D4.5 Quick scan tool for potential of systemic restoration, NBS packages, resulting ESS and BDV gains, for coastal landscape units and present/future climate and management scenarios.

30/09/2024

WP4

Lead beneficiary: Deltares

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REST-COAST

Large Scale RESToration of COASTal Ecosystems through Rivers to Sea Connectivity

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Preface

The Rest-Coast Project (Large scale RESToration of COASTal ecosystems through rivers to sea connectivity) is an EU Horizon 2020 research project (Grant agreement No. 101037097) whose overall goal is to address the key challenges faced by coastal ecosystem restoration across Europe with effective and innovative tools. The approach chosen for this project will deliver a highly interdisciplinary contribution, with the demonstration of improved practices and techniques for hands-on ecosystem restoration across several pilot sites, supported by the co-design of innovative governance and financial arrangements, as well as an effective strategy for the dissemination of results.

Work package 4, Adaptation management for restoration and upscaling, integrates and coordinates coastal adaptation-through-restoration management by developing coastal systemic adaptation pathways. Within the REST-COAST project, Work Package 4 focuses on adaptation management for restoration and upscaling. It aims to provide a comprehensive view of restoration measures as nature-based solutions (NbS), exploring climate adaptation strategies across pilot sites. This report (deliverable 4.5), titled "D4.5 Quick scan tool for potential of systemic restoration, NBS packages, resulting ESS and BDV gains, for coastal landscape units and present/future climate and management scenarios." outlines the development and design of a digital platform aimed at supporting regional and local coastal restoration strategies. This tool enhances ecosystem services by integrating and analysing the potential impacts of different restoration measures and climate scenarios, thereby building a narrative that guides the formulation of adaptation pathways. Additionally, this report demonstrates the application of the Quick Scan Tool, tested at the Wadden Sea Ems-Dollard pilot site.

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Summary

The Quick Scan Tool, hereby renamed the Quick Scan Strategies Tool (QSST) is a GIS-based, decision-support tool designed to aid in the development of regional and local coastal restoration strategies aimed at enhancing ecosystem services. Built in Power BI and supported by an MS Excel database, the QSST is a key product of WP4 within the REST-COAST project. Its primary functions include aligning activities across different case studies into a common approach, enabling the sharing and comparison of case study findings, presenting knowledge and results, and facilitating discussions with local partners, policymakers, and stakeholders. Additionally, the QSST provides valuable support in developing long-term coastal restoration plans.

Central to this deliverable is the QSST's development process, which involves creating a database and integrating it into a user-friendly dashboard environment. A key focus during this process was ensuring that both the database and the dashboard are adaptable across all pilot cases, thereby maintaining consistency and structure throughout REST-COAST. The database is designed to support a wide range of data sources, including model outputs, GIS maps, and interdisciplinary indicators, all of which are essential for ultimately developing and evaluating adaptation pathways. Another critical aspect in the QSST development was the implementation of a scoring system, which provides a common framework for assessing biotope changes, restoration measures, strategies, and adaptation pathways using interdisciplinary data and indicators. This deliverable addresses trade-offs and limitations associated with the software chosen for building the QSST, as well as potential alternatives, balancing functionality and user friendliness for future replication. Additionally, this deliverable includes a user guide to assist the pilots in building their databases and customizing their dashboards to meet the specific requirements of each pilot case. It also discusses the progress made by the pilots in filling out their databases and transitioning from data entry to dashboard visualization.

In summary, this deliverable describes the development of the QSST, and highlights its role and functionalities in supporting coastal restoration planning within REST-COAST, providing evidence-based recommendations for policy-makers, and creating a comprehensive database that will serve as a valuable resource for ongoing research and future projects.

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List of abbreviations

BDV	Biodiversity value
CCR	Climate change regulation
ESS	Ecosystem services
EU	European Union
FP	Food provisioning
PBI	Power BI
QSST	Quick Scan Strategies Tool
RCE	Reduction of coastal erosion risk
RFR	Reduction of coastal flooding risk
SLR	Sea Level Rise
VBA	Visual Basic for Applications
VSM+E	Visions, strategies, measures, and enablers and barriers of restoration efforts
WP	Water purification
WP(i)	Work Package

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1. Introduction

The Quick Scan Strategies Tool (QSST) is a GIS-based digital dashboard tool designed to support the development of regional and local coastal restoration strategies aimed at improving ecosystem services (ESS). Built using Power BI (PBI) and backed by a Microsoft Excel database, the QSST is an integral part of Work Package 4 (WP4 - Adaptation management for restoration and upscaling) within the REST-COAST project. This tool serves multiple functions within the project, including synchronizing activities into a common approach, sharing and comparing pilot results, presenting findings, facilitating discussions, and supporting decision-making for the development of coastal restoration strategies to enhance the flow of ESS.

PBI was chosen to develop this dashboard (hereafter referred to as the QSST) because of its multiple capabilities in data visualization, user-friendliness, and straightforward integration with Microsoft Excel, which allows for efficient data management and analysis (Becker & Gould, 2019; Bosman *et al.*, 2022). Dashboards built with PBI have been successfully applied in previous projects and for various purposes. For instance, PBI has been used in developing environmental and public health monitoring reports, where it helped in visualizing large sets of environmental data, thereby facilitating the formulation of actions and strategies (Mohammed Bello *et al.*, 2021; Wright & Wernecke, 2020; Zulkafli *et al.*, 2022). Another example is its application in disaster risk reduction to track and visualize, for instance, flood risk hotspots (Fleagle *et al.*, 2021; Selvi *et al.*, 2024), providing clear information to authorities and policymakers.

The QSST transforms complex datasets from the different REST-COAST pilot cases and work packages into interactive visualizations. This facilitates the communication of scientific findings and showcases REST-COAST results, thereby supporting decision-making processes relevant to the adaptation and upscaling of restoration measures in European coastal zones. The QSST is an innovative example case designed to improve data-driven decision-making and stakeholder engagement, primarily designed for the Wadden Sea pilot. Application to all other pilots is voluntary and beyond the scope of the DoA.

The QSST integrates data produced within WP2 (modelling of biophysical indicators and quantifying sea level scenarios and restoration measures), WP3 (financial indicators), WP4 (mapping of biotopes, ESS, and adaptation pathways), and WP5 (governance indicators), presenting it in a user-friendly dashboard environment. Specifically, within WP4, the QSST ultimately displays changes in ESS in combination with interdisciplinary indicators (e.g., biophysical, financial, and governance) under different climate scenarios and strategies (Figure 1). These indicators are presented and compared on the QSST using a scoring system designed for straightforward and easily interpretable, aiding decision-making by showing which indicators perform better or worse based on the scoring scale (section 2.2.4).

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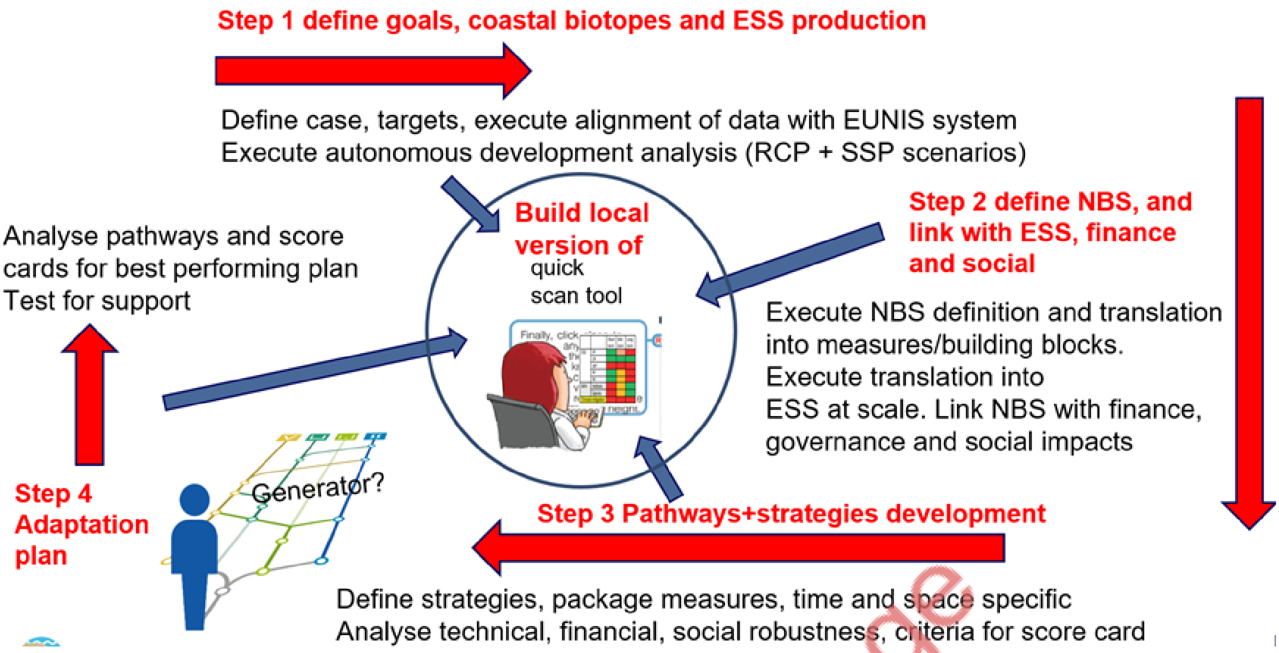

Figure 1 Connectivity between WP4 tasks contributing to and providing data for the local version of the QSST. Source: Mindert de Vries.

By aligning the main structure of the database, the QSST aims to align the different local versions corresponding to each pilot case within REST-COAST, while also maintaining the flexibility and adaptability to incorporate diverse results, tailored to the specific needs of the target areas. Consequently, each local version of the QSST constructs a policy narrative for the development of a long-term strategy. Although this deliverable presents a finalized version of the technical side of the QSST, the tool is designed to be a constant work in progress, evolving to handle large volumes of information effectively as more data is produced by the different work packages and pilots.

In summary, this deliverable describes the development of the QSST, and how the QSST makes use of PBI to transform complex, interdisciplinary data into interactive visuals, thereby facilitating the comparison between pilot cases and the long-term development of coastal restoration plans. By making scientific data accessible and understandable, the QSST supports decision-makers and stakeholders, thereby enabling climate adaptation while enhancing ecosystem service flows in European coastal zones.

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2. Methodology

2.1. Software

The implementation of the QSST relies on two primary software components: Microsoft Power BI and Microsoft Excel. Both software programs are integral to the QSST's functionality, enabling data visualization, management, and analysis. PBI is a business analytics tool by Microsoft (Ferrari & Russo, 2016) and serves as the main platform for creating and displaying the QSST dashboard, while Excel is used for data collection and management (Hossain & Hossain, 2021). Both programs are widely used across the scientific, financial and governmental sectors and therefore offers a wide variety of pre-build visualizations suitable for the multi-disciplinary approach required within REST-COAST. Moreover, the seamless integration between PBI and Excel enhances the user-friendliness of the QSST, which makes it possible for non-experts to work with the QSST.

