}}{\text{No of key pressures of medium importance at MAES level 3}} + 1 * \frac{\text{No of key pressures of low importance at plot}}{\text{No of key pressures of low importance at MAES level 3}} \quad (1)$$

$$PI_{other} = 3 * \frac{\text{No of other pressures of High importance at plot}}{\text{No of other pressures of high importance at MAES level 3}} + 2 * \frac{\text{No of other pressures of medium importance at plot}}{\text{No of other pressures of medium importance at MAES level 3}} + 1 * \frac{\text{No of other pressures of low importance at plot}}{\text{No of other pressures of low importance at MAES level 3}} \quad (2)$$

$$EA_i = aS_{key} + bS_{other} + cF_{key} + dF_{other}$$

EA_i = Ecosystem Attribute index for ecosystem type i

S_{key} = key ecosystem attribute indicator

S_{other} = other ecosystem attribute indicator

a = weight for key ecosystem attribute = 2

b = weight for other ecosystem attribute indicator = 1

F_{key} = key ecosystem attribute indicator

F_{other} = other ecosystem attribute indicator

c = weight for key ecosystem attribute indicator = 2

d = weight for other ecosystem attribute indicator = 1

$$S_{key} = 2 * \frac{\text{No of key structures at plot}}{\text{No of key structures at MAES level 3}} \quad (3)$$

$$S_{other} = 1 * \frac{\text{No of other structures at plot}}{\text{No of other structures at MAES level 3}} \quad (4)$$

$$F_{key} = 2 * \frac{\text{No of key structures at plot}}{\text{No of key functions at MAES level 3}} \quad (5)$$

$$F_{other} = 1 * \frac{\text{No of other functions at plot}}{\text{No of other functions at MAES level 3}} \quad (6)$$

The result of the ecosystem condition calculation from the algorithm is normalized and presented at a −1 to 1 scale, with a relevant color scale and as presented in Table 2.

Table 2. Ecosystem condition algorithm rating scale and the relevant color scale as used in the MAES_GR platform.

Ecosystem Condition	Algorithm Output
Excellent	1.00 to 0.60
Good	0.59 to 0.20
Moderate	0.19 to −0.19
Poor	−0.2 to −0.59
Bad	−0.60 to −1.00

2.4. Ecosystem Services Assessment

Ecosystem services selection and assessment is based on the expert's judgment to provide an overview or actual and potential supply of ecosystem services at each plot. The selection of different types of ES within the CICES [36] class level is guided via the provision of dropdown menus for each CICES section, divided in abiotic and biotic ES. A five-level Likert scale (i.e., 0 = none, 1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high) is used for the assessment of the actual and potential supply of ES, identified at each plot.

2.5. Scale of Interpretation and Analysis

The platform is designed to provide interpretation of the database entries in terms of summary statistics and spatial distribution at the national, regional (NUTS2) and at a 10×10 km EEA reference grid level (see Section 2.6.2).

2.6. Technical Information (IT Part)

2.6.1. MAES Platform Architecture

The main goal of the MAES_GR platform is to collect data in a user-friendly manner, calculate relevant information and provide predefined responses based on the input data for a variety of ecosystems. Data input and visualization is available on all devices. Any user enrolled on the platform has the ability to fill any number of the available forms to input data on the system and receive statistics based on the already registered data.

The MAES_GR platform was developed using Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS) for front-end development, Java programming language for the back-end development and utilizing the Spring Boot framework to create a production-grade application. The object-oriented Java programming language with simple memory management and automatic garbage collection enables the development of a refined platform. Spring Boot facilitates automated configuration of the web application based on the dependencies added to the project (i.e., configuring the database connection or creating the database entities). It also enables MAES_GR platform development as a stand-alone application, stored in a .jar file that is uploaded on a server (with the appropriate Apache database running on the server side). Once uploaded, the .jar and a database server are enough to run the web platform.

The platform architecture (Figure 2) can be distinguished into three main modules: the data input, the database and the data output module.

