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Coastal dynamics analyzer (CDA): A QGIS plugin for transect based analysis of coastal erosion

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ABSTRACT

Coastal erosion is a critical issue affecting shorelines worldwide, imposing effective monitoring and management strategies. We present the Coastal Dynamics Analyzer (CDA), a newly developed QGIS plugin designed for transect-based analysis of shoreline changes, enhancing both the accuracy and efficiency of coastal erosion studies. CDA seamlessly integrates into QGIS, providing an open-source, user-friendly tool that automates the calculation of key shoreline change metrics, including End Point Rate (EPR), Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE), and Linear Regression Rate (LRR). This paper presents the motivation behind the CDA's development, its importance in addressing the limitations of existing tools such as the Digital Shoreline Analysis System (DSAS) and Analyzing Moving Boundaries Using R (AMBUR) and details its implementation. The plugin's functionalities are demonstrated through a case study in the Mediterranean Sea, showing its ability to generate accurate and reliable data for coastal management. By providing high quality results with considerable speed, CDA is promising to become a resource for researchers, coastal engineers, and policy makers involved in coastal erosion management and climate change adaptation planning.

Code metadata

Current code version	1.0.0
Permanent link to code/repository used for this code version	https://github.com/PietroScalaUnipa/CDA
Permanent link to Reproducible Capsule	–
Legal Code License	–
Code versioning system used	Git
Software code languages, tools, and services used	Python/PyQGIS
Compilation requirements, operating environments & dependencies	Python 3 on Linux, OSX or Windows. QGIS (min version 3) Dependencies listed in CDA_algorithm.py in code repository
If available Link to developer documentation/manual	https://github.com/PietroScalaUnipa/CDA/blob/main/CDA_User_Manual.pdf
Support email for questions	pietro.scala@unipa.it – giorgio.manno@unipa.it

1. Motivation and significance

Analysis of shoreline change is crucial for understanding coastal dynamics and planning land management interventions. Shoreline changes can significantly affect the ecosystem and coastal infrastructure. Saengsupavanich, [1] highlights how these sandy deposits (sand spits), shaped by natural and anthropogenic processes, can undergo shifts and transformations that alter coastal habitat and its biodiversity by pointing out how knowing their evolution can lead to planning for appropriate management of these spits (e.g., dredging, community livelihood adaptation, economic development, and even tourism promotion). Similarly, Saengsupavanich et al., [2] studied shoreline change at coastal structures such as jetties, showing how such infrastructure can both protect and alter coastal morphology and understanding how waves and water currents interacted with the jetties. These, and additional examples [3–5] demonstrate the importance of monitoring and understanding shoreline evolution to ensure sustainable coastal zone

Abbreviation: CDA, Coastal Dynamics Analyzer; QGIS, Quantum Geographic Information System; EPR, End Point Rate; NSM, Net Shoreline Movement; SCE, Shoreline Change Envelope; LRR, Linear Regression Rate; DSAS, Digital Shoreline Analysis System; AMBUR, Analyzing Moving Boundaries Using R; TBA, Transect Based Analysis; ABA, Area Based Analysis; API, Application Programming Interface; GUI, Graphical User Interface; AA, Automating Analysis; TOC, Table of Content; CSV, Comma-Separated Values; GCP, Ground Control Points; PCHIP, Piecewise Cubic Hermite Interpolating Polynomial; SCA, Shoreline Change Analysis; ESRI, Environmental Systems Research Institute.

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management.

Studies on shoreline evolution are also crucial to assess the rate of beach accretion or retreat [6–8]. In recent years, researchers have developed many methods with different techniques belonging to various disciplinary fields. Today, Shoreline Change Analysis (SCA) is the most widely used method to assess shoreline evolution [9,10]. In fact, SCA is necessary to implement management strategies that respond to current or potential erosion problems. In the context of coastal erosion management and the development of coastal hazard adaptation plans, it is essential to study the relationship between coastal and marine morphological changes [11,12].

Traditionally, these analyses were conducted through field surveys [13], aerial photographs, and historical maps. SCA was scientifically introduced in the late 1970s [14,15]. These methods required a lot of time and resources, and the data collected were often difficult to compare because of different scales and survey techniques. However, with the advent of GIS technologies and Earth Observation imagery, it has become possible to carry out these analyses more quickly and with greater spatial accuracy [16–19].

The integration of these data into GIS systems is crucial for the analysis of coastal dynamics. The main methods for shoreline analysis are Transect Based Analysis (TBA) and Area Based Analysis (ABA), with TBA being the most popular method [20–22]. The most widely used tools in the field of SCA using TBA are the Digital Shoreline Analysis System (DSAS) [23,24] and Analyzing Moving Boundaries Using R (AMBUR) [25].