2.2. Data sources and data management

The QSST receives data from various tasks within WP4 (Figure 1), WP2, WP3, and WP5 (Figure 2), covering multiple disciplines and formats. These data sources range from ESS rank-scores derived through expert consultation (Baptist *et al.*, 2024), to GIS maps consisting of projected biotope distributions generated through numerical modelling of future scenarios. This section elaborates on these different data sources, illustrated schematically in Figure 2.

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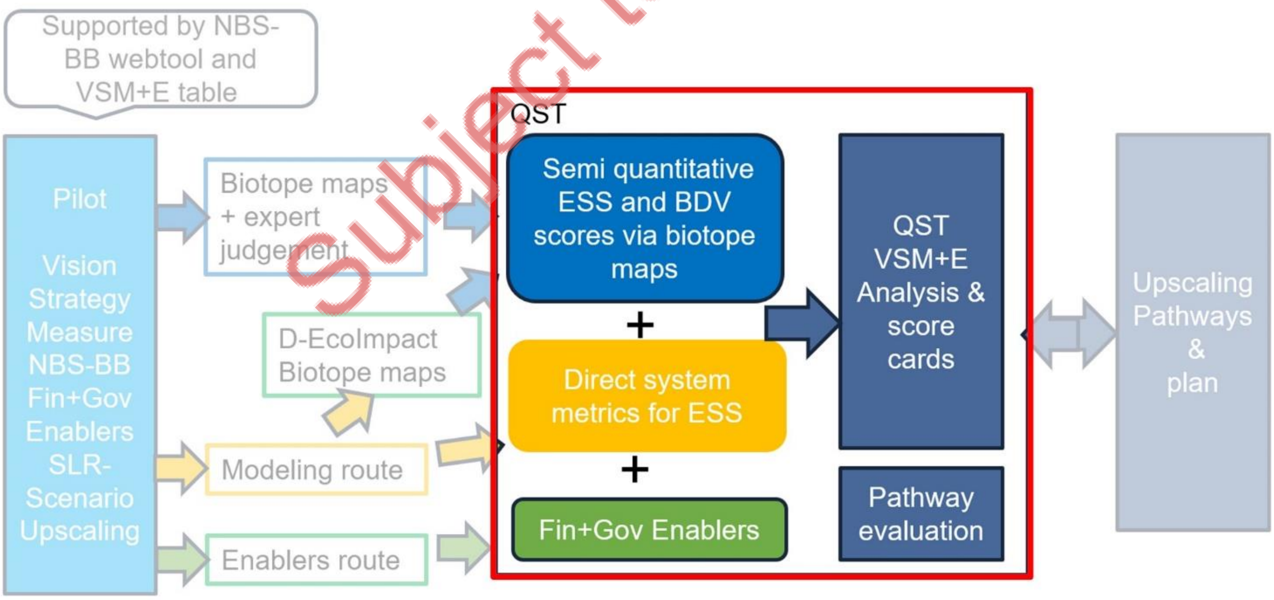

Figure 2 Stepwise approach for WP4 tasks. The QSST, enclosed in red, receives data from multiple sources. Source: Mindert de Vries.

2.2.1. ESS and BDV via biotope maps

The QSST receives information from Deliverable 4.1 (Baptist *et al.*, 2024), which includes EUNIS sub(habitat)[1] maps for each of the pilot areas in REST-COAST. Semi-quantitative scores, ranging from 0 to 5, were assigned to each EUNIS sub(habitats) for five key ecosystem services (Figure 3), linking them to spatial units defined as EUNIS biotopes. This integration of GIS data makes the QSST a GIS-based decision support tool. Additionally, IUCN Red List statuses (Gubbay *et al.*, 2016; Janssen *et al.*, 2016) are assigned to the EUNIS habitat spatial units, based on data from Deliverable 4.1 (Baptist *et al.*, 2024).

The QSST also incorporates a methodology for assessing future changes in ESS and BDV, using equations and a sigmoid curve function developed in Deliverable 4.1 (Baptist *et al.*, 2024). This approach relates changes in the area of biotopes, resulting from implemented measures and climate scenarios, to changes in ESS and BDV, thereby evaluating coastal system behaviour and restoration effects.

The projected biotope maps can originate from either expert judgement or modelling results for the given global climate scenarios (SSP2-RCP4.5 and SSP5-RCP8.5)[2] and for the years 2030, 2050 and 2100. Independent of the source the biotope map projections should be delivered in the same format (further described in section 2.3.1).

2.2.2. Direct system metrics for ESS

WP2 within REST-COAST provides the QSST with projected scenarios that examine the effects of restoration actions on ESS delivery. These projections are based on global climate scenarios (SSP2-RCP4.5 and SSP5-RCP8.5) for the years 2030, 2050, and 2100. These scenarios define the conditions incorporated in the modelling exercises, as well as site-specific variability introduced by the restoration measures (Espino *et al.*, 2024).

In the QSST, these projections are linked to ESS delivery, offering insights into how measures (restoration actions) and external drivers (e.g. climate) can positively or negatively impact ecosystems and their ESS supply. Besides providing an overview of changes to ESS, the QSST also offers a deeper look into specific modelled biophysical indicators (e.g., wave height, land accretion) to inform decision-makers about future changes. These projections consider restoration measures (from strategies) and climate (external driver). These results, displayed in the QSST, are intended to provide additional insights for better scenario comparison and understanding of system changes.

[1] EUNIS provides a broad classification of habitats. Due to its coarse nature, more detailed site-specific sub-habitats may be assigned by the pilots where EUNIS categories are insufficient.
[2] SSP2-RCP4.5 represents a scenario where GHG emissions remain near current levels until mid-century, while SSP5-RCP8.5 depicts a scenario with very high GHG emissions (IPCC, 2021).

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From modelling, the QSST acquires indicators linked to an ESS. The chosen indicators can vary among the different pilot cases. Data should give information about the change in biotopes in the region, preferably spatially, for the available projections. For example, this data might include carbon accumulation rates or erosion rates specific to the pilot area.

2.2.3. Finance and governance indicators

The QSST's narrative of identifying biotopes and their capacity to supply ESS (section 1) transitions into a deeper analysis of biophysical parameters displayed in the QSST for a more thorough assessment of environmental changes (section 2.2.2). However, the QSST's ultimate goal is to support decision-making in designing a long-term adaptation plan. To achieve this, the environmental assessment provided in the QSST must be combined with socio-economic information to offer an integrated perspective.

The QSST incorporates finance and governance indicators alongside ESS to provide a holistic view of how restoration measures impact the system, offering insights into their feasibility and effectiveness. The finance and governance data (indicators and scores) flows from the VSM+E table (Tai *et al.*, *in preparation*), where this data is compiled. Consequently, the QSST receives data from WP3 (Financial arrangements/business plans for restoration upscaling) and WP5 (Transformative governance for restoration upscaling), with indicators directly provided by WP4, where they were adapted and adjusted to evaluate restoration measures and build adaptation pathways. These indicators were integrated into the QSST as tables with scores, derived from an Excel sheet (section 2.3.1). This sheet links indicators to their respective strategies and includes the criteria under which they were classified, such as costs, feasibility, flexibility, and effectiveness. This sheet structure ensures that the QSST can effectively assess and compare different restoration measures, providing a foundation for developing and evaluating adaptation pathways.

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2.2.4. Scoring

Interdisciplinary data and indicators, as described in the previous sections, were displayed in the QSST as rank-scores. This method of visualization, which is applied across all pilots, is designed to be straightforward and easily interpretable for decision-makers, helping them quickly understand what indicators perform better or worse based on the scoring scale.

The scoring of ESS was conducted by comparing changes in biotopes and ESS supply to a baseline scenario. These changes were then transformed into rank-scores according to the methodology outlined in D4.1 (Baptist *et al.*, 2024). The rank-scale ranges from -5 to +5, indicating the extent of negative and positive changes in ESS supply resulting from measures and climate change impacts. In addition to ESS, further biophysical information is provided through direct ESS metrics, such as wave height and land accretion, which are displayed in the QSST as relative changes compared to a baseline scenario.

Moreover, finance and governance indicators are also displayed in the QSST as rank-scores, ranging from -2 to +2, and derived from Milestone 17 (Cobacho *et al.*, 2024). Finance indicators are scored using a normalization equation that standardizes the data for consistent comparison, while governance indicators are assessed based on the enablers/barriers approach, which evaluates factors that either support or hinder the implementation of restoration measures from a governance perspective. This approach to scoring is detailed in Milestone 17 (Figure 3).

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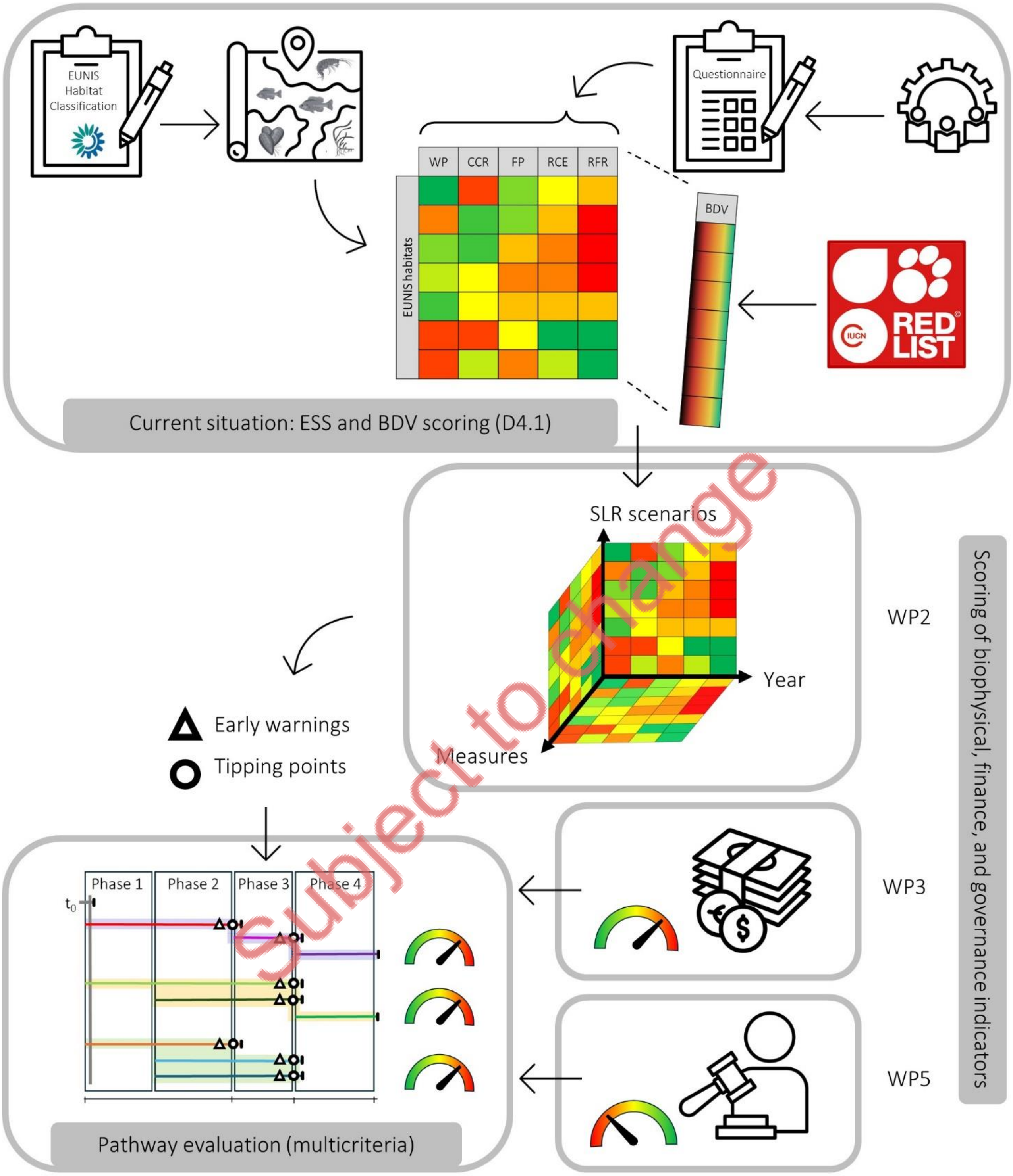