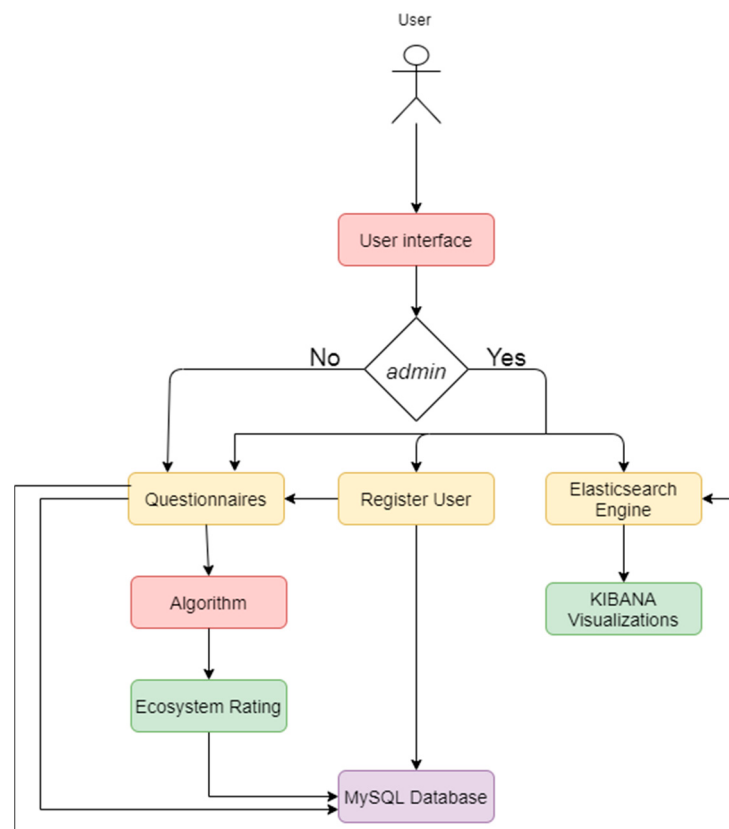


Figure 2. MAES platform programming architecture.

Firstly, for the online MAES_GR platform, users need to log in to their accounts to have access to the platform. All data input is achieved through the input forms or the creation of new users. Once logged in, users can select between 12 input forms. The platform is fully compliant with General Data Protection Regulation (GDPR), meaning that all users remain anonymous and are asked to provide access to the platform for sensitive data, like the user's Global Positioning System (GPS) coordinates. All data remain protected after input and are not accessible from unauthorized users or used in any way that is non-compliant with the platform's goal. The platform algorithm is a pre-established algorithm that exploits the data as they are input by the user. It is compiled upon each successful input form completion and analyzes user input to produce a distinctive value in order to evaluate the ecosystem's condition. This is especially crucial since it provides us the ability to keep track of an ecosystem's condition and evaluate how it evolves over time.

Regarding the database, upon successful completion of any survey protocol form, all data will be automatically fed into the Relational Database (RDB), which is a MySQL database, enabling access to the data. The database stores and provides access to the data (i.e., data export) for the system administrators. MySQL offers unmatched reliability and scalability, being able to handle embedded applications and a multitude of information. It also offers strong data protection, further solidifying our GDPR compliance.

Finally, regarding the output, administrators of the MAES_GR platform can apply three (3) alternative visualizations for the stored data. The visualizations are available on a national, regional and EEA reference grid level. All data used for the visualizations are fetched from an Elasticsearch-based database and are then utilized for visualization and statistical analysis, using Kibana. Upon every successful input form submission, the data provided are stored in the Elasticsearch database and are instantly available on the visualizations. All visualizations are predefined, while the users have the flexibility to use specific filters on the data visualized. More information on the visualization procedure is described below.

2.6.2. MAES_GR Functionality

The end user must connect to the web platform (both administrators and ES experts have access). Then, he/she must select one of the twelve (12) available protocols (namely Urban, Cropland, Grassland, Woodland and forest, Heathland and shrub, Sparsely vegetated land, Wetlands, Rivers and lakes, Marine inlets and transitional waters, Coastal, Shelf and Open Ocean) and then submit the protocol through the platform. Each questionnaire consists of four (4) different sections: (a) General Data, (b) MAES Level 3, (c) Ecosystem Condition and (d) Ecosystem Services, and all sections must be filled in before the result is submitted to the platform. The main page of the platform and an example of a completed protocol form is presented in the Supplementary Material "Screenshot presentation of a completed protocol form".