DSAS (Digital Shoreline Analysis System) developed by the U.S. Geological Survey is a free tool for ESRI's ArcGIS that calculates rates of change in shoreline position using historical vector data. This tool uses the baseline method to calculate shoreline velocity or change at user-specified intervals and is able to assess and resolve the nature of coastal dynamics and trends. However, DSAS is not supported by newer versions of ESRI ArcGIS (10.8) and ArcGIS Pro, and many countries and small management agencies have limited budgets for commercial software such as ArcGIS. Other options, such as SCARPS and BeachTools, also require ArcGIS to work. Due to ESRI ending support for ArcMap, the DSAS software has been updated in April 2024 to version 6.0 to function independently of any specific GIS (https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas). However, due to tight deadlines, this new version has limited functionality. This latest version is presented as a stand-alone software but still decoupled from GIS systems. The user must therefore first set up all the necessary input files on a GIS platform and extract them in GEOJSON format and then run the tool making the procedure longer and more fragmented.

To solve this issue, a free and open-source alternative to DSAS called AMBUR, based on R, was created. AMBUR allows analysis of shoreline change at different time scales but has the disadvantage of being complex to install and configure, requiring modifications to GIS systems such as QGIS or ArcGIS. The lack of user support makes AMBUR less attractive as an open-source option.

One of the most popular open-source geospatial tools is Quantum GIS (QGIS) (http://www.qgis.org/). QGIS offers many tools for data visualization, processing and analysis, making this software useful for researchers in many fields. Thanks to its API, its functionality can be extended by developing plugins in Python language. However, QGIS has not yet provided users with plugins or software that automatically performs SCA based on TBA methods. Considering the large number of users it has [26,27], especially in the fields of coastal geomorphology, maritime hydraulic engineering, and other related disciplines [28], there is a need to develop a rapid tool to perform all TBA-based shoreline change analyses.

With this in mind, Terres de Lima et al. [29] presented the End Point Rate (EPR) tool for QGIS (EPR4Q), a tool integrated into the QGIS graphical modeler to calculate shoreline change using the end point rate method. However, this plugin allows only one of the metrics offered by the DSAS package to be calculated.

For these reasons, this paper presents CDA (Coastal Dynamics Analyser) a QGIS plugin based on an automatic method for SCA with improvements in accuracy and speed. The new tool, written in PyQGIS, adopts the TBA described and presented by Manno et al., [22]. CDA offers a range of features to process and analyse data from baselines and coastal transects, allowing the calculation of End Point Rate (EPR), Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE) and Linear Regression Rate (LRR) metrics.

The CDA plugin represents an advance over the limitations highlighted for example in Albuquerque et al., [30]. The authors pointed out that the methodology adopted in DSAS, while showing good correlation between the data, had the drawback of using equidistant transects, which prevented some morphological features, such as ridges or depressions, in the study area from being taken into account.

The newly developed CDA plugin distinguishes itself by incorporating the morphological characteristics of the beach, such as roughness and irregularity indices [31], into the baseline creation process. Irregularity is defined as the ratio of total number of minima and maxima in shoreline position and the smoothed shoreline length. Consequently, roughness is defined as irregularity multiplied by the mean height of irregularities. For more information, see [22]. Using these parameters the plugin automatically calculates, the threshold space between transects as the inverse of the irregularity. This threshold value represent the upper limit of transects spacing.

This advanced feature provides a more comprehensive analysis compared to traditional tools like DSAS, which do not account for these morphological and shape crucial factors.

2. Software description

The CDA plugin is easily installed using the QGIS plugin manager, either by downloading it online or installing it from a zipped file. The plugin can also be run as a Python script using the Processing Script Editor within the Processing Tools. The plugin builds on a set of QGIS algorithms and scientific libraries to provide a comprehensive and intuitive environment for coastal transect analysis.

The CDA plugin uniquely require as input a linestring shapefile, which connects Ground Control Points (GCPs) ensuring the baseline passes through specific and crucial points. In addition, it requires all desired shorelines for analysis as separate shapefiles (one per shoreline), leveraging these inputs to account for beach morphological characteristics. Specifically, it allows the initial definition of a piecewise polynomial baseline to improve the accuracy in evaluating changes in shoreline position. The tool can also calculate new roughness and irregularity indices to define transect spacing relative to the polynomial baseline as reported in Manno et al., [22].