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Figure 3 Summary overview of the data scoring process within WP4, leading to rank-scores displayed in the QSST (Milestone 17).

By integrating all these indicators and transforming them into a unified rank-score system, the QSST facilitates informed decision-making by highlighting the potential trade-offs of different measures and strategies. This integration also supports the development and evaluation of adaptation pathways through a multi-criteria scoring system, where weights are assigned to four key criteria: Effectiveness, Costs, Feasibility, and Flexibility. Detailed methodology for developing and scoring these adaptation pathways can be found in Deliverable 4.3 (Tai *et al.*, *in preparation*) and Milestone 17 (Cobacho *et al.*, 2024), respectively. The scores, categorized by criteria and pathway, are visualized in the QSST, where the weighted results are displayed (section 2.3.3, Figure 13).

2.3. Development process

As mentioned in section 2.1, the development of the QSST involved creating a dynamic database in Excel, which was subsequently integrated into PBI to build the dashboard. The initial data flowed from the input sheets to the calculated sheets, based on the functionality of each of the sheets within the database (detailed in section 2.3.1), and these were later integrated into PBI. In PBI, visuals were created by combining various types of data (explained in section 2.2). A template dataset and a PBI model based on the Ems-Dollard case are available to all REST-COAST pilot cases, offering a starting point for implementing their local versions of the QSST. This approach aligns the main structure of the QSSTs, facilitating the comparison of different pilot sites.

The QSST is designed to deliver semi-quantitative ESS and BDV scores through two possible routes: the expert judgement route and the modelling route (Figure 2). While both routes use the same input data, the underlying QSST database varies slightly depending on the route chosen by each pilot.

For the direct ESS metrics, as well as the financial and governance indicators, the input also comes from an Excel-based database, which is integrated with PBI and displayed on the designated dashboard tab.

This section describes the QSST development process in Excel and PBI.

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2.3.1. Database

Semi quantitative ESS and BDV scores via biotope maps

The QSST's development process relies on the creation and organization of the Excel database. This database is structured into 16 different sheets, each color-coded based on its function (Figure 4). For clarity, the same color-coding scheme is used in this section to explain the purpose and functionality of each sheet.

Blue: Supporting Sheets

These sheets are not altered due to calculations. They contain background information, mostly consisting of model results, or in their absence, expert knowledge, which are used for cell calculations in other parts of the database.

- Variables: These variables are linked to the Control sheet and are used in looping processes. Default variables to be filled in include:

    - Year: The years for which you have data and want to display in the QSST.
    - SLR: The projected sea level rise for the final year of your data range.
- ConversionTable: Used to create a biotope to ecosystem service (ES) score conversion table, assigning scores to different biotopes. This ensures that biotope changes over time are reflected in the corresponding scores.
- Change Biotope SLR[3]: This sheet contains model results for biotope changes due to sea level rise (SLR). When model results are not available, biotope changes for all indicated years are manually added based on expert judgment or other available sources. This gives the user the opportunity to use the QSST without the need to invest heavily in modelling.

Red: Control Sheet

This sheet contains buttons with VBA Macros to calculate the result sheets (green) by iterating over all possible combinations. Macros in MS Excel must be enabled. No user adjustments are required.

Yellow: Base List of Biotope Polygons

This sheet represents the current biotope mapping. The input to this sheet is the biotope map attribute table of the baseline scenario (current situation). Every polygon of the GIS biotope map is considered as a separate entry. The following attributes from the EUNIS Biotope Map (developed as part of D4.1) are copied into this Excel sheet: Feature ID, EUNIS-code of the biotope, Area (m^2) and coordinates (as centroid points (X and Y) or geometry of the polygon).

Orange: Measures (NbS)[*]

This sheet has the same structure as the Base list and contains the list of projects and related measures. Projects are linked to strategies. When a strategy is selected on the Control sheet [cell C2], the projects/measures are activated, changing Column [DN] from 0 to 1. The year for each NBS implementation must be indicated in this sheet [column X]. Additional columns can be added, but the link between the Measures sheet and ESS_Score must be maintained.

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[3] This sheet is not needed when the user makes use of modelling results for the biotope maps

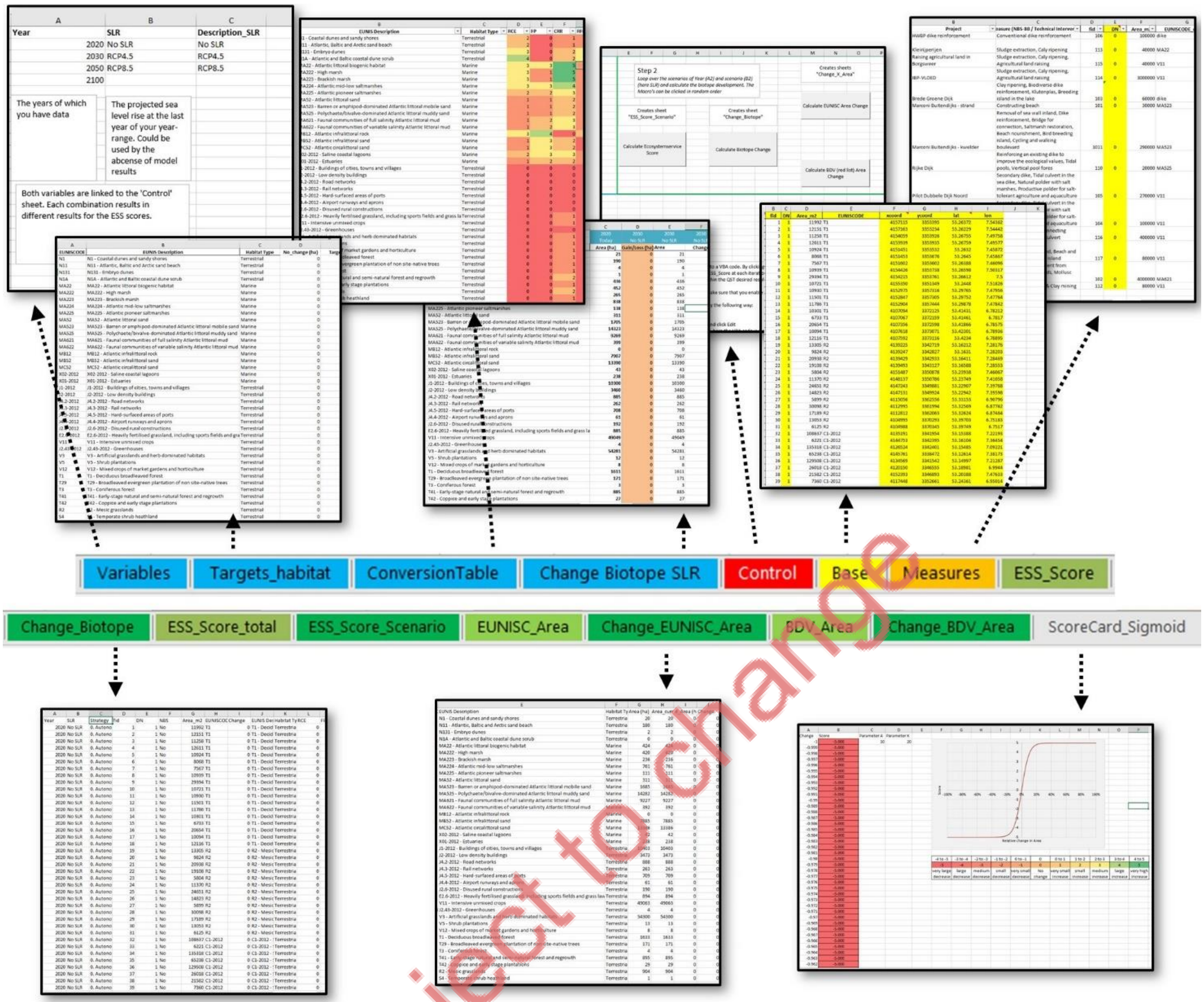

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Figure 4 Overview of Excel database structured in 17 different sheets, each color-coded based on its function.

Green: Result Sheets

There is a distinction between the light green [ESS_Score, ESS_Score_total, EUNISC_Area, BDV_Area] and dark green sheets [Change_Biotope, ESS_Score_Scenario, Change_EUNISC_Area, Change_BDV_Area]. The light green sheets are linked to the blue support sheets and Base sheet and automatically build-up for one selected projection. The dark green sheets display the results of calculations performed by the VBA Macros on the Control sheet consisting of all available projections. These sheets are the source for the QSST dashboard.

Grey: ScoreCard_Sigmoid

This sheet contains a function that calculates scores based on a sigmoid distribution for changes in area per EUNIS biotope, as detailed in Baptist *et al.* (2024).