After the form is submitted, the record is both saved in the MySQL database and is also sent to a Search and Analytics Engine (SAE), namely, web based Elasticsearch SAE (Elasticsearch, n.d). Elasticsearch is a highly distributed RESTful SAE, which allows addressing multiple use cases by storing large amounts of data types (e.g., numbers, geo, text, structured, unstructured), offering extremely fast speeds for searching information and providing a large variety of analytics. The questionnaire survey protocol data is fed to Elasticsearch after being transformed to a JavaScript Object Notation (JSON) file format (JSON, n.d) through the Spring Boot application, written in JAVA, which handles everything related to the platform, both front-end and back-end. Subsequently, the Kibana open-source, web-based visualization tool (Kibana, n.d) is used for data analysis and visualizations. Kibana can offer functionalities, such as:

- User-friendly dashboards that visualize the information received from the Elastic clusters
- Search, view and interact with the stored data in real-time
- Create data queries and visualize information in tables, charts, geo maps, etc.

Kibana is able to efficiently cope with large volumes of data, when properly connected with Elasticsearch through an index pattern which describes the required data input format accepted and the Elasticsearch object(s) of interest for visualization. Subsequently, various visualizations can be created and added to a platform's dashboard. Kibana offers a large variety of data visualization and presentation options, including, among others, line, area, or bar charts, heat maps, pie charts, time series charts, geo maps, etc.

In the case of MAES_GR, only the platform administrator would have access to the relevant statistical data produced by the platform. Regarding the survey statistics, they can be aggregated in the (a) national level, (b) regional Level and (c) 10km EEA reference grid level. Key questions are presented in the visualization format, such as (we indicatively only name a few):

- The number of structures and functions per MAES level 3
- The (low/medium/high) pressures and threats per MAES level 3
- The (low/medium/high) pressures and threats per MAES level 2
- The ecosystem services supported per MAES level 2
- The biotic and abiotic services per MAES level 2
- The actual and potential supplies of cultural services
- Created data queries and visualized information in tables, charts, geo maps, etc.

For each one of the three (3) different aggregation filters needed (national, regional, 10km grid level), the equivalent webpage loads the filter-specific dashboard, and each dashboard is comprised of all the visualizations created. Furthermore, it was necessary to cover the case where the administration would need to filter out the aggregations and focus only on one country, one region or one EEA reference grid cell. As a result, the equivalent webpages for the visualizations allow the administrator to filter out and select a specific country, a specific region or a specific EEA reference grid cell using drop-down lists, which are dynamically updated on every new survey record added.

2.7. Pilot Testing and Data Collection

To identify possible flaws and malfunctions in terms of the conceptualization as well as the technical development, we conducted pilot, field surveys in early 2019 at different ecosystem types. These surveys took place in areas where the ecosystem categories were known, i.e., inside Natura 2000 Special Areas of Conservation (SACs), as well as outside Natura 2000 sites [37]. Survey teams consisted of experts on field ecological assessments, members of the LIFE-IP 4 NATURA project consortium [24], in order to properly assess not only the target objectives (i.e., ecosystem condition and ecosystem services), as well as the time-consuming result of the completion of the protocol at each plot in the field, as well as the time gained due to the automatic registration into the online database. The results were compared to similar assessment procedures that use printed, predefined protocols, filled in by hand from the expert; as a reference, we used the results of the recent nation-wide, Habitats Directive monitoring project [33].

In early May 2020, field surveys started with the priority to provide input from areas outside the Natura 2000 network SACs, where main data gaps are reported for ecosystem identification, ecosystem condition as well as on ecosystem services [22,23]. To provide a preliminary efficiency assessment for the time needed by the surveyor to complete all fields of the platform and submit the protocol form, each surveyor had the obligation to report, via a personal logbook, the time spent at each plot. The mean time needed per MAES level 2 ecosystem type is extracted by combining all reported data.

3. Results

3.1. Field Surveys

Since May 2020, and under the applied mobility restrictions for the pandemic containment, we have completed 934 field surveys (plots) at the mainland and insular parts of Greece and at all MAES level 2 ecosystem types (Figure 3). In the following sub-sections, the results of this survey are presented, followed by the relevant analysis.



Figure 3. Field-survey plots per MAES level 2 ecosystem type.

3.1.1. Platform Efficiency

Based on the reports provided by the field teams, regarding the time spent at each plot to submit a fully completed protocol via the platform, and the subsequent analysis per MAES level 2 ecosystem type, we obtained the following results (Table 3):

- The mean time needed to complete a protocol is 10.2 minutes. Surveys at woodland and forests are the most time consuming (mean 15 minutes); surveys at wetlands and at heathland and shrub follow, with 14 and 11 minutes, respectively.
- Comparing the time needed to submit a completed protocol via the MAES_GR platform, with the respective time needed to complete a paper protocol used for the habitat conservation status assessment [35,38], a significant gain is reported in most cases. More precisely, a time gain of 43% is reported for sparsely vegetated land, followed by the woodland and forest (40%) ecosystem type when using the platform.