Then, using the baseline generated by the plugin or entered by the user, it will be possible to generate transects for shoreline advance/retreat analysis. The intersection analysis of transects with shorelines allows the generation of reports in .csv format and shapefiles of the most commonly used metrics in DSAS, such as End Point Rate (EPR), Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE), and Linear Regression Rate (LRR). The description of the indices just given is provided below in Eqs. (1)-(4).

$$SCE = D_{max} - D_{min}\ [m] \tag{1}$$

$$NSM = D_y - D_o\ [m] \tag{2}$$

$$EPR = \frac{D}{T}\ \left[\frac{m}{time}\right] \tag{3}$$

$$y = mx + b \rightarrow LRR = m\ \left[\frac{m}{time}\right] \tag{4}$$

The *SCE* represents the maximum distance between the first and last shoreline positions over time. It is not a rate but a measure of total change. In Eq. (1), D_{max} represents the maximum distance between all shorelines while D_{min} the minimum distance of all coastlines from the baseline.

NSM measures the net change of the shoreline over time, calculated as the difference between the final and initial positions. In Eq. (2) D_y is the distance from the baseline of the most recent shoreline while D_o is the from the baseline of the older shoreline.

Instead, *EPR* calculates the rate of change between the two points of intersection of the generic transect and two shorelines by dividing the result by the elapsed time between the two locations. In fact, in Eq. (3), D is the shoreline displacement distance between the "start" point and the "end" point whereas T is the time period between the two survey dates. In general, *EPR* is calculated as *NSM*/time.

Finally, the *LRR* calculates the rate of change using a linear regression on all available data points along the generic transect (all intersections between shorelines and the transect over time). It is defined by the slope of the regression line. In Eq. (4), y represents the shoreline position on the generic transect, x is time, m represents the slope of the regression line (representing the *LRR* rate of change) and b is the intercept.

A visual explanation of all the presented parameters is shown in Fig. 1.

The TBA approach, on which the plugin is based, has been validated both by synthetic benchmarks and in a case study [22], providing interesting results in terms of accuracy and ease of use.

CDA plugin delivers high-quality results with remarkable speed, making it suitable for regional studies and directly providing the parameters needed for erosion management strategies.

3. Plugin functionalities

The QGIS CDA plugin is structured to guide the user through various steps of analysing coastal dynamics. Each step in the process is detailed to automate specific tasks and use QGIS features effectively. Below is a summary of the main steps and implemented features:

Step 1. Main dialog box

- The code begins by importing the necessary libraries for QGIS and defining a dialog box (NumberInputDialog) that guides the user through the possible calculation steps of the plugin.

Step 2. Implementation of the NumberInputDialog class.

- **Window configuration**: The dialog box with titles, layouts and elements such as information labels, text fields for user input and buttons for interaction is configured. This window represents the main GUI (Graphical User Interface) of the CDA plugin (Fig. 1).
- **Event handling**: The on_ok_clicked function is defined that handles the "Run CDA" button click event, validating user input and closing the window if the input is valid.
- **User interface**: The interface includes formatted instructions for each step of the coastal dynamics analysis, helping the user easily navigate through the process.

Step 3. Automating Analysis Processes (AA Steps)

- AA = 0: Creation of the baseline.

  ○ Selection of folders for input and output files.
  ○ Interpolation parameterization and creation of new points on the baseline.
  ○ Saving the results as shapefiles and adding them to the QGIS Table of Content (TOC).

- **AA = 1:** Calculation of transects.