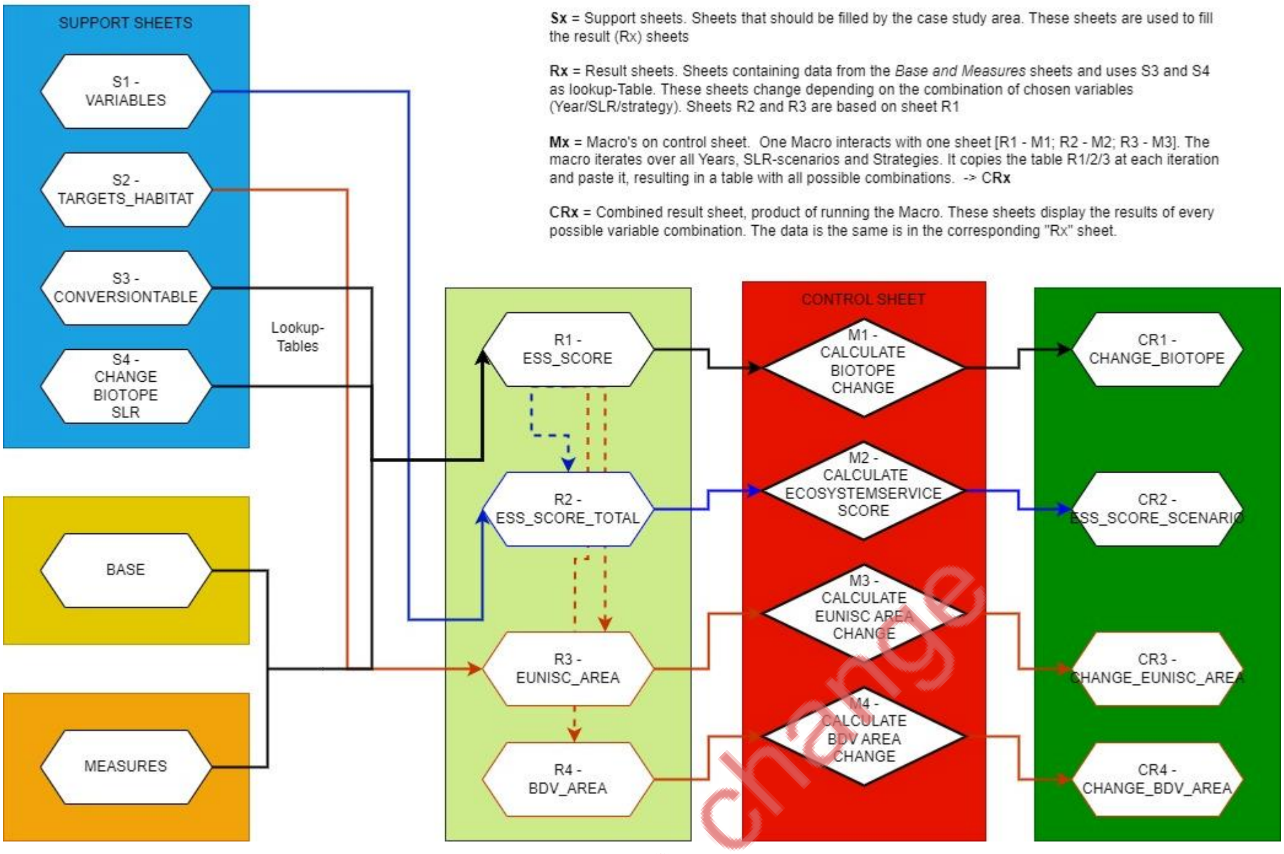

Figure 5 Flowchart showing how the different Excel sheets within the QSST database are interlinked. Excel sheets are color-coded according to their functions.

Integrating multiple data sources (section 2.2) increased the complexity to the database. Additionally, the pilots varied in complexity, requiring the database to be designed to accommodate even the most complex cases. This complexity resulted from the number of modelled scenarios (e.g., sea level rise and year), the number of NbS solutions proposed, the number of strategies considered, and the ecosystem diversity, ranging from 2 to 48 EUNIS classes (Baptist *et al.*, 2024). Consequently, the database had to generate all possible combinations. These combinations were achieved by interconnecting the Excel sheets in the database, as illustrated in Figure 5.

Direct system metrics for ESS

The modelling results must be converted into an Excel format similar to that of the biotope maps. The data collected should enable comparisons across projected years and different climate change scenarios. Depending on the choices made, the modelling data may consist of a spatial variety of multiple points showing values such as *wave height* (indicator for the ESS: RFR) or a single value per projection. The changes are represented both quantitatively and qualitatively in the QSST to reflect the relative change and impact of the proposed and modelled measures.

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Finance and Governance Indicators + Pathways

As described in section 2.2.4, the finance and governance indicators are scored for every measure and assigned to one of the four pathway criteria: Cost, Effectiveness, Feasibility and Flexibility. Using a multicriteria approach, the pre-designed pathways are scored (Tai *et al.*, *in preparation*). All relevant data is compiled in a single Excel file, which serves as the input for the QSST. This file includes data for each indicator: scores for the selected pathway, the type of indicator (finance or governance), the associated pathway criteria, and specific measure to which it applies.

2.3.2. Dashboard overview

PBI offers an intuitive dashboard environment with a ribbon at the top, similar to Microsoft Office products. In the QSST, the development of the dashboard was highly dependent on the completeness of the database and its integration in PBI. Data from Excel sheets were imported into Power BI (PBI), where they were automatically structured into tables. This process is automated, but any errors can be manually corrected using Power Query.The columns within these tables were then translated into fields within the dataset (Figure 6). Initially, PBI detected and assigned data types (e.g., text, number, date) to the fields based on the nature of the imported Excel data. These data types and other formatting were subsequently adjusted as necessary for each field using the Query Editor. The Query Editor provides multiple tools for data transformation and cleaning, such as filtering, merging, and aggregating data. These tools were used for creating measures, which are mathematical calculations performed using formulas. These measures were sometimes necessary to further process the data, depending on the variables required for the visuals, and produced new calculated fields derived from the existing fields.

After the data was imported and processed, all the fields became visible on the right side of the PBI "Report" tab, within the "Data" panel. Data fields could then be dragged and dropped from the "Fields" panel onto the report canvas to create visualizations (Figure 6). This functionality made it easy to develop the QSST visualizations without requiring extensive technical knowledge.

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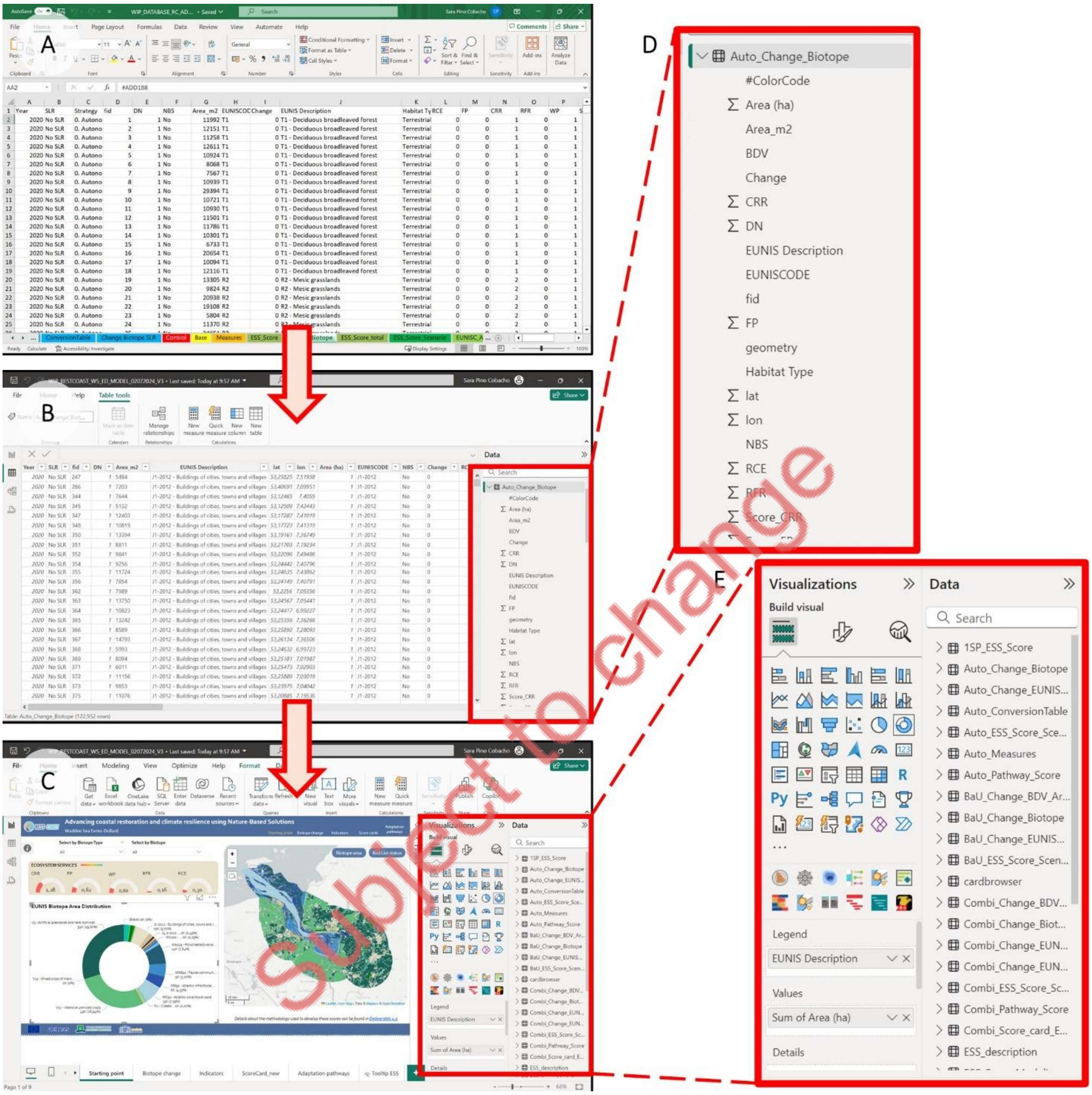

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Figure 6 Transitioning data from Excel sheet (A) to PBI tables (B), where columns are structured into fields (D). These fields are then listed in the "Data" panel, from where they can be dragged and dropped into the "Visualizations" panel (E), serving as input data for visuals on the "Report" tab of PBI (C).

The size and complexity of the database influenced the dashboard development, making it challenging to connect all data sources to form visuals. However, PBI handles most of these connections automatically. It was crucial to interconnect all the different data sources to establish relationships between data, such as biotopes on maps, ESS, finance, and governance indicators, etc. This required relating data from the various sources (section 2.2) to create interactive visualizations. When these relationships were not automatically established, they were manually configured using the relational model in PBI (Figure 7). Establishing these relationships between different data sources was crucial for the development of the QSST, as explained in section 2.2. Therefore, the visuals created in Power BI are interactive, meaning users can click on elements within the visualizations such as buttons or graphs to show or highlight specific information, such as specific climate scenarios or strategies.