The time needed to complete a full assessment at each ecosystem type (plot) using the web-based platform in comparison with the relevant action for the habitat's monitoring [35,38] is presented in Table 3.

We should also highlight that all data are simultaneously registered in the platform online database, in contrast with the paper protocol, where further effort and time is needed at the laboratory to manually register all field data into a database.

Table 3. Time spent to complete a full assessment at each ecosystem type (plot) using the MAES_GR platform in comparison with the relevant action during the habitat monitoring project in Greece.

Ecosystem Types (MAES Level 2)	Mean Time Needed for Completing the Protocol	
	MAES Platform Assessment (Total Number of Survey Protocol Forms)	Natura 2000 Monitoring with Paper survey Protocol Forms (% Difference from the Platforms' Performance)
Urban	8 min (4 protocols)	n/a
Cropland	7 min (134 protocols)	n/a
Woodland and forest	15 min (431 protocols)	25 min (+40%)
Grassland	10 min (36 protocols)	10 min (=)
Heathland and shrub	11 min (182 protocols)	15 min (+27%)
Sparsely vegetated land	7 min (82 protocols)	15 min (+43%)
Wetlands	14 min (36 protocols)	20 min (+30%)
Rivers and lakes	10 min (23 protocols)	15 min (+33%)
Marine inlets and transitional waters	10 min (6 protocols)	10 min (=)

3.1.2. Ecosystem Condition

The analysis of the ecosystem condition assessment data (Table 4) revealed that most plots correspond to moderate and above moderate ecosystem condition, regardless of the rating method (i.e., expert judgment or calculation via the integrated algorithm). However, there are significant differences between the expert judgement score and algorithm output within the different rating categories and ecosystem types. The ecosystem condition rating is more similar between the two different rating approaches at the sparsely vegetated land and wetlands ecosystem types, where the similarity is above 65% (reaching 100% for the moderate ecosystem condition at the sparsely vegetated land assessment). We highlight the results from the woodland and forest ecosystem type (presently, the majority of field protocols originate from this ecosystem type), that point out a moderate to above moderate ecosystem condition, both from the experts' judgment, as well as from the algorithm calculation; similar results are evident for the heathland and shrub ecosystem type.

Table 4. Ecosystem condition results based on experts' judgment and algorithm calculation.

Ecosystem Types (MAES Level 2)	Ecosystem Condition (Expert Judgment/Algorithm)					Total Number of Protocols
	Excellent	Good	Moderate	Poor	Bad	
Urban	3/na	-/na	1/na	-/na	-/na	4
Cropland	48/na	68/na	16/na	2/na	-/na	134
Woodland and forest	135/68	194/173	87/189	13/-	2/1	431
Grassland	10/4	22/11	2/20	2/1	-/-	36
Heathland and shrub	48/27	93/127	33/26	5/-	3/2	182
Sparsely vegetated land	40/33	18/27	16/16	2/-	6/6	82
Wetlands	4/3	15/20	14/13	3/-	-/-	36
Rivers and lakes	5/3	11/5	6/15	1/-	-/-	23
Marine inlets and transitional waters	-/-	3/5	2/1	1/-	-/-	6

3.1.3. Ecosystem Services

The analysis of the ES assessment data revealed that a total of 77 unique (abiotic and biotic) ecosystem services have been identified and rated for their actual and potential supply. More precisely, we identified the following: (i) 30 provisioning ES (13 abiotic and 17 biotic), (ii) 30 regulating and maintenance ES (8 abiotic and 22 biotic) and (iii) 17 cultural ES (5 abiotic and 12 biotic). A detailed presentation of the identified ES under each major ES category is provided in Table S3.

Most ES are identified and registered for the woodland and forests (67 ES), followed by heathland and shrub (60 ES), cropland (50 ES) and wetlands (48 ES) ecosystem types. We should highlight also urban ecosystems, where 34 different ES have been recorded, despite the fact that only four protocols have been registered. A synopsis of major ES categories [36] identified at each ecosystem type is also presented in Table 5 and in more detail (per ES category) in the supplementary Table S4.