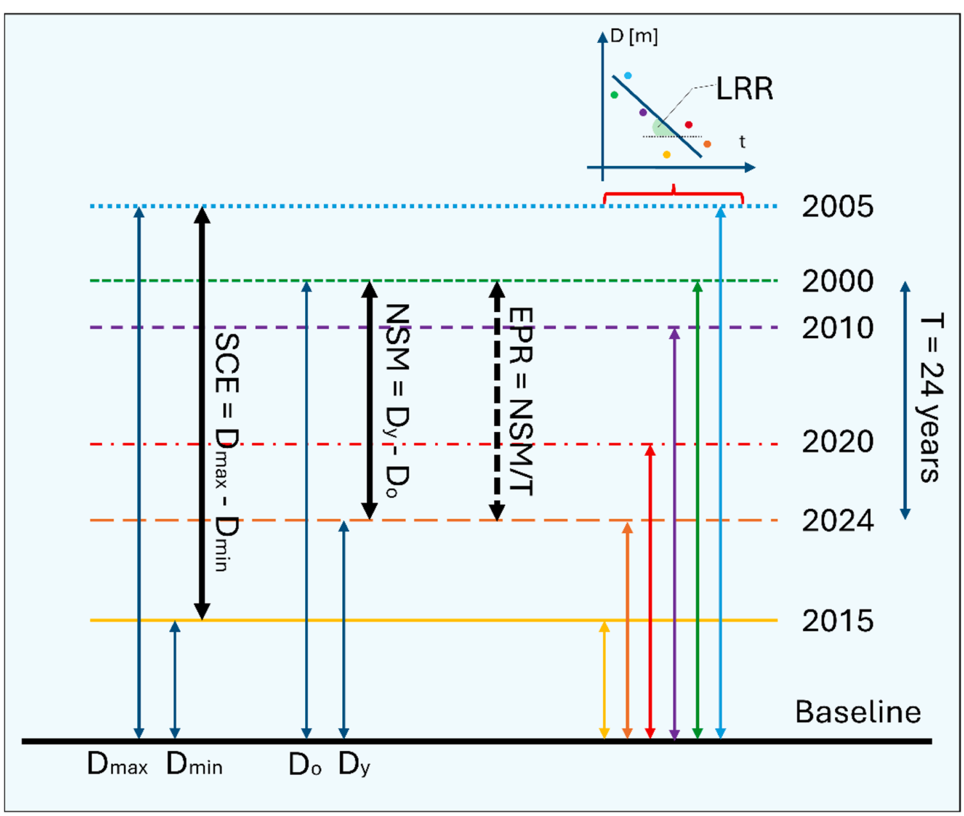

Fig. 1. Graphical explanation of SCE, NSM, EPR and LRR.

◦ Using QGIS tools to generate points along the baseline, transform them into paths, and create perpendicular transects.
◦ Calculation of intersections between transects and shoreline for subsequent analysis.

- **AA = 2**: Selection and correction of transects.

◦ Implementation of a custom dialog box for selecting transect layers to be corrected.
◦ Using algorithms to automatically identify and correct transects with invalid or inconsistent lengths.

- **AA = 3**: Saving selected transects.

◦ Export selected transects to a Comma-Separated Values (CSV) file for external analysis.

- **AA = 4**: Analysis of saved transect data for SCE and LRR calculation.

◦ Statistical analysis of transect data to calculate rate of change and other parameters of interest (SCE and LRR).
◦ Aggregation of results into a CSV file for further analysis.

- **AA = 5**: Clipping of transects for calculation of NSM and EPR.

◦ Algorithm for calculating the distance expressed in meters between the oldest and youngest shoreline and then (NSM) and then the 'EPR which is obtained from the ratio of the NSM divided by the time that has elapsed in detection between the two shorelines.

In addition, each step of the CDA plugin is meticulously designed to integrate seamlessly with QGIS, utilizing its API (Application Programming Interface) and processing tools. The user interface is thoughtfully crafted to provide clear instructions and relevant information, guiding the user through the various steps of the analysis. Additionally, the code incorporates robust validation mechanisms to ensure that user inputs are accurate, providing appropriate feedback in case of errors. This approach not only simplifies the coastal dynamics analysis process but also illustrates how QGIS can be extended via plugins to automate complex geoprocessing and data analysis tasks. More information on the operations performed specifically by each step can be found in Supplementary Materials in which user guide manual is presented.