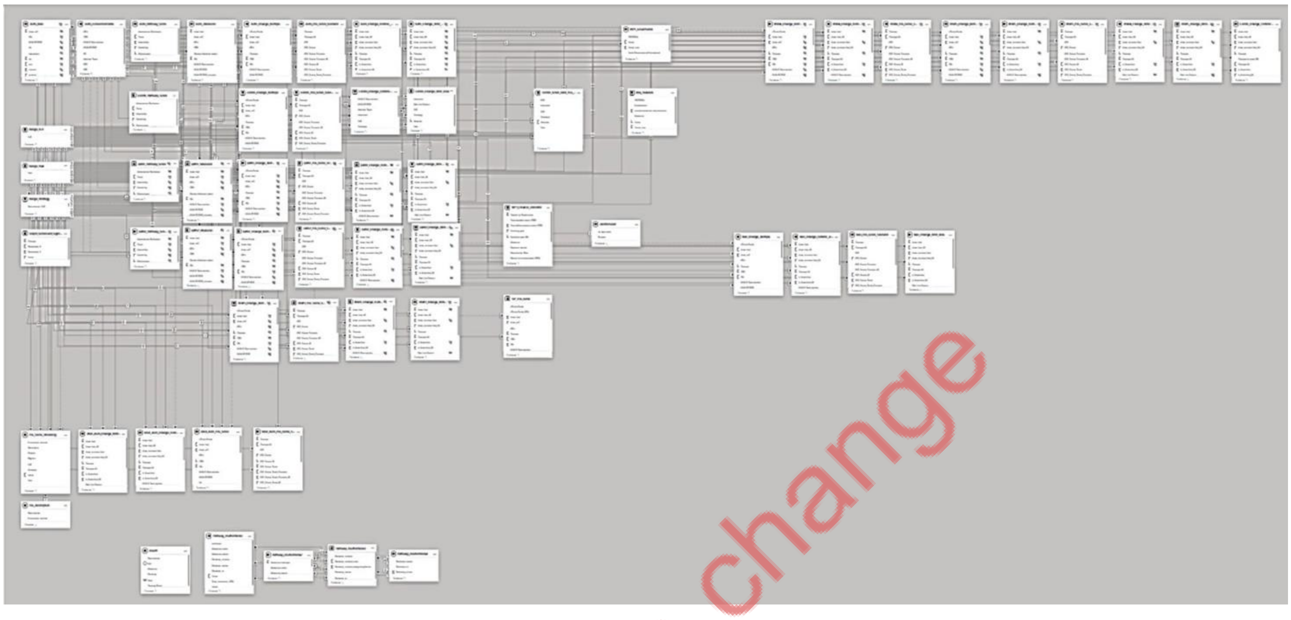

Figure 7 QSST's relational model in PBI.

Lastly, the dashboard canvas was customized to match the colour theme and style of REST-COAST, ensuring a uniform appearance that could be adapted by all pilots and aligned with the project's branding. This customization involved changing colours, fonts, and layouts, as well as adding custom visuals such as logos.

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2.3.3. Tab descriptions and functionalities

The QSST dashboard, which can be accessed here, is structured across six different tabs and is designed to create a cohesive narrative for developing coastal restoration strategies based on data that supports decision-making. Each successive tab builds on the information presented in the previous one, or integrates previous information with new knowledge, facilitating progress in the decision-making process. These tabs are located in the top-right corner of the dashboard, within the top panel where the title is also displayed. The tabs are designed as clickable buttons, allowing users to navigate between them.

The first tab introduces the narrative that the QSST aims to build, providing a concise overview of the REST-COAST project and outlining the objectives of the tool within WP4. This tab does not present any data, as its goal is to summarize the project's vision, highlight the unique characteristics of the pilot region and the pressures it faces, and describe the anticipated impact of REST-COAST in this area. Additionally, it briefly introduces the ecosystem services that will be the focus of the data in the subsequent tabs (Figure 8).

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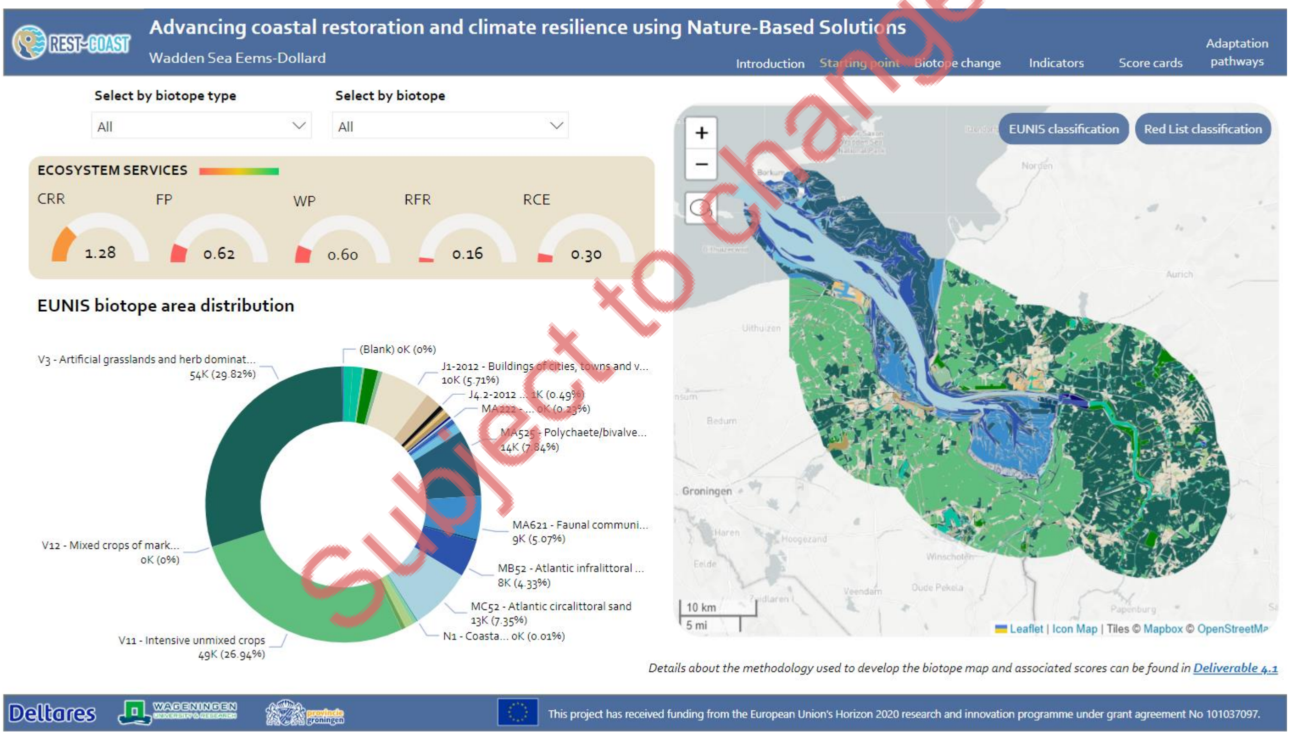
Figure 8 First tab of the QSST- Introduction. It introduces the objectives of the REST-COAST project and the Quick Scan Strategies Tool (QSST) within WP4, while also highlighting the key features of the pilot region.

The second tab (*Starting point*) offers an overview of the current situation at the restoration site, using the Ems-Dollard pilot site as the case example for this deliverable (Figure 9). It presents a map displaying the biotopes present at the site (Baptist *et al.*, 2024). The ESS supply of each biotope is represented by a gauge visual, scaled from 0 to 5 and color-coded for clarity. Additionally, a pie chart displays the area distribution of each biotope within the pilot site, highlighting the most abundant or dominant biotopes and those that are less prevalent.

On this tab, biotopes are categorized according to two classifications: EUNIS habitats and the Red List status, as detailed in D4.1 (Baptist *et al.*, 2024). Users can switch between these classifications by clicking a button on the top-right side of the map, which is linked to a bookmark in the dashboard. This dynamically updates the ESS and area distribution visuals accordingly. Slicers at the top of the tab allow users to select specific biotopes, providing a more focused view on the map and visuals. This tab is easily replicable for the other pilots, as each has produced biotope maps with corresponding ESS and BDV scores as part of D4.1 (Baptist *et al.*, 2024).



Subject to change

Figure 9 Second tab of the QSST- Starting point. It provides an overview of the current biotopes in the Ems-Dollard estuary.

The third tab (*Biotope change*) is dedicated to analysing changes in biotopes, specifically focusing on how climate change scenarios impact the area distribution of these biotopes (Figure 10). It also examines how these area changes, based on the methodology developed in D4.1, affect the ESS supply of the biotopes. This tab introduces restoration measures, as they play an important role in altering biotope distributions. The layout of this tab resembles that of the previous one to maintain user familiarity. The map retains the same colour scheme, and the ESS are visualized using gauges, similar to the *starting point* tab. However, in this tab, the gauges can show negative values, ranging from -5 to 5, to represent reductions in biotope areas due to climate impacts.

Central to this tab is a gauge visual that displays changes in biotope areas, with a target value representing the current area of the selected biotope(s) and a projected area for the chosen scenario and year. This gauge is color-coded for clarity. Additionally, a scorecard visual provides precise measurements of area loss or gain in hectares between the selected scenario and the current situation. It is important to note that the changes shown in this tab are based on model projections and are subject to uncertainty. This disclaimer is displayed on the page to inform users of the limitations in the projections. When no models are used, the changes shown here are based on expert judgement.