Regarding the actual and potential supply of the identified ES, the analysis highlights the following main outcomes, for each ecosystem type:

- Urban: The highest (mean) rating of actual supply is recorded for cultural biotic ES (3.68), followed by regulating and maintenance biotic ES (3.11). Highest (mean) rating for potential supply refers to cultural abiotic ES (4.33) and biotic ES (4.32).
- Cropland: The highest (mean) rating of actual supply is recorded for provisioning biotic ES (2.93), followed by regulating and maintenance abiotic ES (2.15). Highest (mean) rating for potential supply refers to provisioning biotic ES (3.46), followed by cultural abiotic ES (2.81).
- Woodland and forest: The highest (mean) rating of actual supply is recorded for regulating and maintenance abiotic ES (2.54), followed by cultural abiotic ES (2.52). Highest (mean) rating for potential supply refers to cultural abiotic ES (3.64), followed by regulating and maintenance abiotic ES (3.28).
- Grassland: The highest (mean) rating of actual supply is recorded for provisioning biotic ES (2.67), followed by regulating and maintenance abiotic ES (2.31). Highest (mean) rating for potential supply refers to cultural ES (both abiotic and biotic) (3.83), followed by provisioning biotic ES (3.19).
- Heathland and shrub: The highest (mean) rating of actual supply is recorded for regulating and maintenance biotic ES (2.59), followed by cultural biotic ES (2.54) and abiotic ES (2.49). Highest (mean) rating for potential supply refers to cultural abiotic ES (3.76) and biotic ES (3.66), followed by regulating and maintenance biotic ES (3.39).
- Sparsely vegetated land: The highest (mean) rating of actual supply is recorded for cultural biotic ES (3.54), followed by regulating and maintenance abiotic ES (3.00). Highest (mean) rating for potential supply refers to cultural biotic ES (4.39), followed by regulating and maintenance abiotic ES (4.27).
- Wetlands: The highest (mean) rating of actual supply is recorded for regulating and maintenance abiotic ES (4.17) and biotic ES (3.95), followed by cultural biotic ES (3.76). Highest (mean) rating for potential supply refers to regulating and maintenance abiotic ES (4.41) and biotic ES (4.36), followed by cultural biotic EC and provisioning abiotic ES (4.21).
- Rivers and lakes: The highest (mean) rating of actual supply is recorded for regulating and maintenance abiotic ES (4.12), followed by provisioning abiotic EC (3.85). Highest (mean) rating for potential supply refers to regulating and maintenance abiotic ES (4.35), followed by provisioning abiotic ES (4.15).
- Marine inlets and transitional waters: The highest (mean) rating of actual supply is recorded for regulating and maintenance abiotic ES (4.38), followed by cultural abiotic ES (4.20). Highest (mean) rating for potential supply refers to regulating and maintenance abiotic ES (4.88) and biotic ES (4.62), followed by cultural abiotic ES (4.60).

An overview of actual and potential ecosystem services supply per MAES level ecosystem type is presented in Table 6.

Table 5. Number of different ecosystem services per ecosystem services major categories [36] and per MAES level 2 ecosystem type.

Ecosystem Services	Urban	Cropland	Woodland and Forest	Grassland	Heathland and Shrub	Sparsely Vegetated Land	Wetlands	Rivers and Lakes	Marine Inlets and Transitional Waters
Provisioning (Biotic)	1	9	13	9	12	9	6	5	1
Provisioning (Abiotic)	1	4	10	4	7	4	4	2	4
Regulating and Maintenance (Biotic)	15	15	21	13	20	15	17	14	9
Regulating and Maintenance (Abiotic)	4	7	8	7	6	2	8	7	5
Cultural (Biotic)	10	11	11	8	11	10	10	8	4
Cultural (Abiotic)	3	4	4	1	4	3	3	3	1
Total	50	42	60	24	39	43	34	48	67

Table 6. Major ecosystem services categories actual and potential supply per MAES level 2 ecosystem types. Each record depicts: mean rating; median of rates; (reference number of protocols).