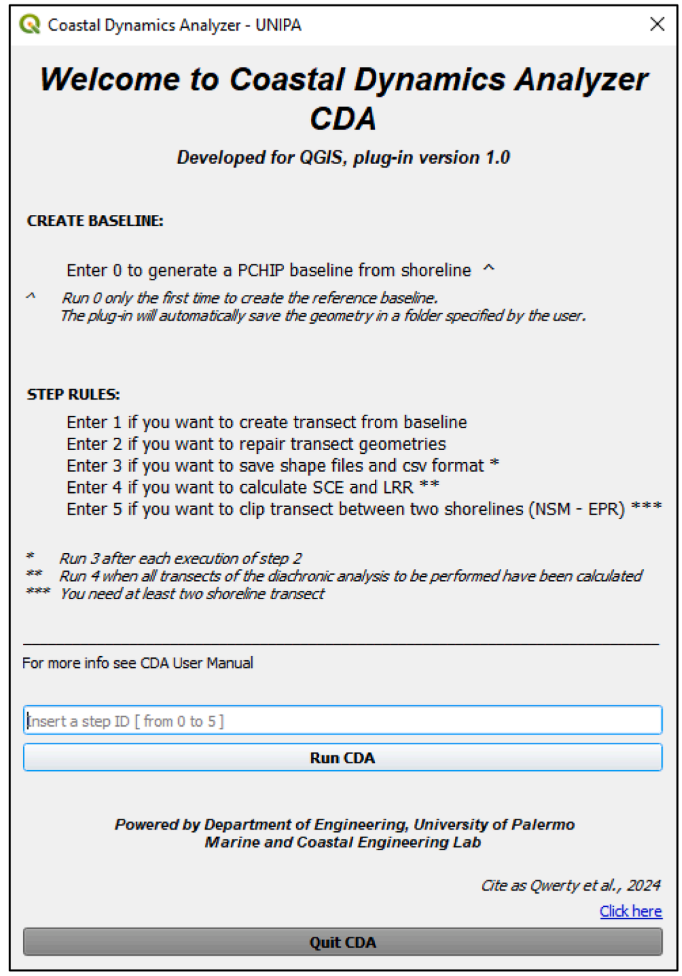

Fig. 2. Main GUI of CDA. From this window shown, all AA steps can be accessed by entering their respective identifier. The window notes explain to the user how and when to use the generic step. The Run CDA button allows steps to be executed only if a valid step (between 0 and 5) is entered. The link in the lower right hand corner redirects to the plugin web page where the documentation and related manuscript can be downloaded.

4. Illustrative example

The application area of the plugin is the beach of Eraclea Minoa (Fig. 2) located along the southern coast of Sicily (south Italy). This area has already been analyzed by Manno et al. [22], who provided a detailed description in their study on diachronic analysis methodology, from which the plugin takes its cue.

According to Manno et al. [22], Eraclea Minoa beach has experienced significant shoreline retreat since 1989. The beach, 5605 m long, is bordered on the north by the Capo Bianco promontory and on the south by the Torre Salsa promontory, both in protected natural areas. Capo Bianco, with a cliff about 30 m high, is home to the archaeological site of Eraclea Minoa, while Torre Salsa, about 20 m high, is characterized by the presence of the 16th-century tower of the same name.

The coastal area belongs to Sicilian Physiographic Unit No 11 and has no coastal defense structures or ports. North of Capo Bianco, the mouth of the Platani River, with a basin of 1784 km^2, has a reduced sediment flow due to various river structures (For more information on spatial setting see Manno et al., [22]). The prevailing littoral current has a NW-SE direction. At the base of the marly cliff, a narrow beach about 3 m wide and 600 m long is interrupted by boulders. The cliff is connected to the beach by clastic deposits. In a southeasterly direction is the dissipative beach of Heraclea, with a slope of about 5°, behind which lies a retreating pine forest. The beach ends with the promontory of Torre Salsa, at the base of which is a small beach about 20 m wide, exposed to SE and W-NW swells.

For the case study under consideration, the roughness coefficient was found to be 1.98 while the irregularity was 0.11.

The tool described in this paper was used to develop the SCA analysis of the sandy beach in the study area. Initially, a GIS project is created in which to insert all the coastlines to be analysed and a linear type layer that joins the control points for baseline construction. This last layer can be a break joining the aforementioned points.

The shorelines used cover the period from 1989 to 2020 and are the same as those used by Manno et al., [22]. Moreover, the shorelines proxy used was the wet/dry boundary as defined by Boak and Turner, [32].

Next, starting the plugin and running Step 0 from the main GUI automatically generates the PCHIP baseline related to the input required layer (the GCP baseline union line type layer of Ground Control Points).

The baseline thus generated is automatically loaded into the Table of Content (TOC) of QGIS and saved in a folder chosen by the user during execution. It should be specified that in order to obtain an optimal baseline result, the plugin will ask the user to also select the folder where all the shorelines to be analysed are located. This condition was included to generate a PCHIP spline that is as concordant as possible with the roughness variations of all shorelines and to allow transect generation as perpendicular as possible for all shorelines. More details are reported in Manno et al., [22].

The second step is to start step 1 from the CDA GUI that allows transect generation via the *CDA - Calc_Transect* algorithm by entering as input the baseline layer (obtained from step 0), the date of shoreline acquisition, the shoreline layer (one shapefile per shoreline), the transect length, the resolution (transect-transect interdistance) and the side of the baseline on which to generate transects.

The process can be run serially to generate transects related to each shoreline by filling in the input dialog box only once in Fig. 3.

In the present case, 515 transects with an average resolution of 10 m (according to an irregularity of 0.11) were generated for each shoreline. Each transect has as its start point a point belonging to the baseline and as its end point the intersection of the transect with the generic shoreline.