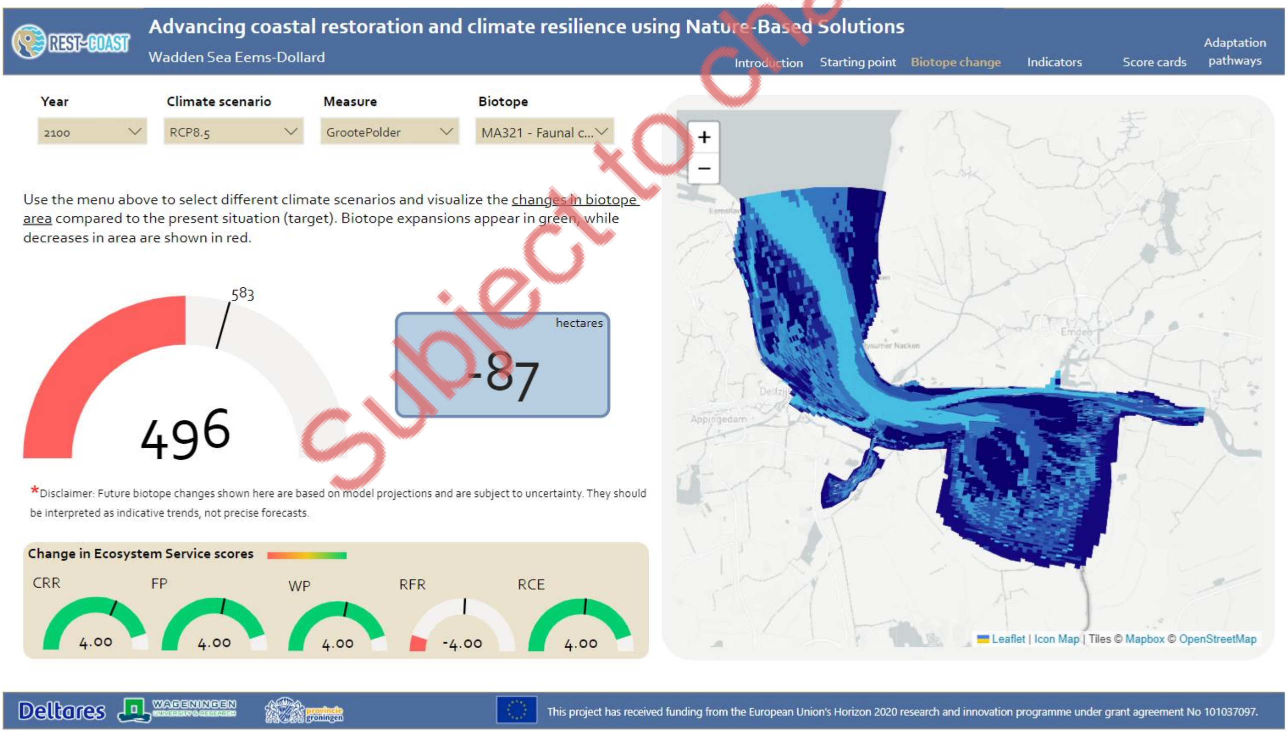


Figure 10 Third tab of the QSST- Biotope change. It focuses on the impact of climate change on biotopes, showing projected changes in areas and ESS supply.

Subject to change

The fourth tab (*Indicators*) is designed to provide a detailed analysis of the underlying data behind ESS supply assessments (Figure 11). It dives deeper into the impact of climate change on the restoration area by focusing on specific biophysical variables, such as carbon sequestration and wave height, which influence the ESS. Users can explore model outputs related to these biophysical variables through a map, which highlights multiple regions within the pilot area. This map is linked to a bar graph that displays data values over time for the selected variables, climate scenarios, restoration measures, and regions within the pilot area, allowing users to assess the intensity of changes across different parameters. This tab maintains the consistent layout of the previous two tabs, with an interactive map on the right side of the dashboard and slicers at the top for scenario and data selection.

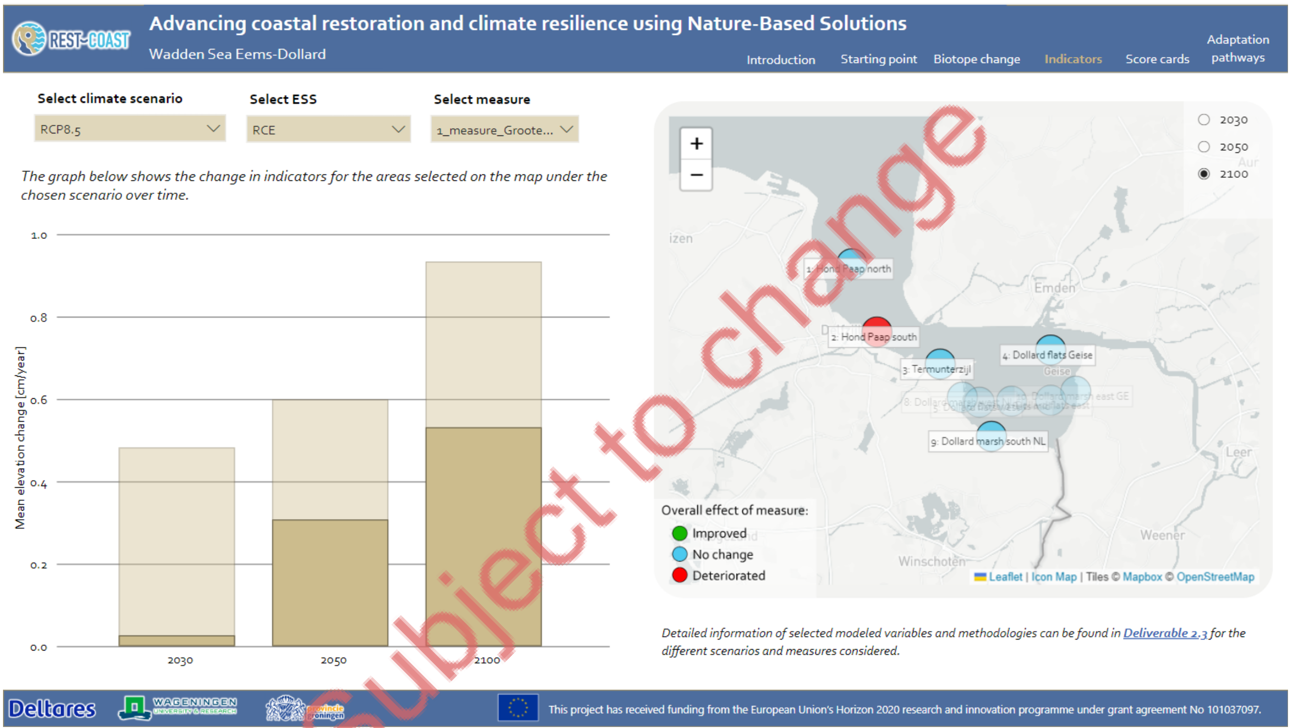


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Figure 11 Fourth tab of the QSST- Indicators. Users can explore biophysical variables linked to different restoration measures.

The fifth tab (*Score cards*) introduces new indicators from finance and governance disciplines, linking these indicators and ESS supply to the restoration measures (so-called projects or NbS, depending on context) considered for the pilot site (Figure 12). Data on these indicators can be filtered by climate scenario and strategy at the top of the dashboard, as not all measures apply to every strategy. This tab includes a new Card Browser visual, allowing users to select restoration measures associated with each strategy. The Card Browser provides brief descriptions and images of the measures, including photographs or sketches of planned measures that have not yet been implemented. When a strategy is selected from the slicers above, the map on the right side of the dashboard zooms in on the relevant measures, displaying their locations as points or polygons. Further zooming occurs when a measure is selected in the Card Browser. The gauges and visuals at the bottom of the page then update to show values for the interdisciplinary indicators related to the selected measure.

This tab facilitates a thorough analysis of the socio-ecological system by integrating finance and governance indicators with ecosystem services. It enables users to evaluate trade-offs between the indicators and provides a holistic view of the restoration measures.

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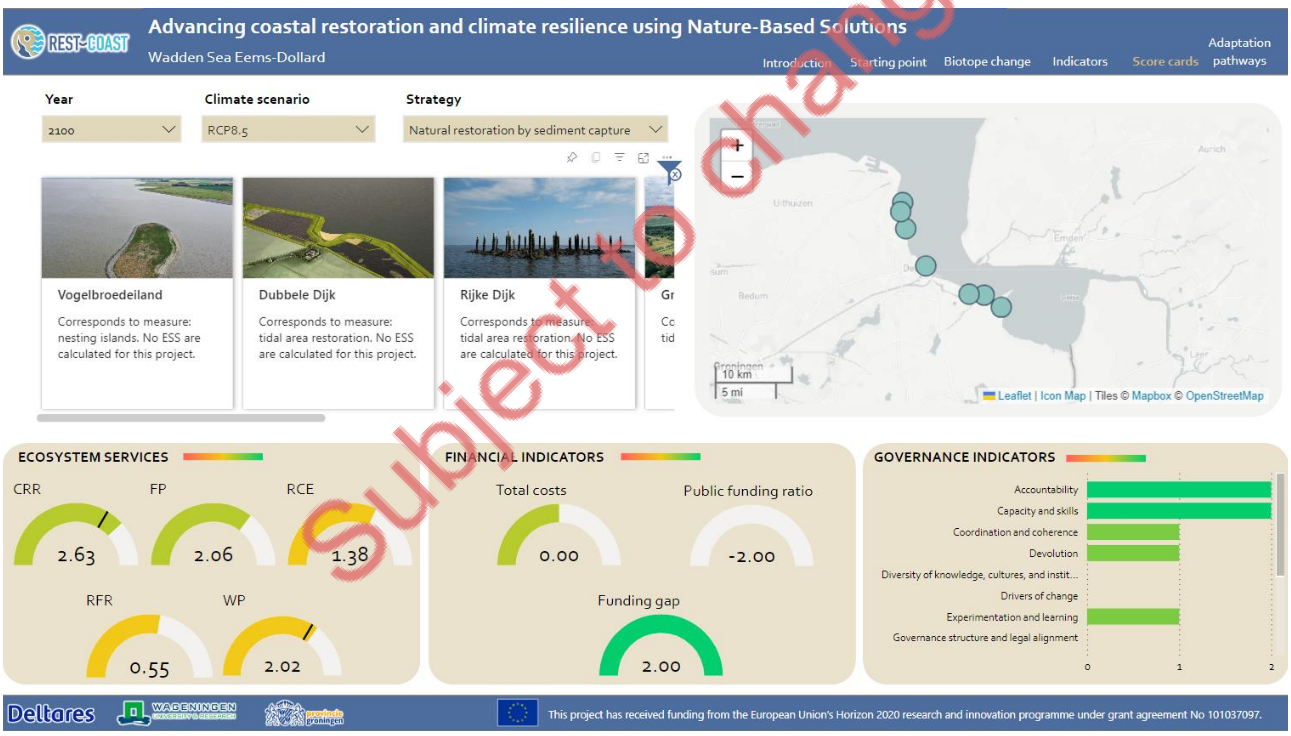

Figure 12 Fifth tab of the QSST- Score cards. It integrates finance and governance indicators with ESS supply.

The final tab (*Adaptation pathways*) shows adaptation pathways, allowing users to visualize and compare different adaptive strategies over time (Figure 13). This tab provides an understanding of how various measures can be implemented, highlighting critical events such as early warnings and tipping points. These events indicate when the effectiveness of current measures may decline, requiring subsequent measures to achieve long-term coastal adaptation and resilience goals. In the Ems-Dollard example, each pathway corresponds to a specific coastal restoration strategy with different goals (Tai *et al.*, *in preparation*):

1. Agricultural productivity through farmland raising.
2. Coastal protection via sediment reuse.
3. Natural restoration through sediment capture.