Ecosystem Types (MAES Level 2)	Total Number of Protocols	Provisioning (Biotic)		Provisioning (Abiotic)		Regulating and Maintenance (Biotic)		Regulating and Maintenance (Abiotic)		Cultural (Biotic)		Cultural (Abiotic)	
		Actual Supply	Potential Supply	Actual Supply	Potential Supply	Actual Supply	Potential Supply	Actual Supply	Potential Supply	Actual Supply	Potential Supply	Actual Supply	Potential Supply
Urban	4	2.00;2; (1)	3.00;3; (1)	1.00;1; (1)	2.00;2; (2)	3.11;3,5; (18)	3.44;3,5; (18)	1.75;2; (4)	2.50;2,5; (4)	3.68;4; (22)	4.32;4; (22)	3.00;3; (3)	4.33;4; (3)
Cropland	134	2.93;3; (111)	3.46;3; (111)	1.70;1,5; (30)	2.30;2; (141)	1.89;1; (264)	2.43;2; (264)	2.15;1; (73)	2.49;2; (73)	0.98;1; (110)	2.78;3; (110)	1.15;1; (26)	2.81;3; (26)
Woodland and forest	431	2.07;2; (378)	2.83;3; (378)	1.99;2; (108)	2.71;3; (486)	2.48;2; (1404)	3.20;3; (1404)	2.54;2; (315)	3.28;3; (315)	2.31;2; (765)	3.26;3; (765)	2.52;2,5; (132)	3.64;4; (132)
Grasslands	36	2.67;3; (43)	3.19;3; (43)	1.30;1; (10)	2.20;2; (53)	2.24;2; (80)	2.79;2; (80)	2.31;1; (29)	2.69;2; (29)	1.38;1; (42)	3.83;4; (42)	1.33;1; (12)	3.83;4; (12)
Heathland and shrub	182	2.11;2; (260)	2.91;3; (260)	1.85;2; (34)	2.41;2; (294)	2.59;2; (695)	3.39;3; (695)	2.09;2; (132)	2.97;3; (132)	2.54;3; (401)	3.66;4; (401)	2.49;3; (75)	3.76;4; (75)
Sparsely vegetated land	82	2.54;2; (52)	3.54;3; (52)	2.30;1,5; (10)	3.60;3; (62)	2.94;3; (244)	3.89;4; (244)	3.00;3; (30)	4.27;4; (30)	3.54;4; (186)	4.39;5; (186)	2.59;3; (41)	3.63;4; (41)
Wetlands	36	3.03;3; (30)	3.57;4,5; (30)	3.37;5; (38)	4.21;5; (68)	3.95;5; (155)	4.36;5; (155)	4.17;5; (94)	4.41;5; (94)	3.76;5; (38)	4.21;5; (38)	3.35;3; (17)	4.12;5; (17)
Rivers and lakes	23	2.69;2; (13)	3,38;3; (13)	3.85;5; (33)	4.15;5; (46)	3.74;4; (76)	4.09;5; (76)	4.12;5; (65)	4.35;5; (65)	3.56;3; (43)	4.02;4; (43)	3.79;4; (14)	4.00;5; (14)
Marine inlets and transitional waters	6	3.00;3; (1)	3.00;3; (1)	3.46;3; (13)	3.69;3; (14)	4.13;5; (30)	4.62;5; (29)	4.38;5; (16)	4.88;5; (16)	4.00;5; (7)	4.14;5; (7)	4.20;5; (5)	4.60;5; (5)

4. Discussion

Geospatial data are one of the most crucial elements in field-based research focusing on land-use, vegetation and biodiversity attributes' recording and delineation [27], providing baseline and reference information with a variety of applications. Web-based platforms for field data collection and automatic registration into a database (e.g., cloud), are likely to dominate future assessments replacing traditional practices which are time and money consuming. Already, the available internet access in most areas of Greece is to be enhanced by the introduction of 5G networks and devices, as well as with offline, on-hold submission procedures in cases where internet access is not available, and the subsequent automatic online submission when the device is back online.