Next, step 2 is started. At this point, a window is opened that allows the user to select (flag) in the TOC the shapefiles of the transects to be repaired. The term "repair" indicates that the plugin will select the correct transects, i.e., those whose extremes are the green stars in Fig. 4. These errors occur in transects when sand spit or folding of shorelines back on themselves are present in the shorelines.

The user than can start step 2, and the plugin will automatically select all the correct transects, i.e., those crossing the green stars. If the red and green star conditions shown in Fig. 4 do not occur during the analysis, this means that all the transects are already "correct," and the plugin will simply select all starting transects, since they are found to be already correct and valid. Next, the user can start step 3, and the plugin will ask at this point to select the folders where to save the corrected transects in CSV and shapefile formats. It is important to note that the transects that cross the green stars are those that start from the baseline and first meet the shoreline. Subsequent intersections of the same transect are not considered. The same reasoning is applied by the plugin if the baseline is drawn on the land side. Either way, the user can decide whether to perform TBA on all transects (internal and externals) and thus bypass Step 2 or to repair them. In this case study, there were no transects to repair.

At this point, once the plugin has saved the csv and shapefiles of the transects in appropriate folders, the user can continue by starting step 4 from the CDA GUI. In this case, the user only needs to select the folder where the csv files were saved in the previous step. The algorithm will automatically calculate the SCE and LRR for each transect in relation to all shorelines on the same csv and shapefiles. It is important to note that the user can only proceed to step 4 once all transects have been calculated relative to each shoreline.

Fig. 5 reports the results of SCE and LRR for the Eraclea Minoa case study. Transect are labelled from 1 to 515 respectively starting from Capo Bianco to Torre Salsa (Fig. 3).

The first row (top) of Fig. 5 shows the trend of SCE along ID transects. The values of the SCE vary from around 0 m to over 190 m. A significant peak is observed between transects 60 and 100, where the SCE reaches maximum values around 190 m, indicating a higher variability in shoreline position in that area. Thereafter, the SCE tends to decrease gradually, stabilizing around 50–100 m for transects beyond 200.

The bottom row of Fig. 5 shows the trend of LRR. The LRR values vary from about −5 m/year to +1.9 m/year. An initial negative trend (up to −5 m/year) is observed between transects 0 and 80, a sign of significant erosion in this area. Thereafter, a reversal of the trend is seen with LRR values increasing, reaching up to +1.9 m/year toward transects over 400, indicating an advancement of the shoreline or otherwise a reduction in erosion.

The last step to complete the diachronic analysis is to start Step 5 from the CDA GUI. In this case, the user displays the *CDA* algorithm data input window - *TRANSECT_Clip* shown in Fig. 6.

The inputs to be entered are the transect referenced at time T1, and the transects at time T2 with T1<T2. Another input parameter is the time elapsed between the two transect layers and thus between the two connected shoreline acquisitions. Again, the algorithm can be run serially (in batch) for all pairs of transects to be analysed in order to speed

Fig. 3. Map showing the input baseline and PCHIP baseline generated by CDA for the shoreline change analysis in Eraclea Beach and Bovo Marina. The yellow line represents the input baseline, while the red line indicates the Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) baseline. Ground Control Points (GCPs) are marked with black and white dots. The images on the right provide detailed views of two stretches of beach where the differences between the PCHIP baseline and the input baseline with GCPs can be appreciated. Bottom left subplot show the beach setting in Sicily region (south Italy).