This tab includes a visual representation of adaptation pathways, illustrating how different pathways branch out into specific measures over time. Each pathway contains information on the measures, previously elaborated in the scorecards tab. On the right side of this tab, a radar chart displays key indicators grouped under four criteria: feasibility, flexibility, effectiveness, and costs (section 2.2.4). These indicators are used to evaluate the pathways (Cobacho *et al.*, 2024; Tai *et al.*, *in preparation*), enabling users to understand the trade-offs, implications, and benefits of each strategy.

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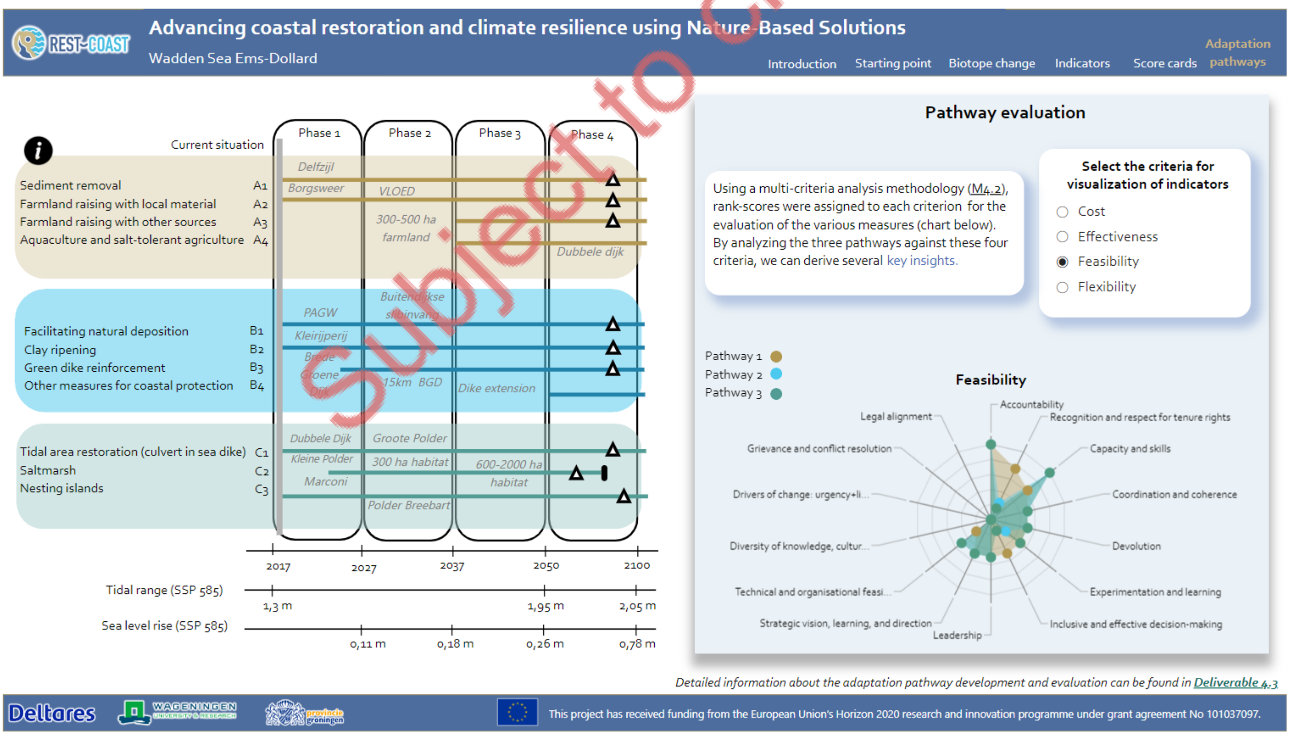

Figure 13 Sixth tab of the QSST- Adaptation pathways. Users can compare different pathways, evaluating their effectiveness, feasibility, costs, and flexibility.

Overall, each tab in the QSST is designed to guide users through a narrative for developing coastal restoration strategies based on data that supports decision-making. From assessing current biotope distributions to evaluating future climate impacts, and from exploring biophysical variables to integrating interdisciplinary indicators, the QSST provides a toolset for analysis and decision-making.

Subject to change

3. User guidance

To support the development of other local versions of the QSST by the REST-COAST pilots, a step-by-step user guide has been created. This guide offers detailed instructions for developers on how to fill out and customize their own databases and dashboards. It ensures structural consistency across different versions by using a standardized database template and PBI model. The database and the model are based on the fully developed and tested Ems-Dollard pilot, which serves as the reference case presented in this deliverable.

3.1 Filling out the database

1. Start by opening the database template file “Demo_DATABASE_RC_empty.xlsm”. Paste your data from the biotope map attribute table into the sheet labelled "Base".
2. Every polygon of the GIS biotope map is considered as a separate entry (row). The following attributes from the EUNIS Biotope Map are copied into this Excel sheet: Feature ID, EUNIS-code of the biotope, Area (m^2) and coordinates (as centroid points (X and Y) or geometry of the polygon).Ensure that the sheets "ConversionTable" and "Change Biotope SLR" are present in your database. Verify that the "EUNISCODE" column contains the appropriate codes for the biotopes specific to your pilot case. These codes and their descriptions can be found in D4.1 (Baptist *et al.*, 2024).
3. Input the list of restoration measures (NbS) relevant to your pilot case, along with any additional data related to these measures, into the sheet labelled "Measures".
4. The information provided to the "Base" and "Measures" sheets, is automatically combined into the "ESS_Score" sheet in the database. You should check if the links are still correct and if there are no *#N/A* values present. When present, delete the rows which consist of *#N/A* values.
5. Update the "Variables" sheet to reflect the specific variables and current values for your pilot case.
6. Make sure that you enable the Macro functionality and allow for Iterative Calculation in Excel [OPTIONS → FORMULAS → Enable iterative calculation]. After confirming that the sheets are free of errors, navigate to the "Control" sheet and run the three Macros to generate the result sheets for one strategy. You can choose your desired strategy in column C2.
7. Ensure that there are no cells showing *#N/A* in the result sheets, as PBI cannot process these blank cells.
8. Save your results with the Macro button “Save Your Strategy” as a *.xlsm* file at the directory your PBI dashboard is linked to. Repeat the process (6-8) to create scorings for different strategies.

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3.2 QSST visualization (PBI)

9. After installation, open PBI and browse to the PBI project you want to open. We recommend starting with the example for the Ems-Dollard pilot to familiarize yourself with the features incorporated in the dashboard visualization, "DEMO_RESTCOAST_WS.pbix".
10. Change the path to your Excel database to initialize the connection between the database and dashboard.
    a. Go to the File ribbon (top left).
    b. Select "Options and settings".
    c. Choose Data source settings. A menu will appear.
    d. Select the data source and click "Change Source…".
    e. Browse to your database file and click OK.
    f. Once all data sources are set, click Close. Power BI is now connected to your database.
11. When you make changes to your database, press "Refresh" in the top bar, and the data will automatically update your visuals.
12. Check for Errors. Power BI cannot handle error values and will return an error if they are present in the database.
13. To add data sheets, click the "Get Data" button on the Home ribbon. The imported sheets will appear on the right side of your screen, ordered alphabetically. If you need to adjust your data without altering the database structure, use Power Query.
14. To open Power Query, click the Transform Data button on the Home ribbon. Power Query allows you to modify your data to suit your needs, including changing column data types, transposing tables, or combining tables. The example provided includes seven combined tables from different strategies:
    - Combi_Change_Biotope: Combined from the Change_Biotope sheet.
    - Combi_Change_EUNISC_Area: Combined from the Change_EUNISC_Area sheet.
    - Combi_Change_EUNISC_Area_graph: Combined from the Change_EUNISC_Area sheet.
    - Combi_Change_BDV_Area: Combined from the Change_BDV_Area sheet.
    - Combi_ESS_Score_Scenario: Combined from the ESS_Score_Scenario sheet.
    - Combi_Pathway_Score: Combined from the Pathway_Score sheet.
    - Combi_Score_card_ESS_Score_Scenario: Combined from the ESS_Score_Scenario sheet with additional table transformations.
15. Changes made to the source database will automatically update the combined tables in Power Query.
16. Ensure that sheets containing latitude, longitude, and area columns are set to the Decimal Number data type.

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17. Deleting a column in Power BI will trigger an error message if the column is referenced in the model. Power BI navigates using column names, so missing or renamed columns will cause errors. You can manually adjust or delete column names through the Applied Steps menu in Power Query. Subsequent steps will automatically update based on your changes
18. Changes made to the source database will automatically update the combined tables in Power Query. Ensure that sheets containing latitude, longitude, and area columns are set to the Decimal Number data type
19. Get familiar with PBI visuals and slicers
    - PBI translates numeric data into dynamic visuals to build a narrative. The QSST includes five tabs (explained in detail in section 2.3.3) with various visuals such as maps, graphs, and tables. Each page features slicers to filter data by year and SLR scenario. Ensure that any new sheets added to the QSST have the same structure to maintain consistency.
    - Each visual displays data from the fields (former columns) assigned to that visual, and slicers filter this data based on the selected criteria (Figure 14).
    - Default Slicer Settings: Visuals change with different slicer configurations, but the underlying data columns remain consistent. Data only needs to be assigned once.
    - Power BI allows you to apply filters to individual visuals, which is useful for meeting multiple criteria. For instance, on the Overview Spatial page, filters were applied to the visual showing the number of NBS in place during a specific period. The filter criteria included:
    - Year: Check if the NBS was in place at the selected time.
    - NBS Status: Verify if the row is considered an NBS (NBS = Yes).
    - Strategy Inclusion: Confirm if the NBS is part of the strategy, indicated by changing the DN column from 0 to 1.

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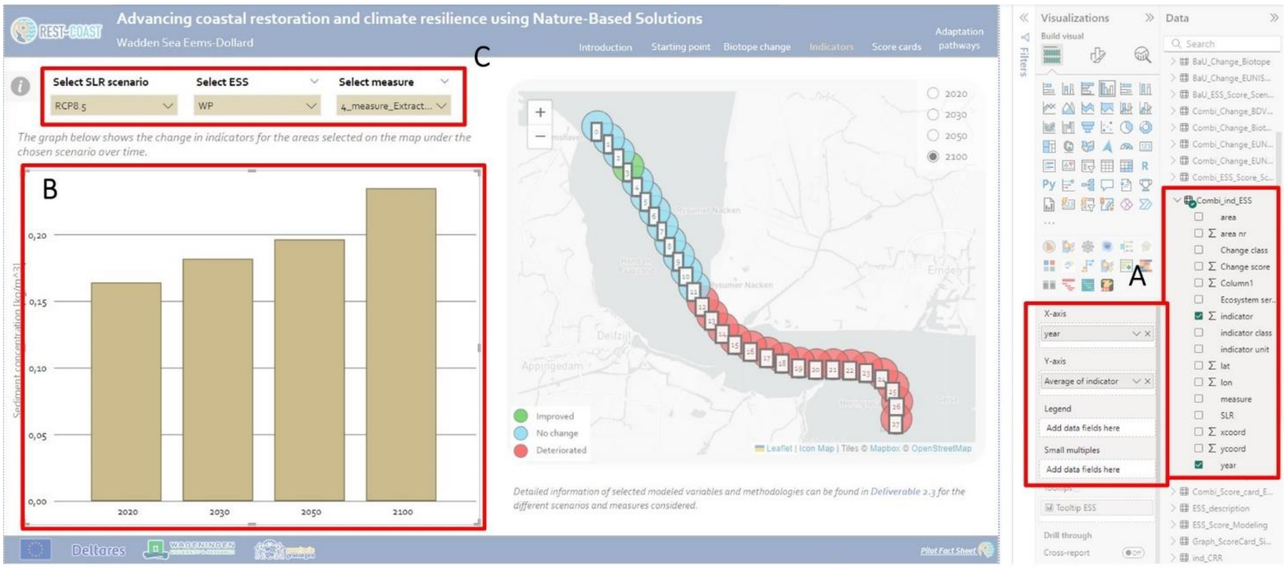

Figure 14 Each visual displays data from the fields (A) assigned to that visual (B), and slicers filter this data based on the selected criteria (C).