4.1. The Importance of Field Sampling into MAES Implementation

The MAES_GR platform provides a tool for extensive sampling and data gathering to map and assess the ecosystem condition and its services at the national level; this is in line with the study of Le Clec'h et al. [19] that highlights the importance of field samples to support robust statistical methods for ES mapping and the creation of operational maps which incorporate the site effect and local characteristics. Additionally, van der Biest et al. [39] pinpoint that for operational applications, only local scale maps are capable of supporting decision making; thus, local scale assessments and data are needed. Hence, the development of the MAES_GR platform contributes to (a) providing the best available information for operational MAES studies, and (b) providing guidance for further research on specific attributes of ecosystems and their services, based on the data gaps to be identified by the extensive use of the platform. This procedure will tackle inherent assumptions of current mapping methods, which are based mainly on modeling scarce or small-scale data. This data and its modeling results affect decision making since the provided maps incorporating these outputs are black boxes for decision-makers [40] and provide misinterpretation of the real conditions. For instance, woodland and forest areas characterized with a moderate (or below moderate) condition should be accordingly prioritized for designing and implementing conservation and restoration actions for any of their degraded characteristics. In addition, in these areas, an analysis for the prioritization of ES demand should be further elaborated in order to sustain the ecosystem supply and prevent further ecosystem degradation. Within such a spatial planning procedure, the experts of the MAES_GR platform could inform and update the planning process continuously, providing real-time data to the ecosystem managers and authorities. The results of the MAES_GR based survey could also be used for raising public and political awareness on potential hotspots of decline observed across various ecosystem types.

4.2. Pros and Cons of the Platform and Future Steps

The advantage of the MAES_GR platform is the ease of using an extensive and simultaneously updating database that creates georeferenced data for (a) ecosystem types, (b) the ecosystem condition and (c) the actual or potential supply of ecosystem services. By this, the administrators of the database have a live update of the dataset, identifying data gaps (sampling gaps) at all scales (national, regional, local) in order to guide further efforts regarding administrative, conservation, management and policy needs that arise. Moreover, the data collected for the ecosystem condition assessment are robust and in line with the Habitats Directive monitoring prerequisites and can be utilized also for habitat type monitoring outside the Natura 2000 network sites and vice versa. This means that specific, already available data from the Habitats Directive monitoring procedure can be directly registered into the platform and provide results for ecosystem condition. As far as ecosystem services are concerned, the MAES_GR database provides, for the first time, spatial information for ecosystem services and for all ecosystem types, based on field observations. This database has also several limitations at the ecosystem services part; ecosystem services are registered and assessed regarding the supply and potential supply based on experts' elicitation and assigned to one of the relatively broad ES categories at

the CICES class level. By this, currently, only a general view of ES distribution is achieved; however, it provides valuable information for targeted studies on identified, specific ES when, where, and at any scale, it is needed, providing a basis for relevant decision-making on management needs. It is evident that the results of the database guide future steps and actions regarding the MAES implementation in Greece, pinpoint diversity of the ecosystem condition and ecosystem services, and thus triggers ecosystem amelioration actions and the ecosystem services' importance in space and time. The herein presented platform acts also as a potential crowd-sourcing tool; however, to control data input, a user rating system is required to apply quality control. At this stage, only qualified scientists have access to the platform, since the main goal is to have robust field information for the ecosystem extent, condition, and identification of their services.

4.3. Contribution to MAES and EU Directives Reporting

Based on the ESMERALDA MAES barometer [41], most EU Member States present significant level and/or progress on MAES implementation.

The reporting method incorporates all MAES related activities conducted by each EU Member State [42], providing a detailed overview of the progress across EU. The present study suggests a reporting format under the EEA 10x10 reference grid cell for MAES level 2 and MAES level 3 ecosystem types in order to integrate national data into EU assessments and, by this, support time series creation towards "MAES-chained" natural capital accounts. Moreover, MAES monitoring and reporting, as herein proposed with the use of the MAES_GR platform, could be conducted simultaneously with the Habitats-, the Birds- or/and the Water Framework-Directives' monitoring activities, by modifying and enhancing the platform to record also the data needed for each different purpose. By this, time and resources will be limited to a minimum, while a monitoring network expansion could be more easily suggested and supported by using the saved resources (monetary and human).

5. Conclusions

This work provides the first field data collection platform, based on internet technologies, for mapping and assessment of ecosystems and their services in Greece, through direct field observations. It is in line with the assessment guidance and assistance provided by the European Commission and aims to support operational MAES studies, by providing an efficient and low-cost tool for extensive, nation-wide assessment, as the one needed in data-scarce regions, such as Greece. The platform and its outcomes are designed (a) to provide information at the national, regional and EEA reference grid level, (b) to standardize the assessment procedure, (c) to analyze and report MAES-related data from the local to the EU scale, and (d) to guide environmental management strategies and policy making, in the frame of the EU Biodiversity Strategy and the EU Green Deal provisions.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/land10040381/s1>, Table S1: Ecosystem type typology, Table S2: Lists of "key" and "other", pressures, structures and functions, Table S3: Ecosystem services records, Table S4: Ecosystem services records per ecosystem type, Screenshot presentation of a completed protocol form.

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