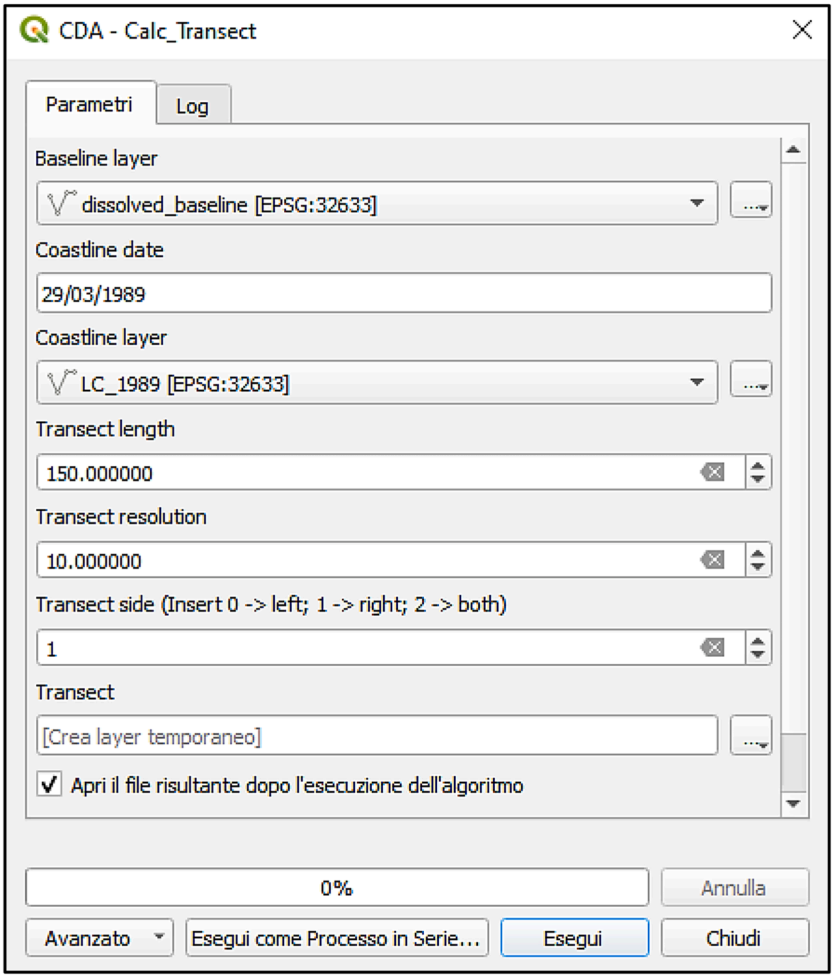

Fig. 4. Screenshot of the CDA algorithm - Calc_Transect of the CDA plugin (Step 1). Calculation of transects from the baseline for each shoreline in QGIS. Parameters set include baseline, shoreline date, shoreline layer, transect length, transect resolution, transect side, and option to open the resulting file after running the algorithm.

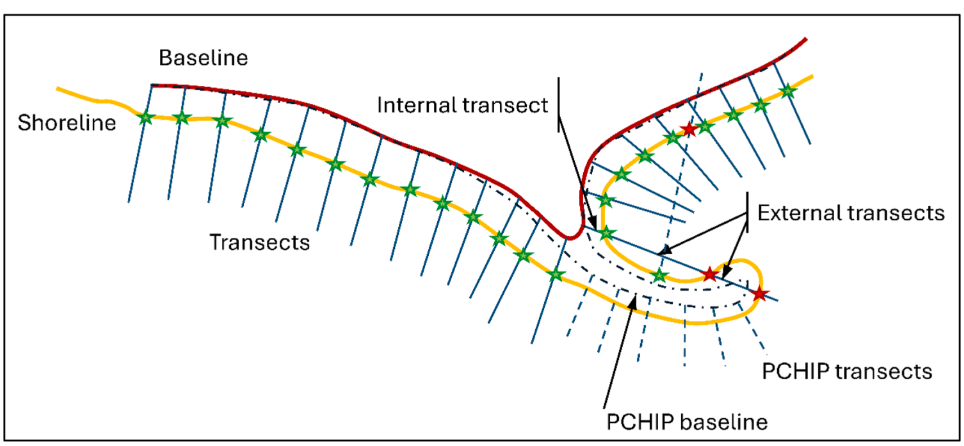

Fig. 5. The image depicts a diagram illustrating the process of selecting transects for repair in the context of shoreline analysis. The diagram shows a baseline and a shoreline with several transects extending from the baseline (land side) to the shoreline. The green stars represent the right transect-shoreline intersection while the red stars the wrongs.

up the process and facilitate handling a large number of transects to be analysed.

The plugin outputs shapefiles contain the attribute table where the calculations of the NSM and EPR indices are stored. The results are shown in Figs. 7 (NSM) and 8 (EPR).

The transects in Fig. 7 have been colored according to the degree of erosion or accretion. In particular, the areas in red and orange show severe erosion, with NSM values ranging from −148.8 m to −16.8 m. The northern area of Heraclea Beach appears to be particularly prone to severe erosion. Areas in yellow and green indicate less erosion or even