20. To design your own dashboard, open the Template File "DEMO_RESTCOAST.pbix" located in the QST_DEMO → TEMPLATE folder. This file contains the same template used for the Ems-Dollard case, providing a consistent starting point for your design.
21. Two empty database structure files are included, "DEMO_DATABASE_RC_EMPTY.xlsm" and "DEMO_DATABASE_RC_STRATEGY1_EMPTY.xlsm". These files are initially linked to the Ems-Dollard dashboard. Modify these files to align with your pilot's data and ensure you update the directory path to your local computer (see paragraph number 101st.10).
22. After configuring your database files, refresh the data in PBI by selecting the Start ribbon. If your database structure matches the template, the visuals will automatically update to reflect your pilot's data.
23. Ensure your database files are properly prepared and linked (see paragraphs 1 to 6). The provided empty databases are designed for only two strategies. If your case uses fewer strategies than the seven strategies in the Ems-Dollard pilot, you will need to remove references to unused strategies from your model in Power Query. This may result in errors in the "Combi" files (see paragraph number 14). To fix these errors, delete the references from the query line at the top of your Power Query screen.
24. If PBI encounters errors during data refresh, follow the troubleshooting steps outlined in paragraph 17. This may require adjustments in Power Query to address any issues.

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4. Case studies and pilot projects

REST-COAST includes nine pilots, each with the opportunity to develop their own local version of the QSST, supporting the visualization of their adaptation pathways (Milestone 19) and the development of upscaling plans (Deliverable 4.4). To assist the pilots in getting started, user guidance on database and dashboard development was initially released in November 2023, with an updated version made available in March 2024. At the time of this deliverable, the pilots were at varying stages of development. In the remainder of the project Deltares together with the pilots will aim to develop a localized version of the QSST. These results will go beyond the scope of the DoA.

Since November 2023, when the database template was shared and made available for data entry, the pilots have made significant progress. Most pilots indicate to be currently entering the restoration strategies relevant to their pilot cases into the database. Some pilots have completed this step and are now ready to fill in the scores for evaluating adaptation pathways, stored in their VSM+E tables (Tai *et al.*, *in preparation*). The VSM+E table serves as a repository for pilots without modelling data, allowing them to store expert judgment results directly. Further development of the indicators and the VSM+E table is expected during the last trimester of 2024. So far, only one other pilot, the Arcachon Bay pilot, has transitioned from the database to the dashboard (Figure 15). This pilot has made a number of necessary adaptations, providing valuable insights into the integration of the database with the dashboard using the provided template files (section 2.3.2). These lessons will help support the development of the other local versions, with further progress expected in the final trimester of 2024. It should be noted that the application of QSST to all pilots is not a requirement of the DoA. Application to the Ems-Dollard as an example case is the minimum required result.

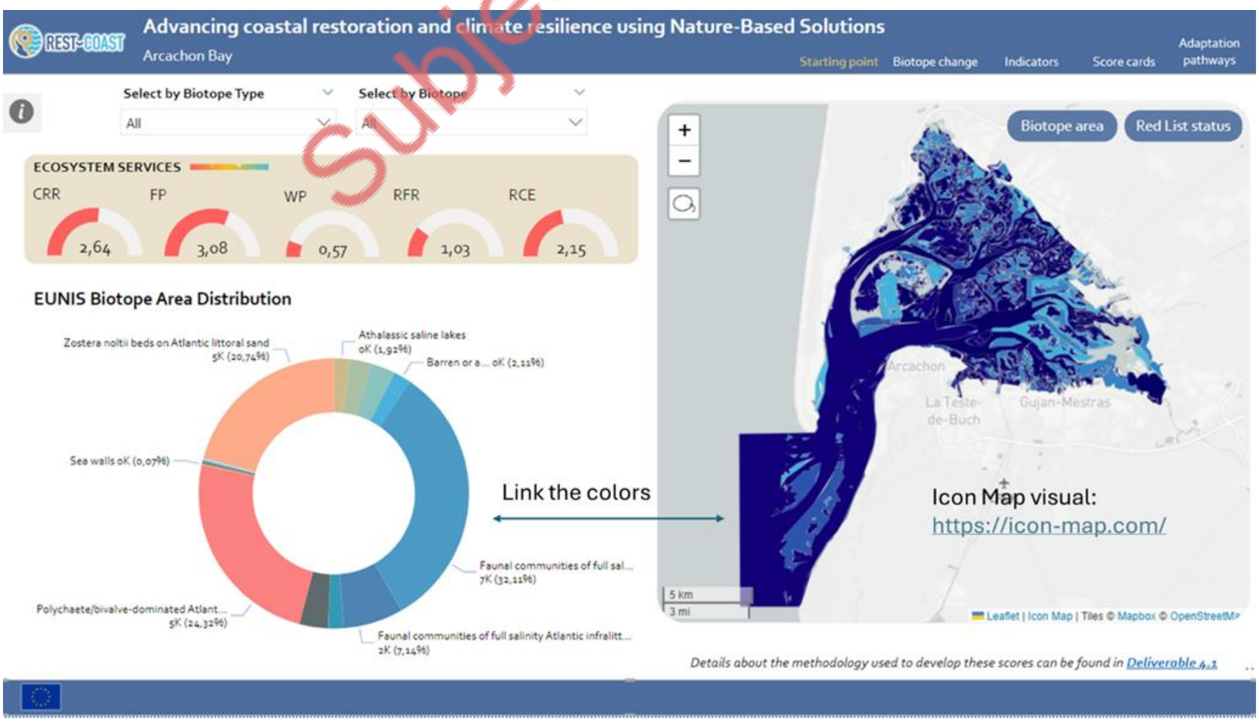

Figure 15 Example of QSST dashboard visualization for the Arcachon Bay pilot.

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The pilots have indicated that they have (or expect to have) suitable data to input into the QSST. This data includes biotope maps developed as part of D4.1, which were created by all pilots. Some pilots also report having modelling results, remote sensing imagery, and other climate change data sources from digital repositories. Additionally, some pilots plan to use the D-Eco Impact tool (Weeber *et al.*, 2024) following the February 2024 workshop on creating biotope maps. Alternatively, they may rely on expert knowledge, which could pose challenges to the rank-scoring system (Milestone 17). If rank-scores cannot be developed, this could degrade the comparison between different pilot cases.

Deltares plans to hold a workshop in November 2024 to assist pilots in transitioning from the database to the dashboard. Therefore, the specific pilot responses will provide valuable insights for further support.

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5. QSST application to Ems-Dollard pilot case

In this section, we present a video demonstration to effectively illustrate how the QSST can be utilized to address the challenges faced by the Ems-Dollard region. This video showcases the features of the QSST. Please click on the image below to watch the demonstration.

6. Scope, limitations, and recommendations for replication

The QSST is developed to determine the potential of systemic restoration, NBS packages, and the resulting ESS and BDV gains for coastal landscape units and present/future climate and under management scenarios. This is all supported by the integrated Excel-Power BI framework. Moreover, to replicate and adapt the QSST for all REST-COAST pilots, an easily accessible and user-friendly tool is required. The seamless integration between these established software packages makes this possible, allowing users to start using the tool without a technical/programming background, thanks to the variety of pre-built visuals in Power BI.

The pre-built visuals and the largely no-coding environment also come with limitations, such as reduced flexibility in what the dashboard can display. For example, coding the dashboard using tools like *Plotly Dash* offers more freedom to design visuals as desired, but this requires a certain in-depth knowledge of coding languages like Python. At the start of the development process, this knowledge was not available among the team assigned to work on the QSST development for the specific pilot cases. Therefore, there will always be a trade-off between functionalities and user/developer accessibility and friendliness.

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7. Conclusion

The QSST is a dynamic GIS-based tool for data visualization and coastal restoration planning developed within WP4 of REST-COAST, supporting decision-making and upscaling plans by achieving several critical objectives. The QSST is developed using a combination of Microsoft Excel and Power BI to ensure an accessible and user friendly tool. The QSST integrates and improves the assessment of ESS supply and BDV gains (section 2.2.1, Figure 9 and Figure 10), ensuring that restoration efforts are measurable in terms of ecological benefits, making use of a scoring system (section 2.2.4). Secondly, the QSST includes scenario analysis by visualizing various climate change scenarios and their impacts on biotopes and ESS (Figure 10), as well as providing an in-depth analysis of biophysical variables (section 2.2.2, Figure 11) and socio-economic indicators (section 2.2.3), crucial for developing resilient and climate-adaptive restoration plans. Furthermore, the QSST facilitates the identification of optimal strategies by providing a structured, data-driven approach. It enables users to compare restoration measures, ultimately guiding the selection of the most effective strategies tailored to specific environmental and socio-economic goals, while also highlighting potential trade-offs (Figure 12). The data-driven narrative culminates in the development of adaptation pathways (Figure 13) by synthesizing the information provided in the various tabs, enabling users and stakeholders to make informed decisions and ensuring long-term, resilient coastal adaptation plans.

Lastly, the detailed and structured database created for the QSST (section 2.3.1) serves as a valuable resource for future research. It not only supports ongoing monitoring and evaluation of REST-COAST pilot sites but also contributes to the broader scientific understanding of coastal ecosystems and their management. Additionally, it provides a platform for data storage concerning REST-COAST in a structured way (Figure 4), containing data from multiple work packages and tasks (section 2.2).

8. Data availability statement

The Quick Scan Strategies Tool dashboard described in this deliverable is available here, and the video demonstration of its functionality can be accessed here. The database underlying this Quick Scan Strategies Tool, tested at the Ems-Dollard pilot site, can be made available for review upon request.

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