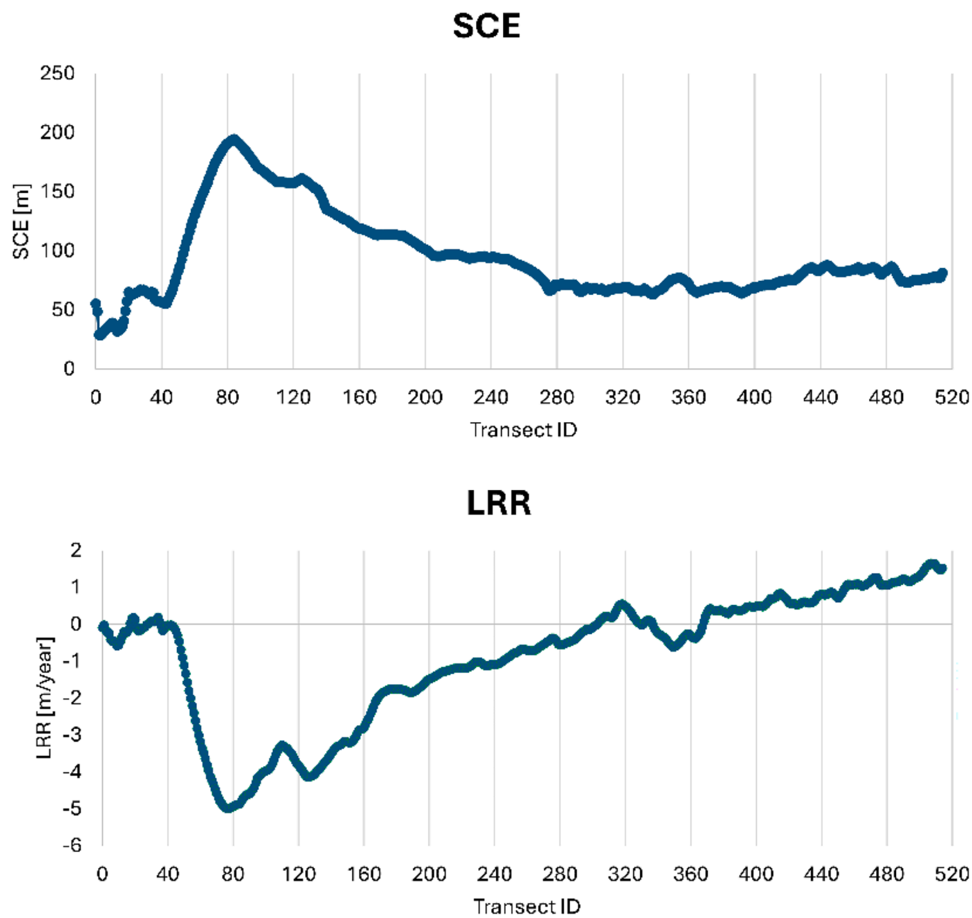

Fig. 6. SCE and LRR results for Eraclea Minoa Beach. In x axis are reported the transect number ID, in y-axis the SCE and LRR respectively for the top and bottom subplots.

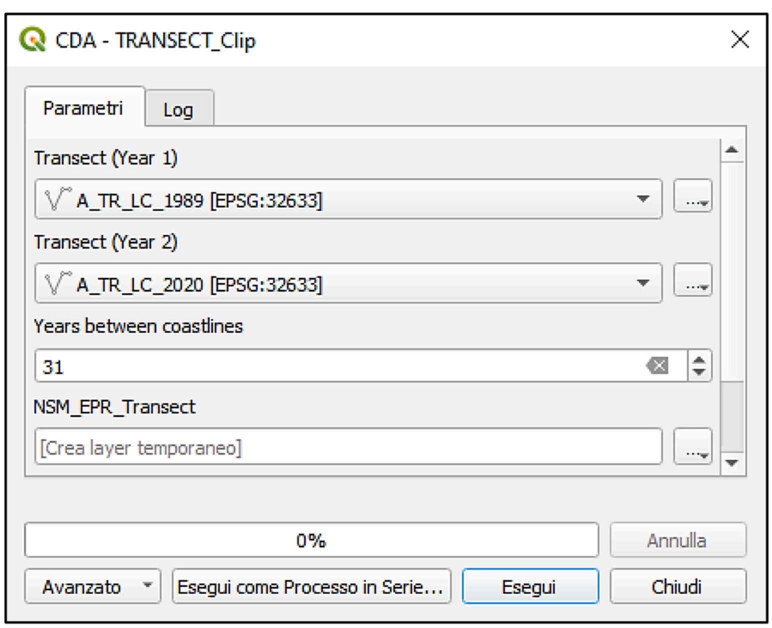

Fig. 7. CDA algorithm screenshot - TRANSECT_Clip (Step 5). The window allows the user to select the two transect layers whose SCE and EPR metrics are to be calculated and to enter the elapsed time between the two transect reference shorelines.

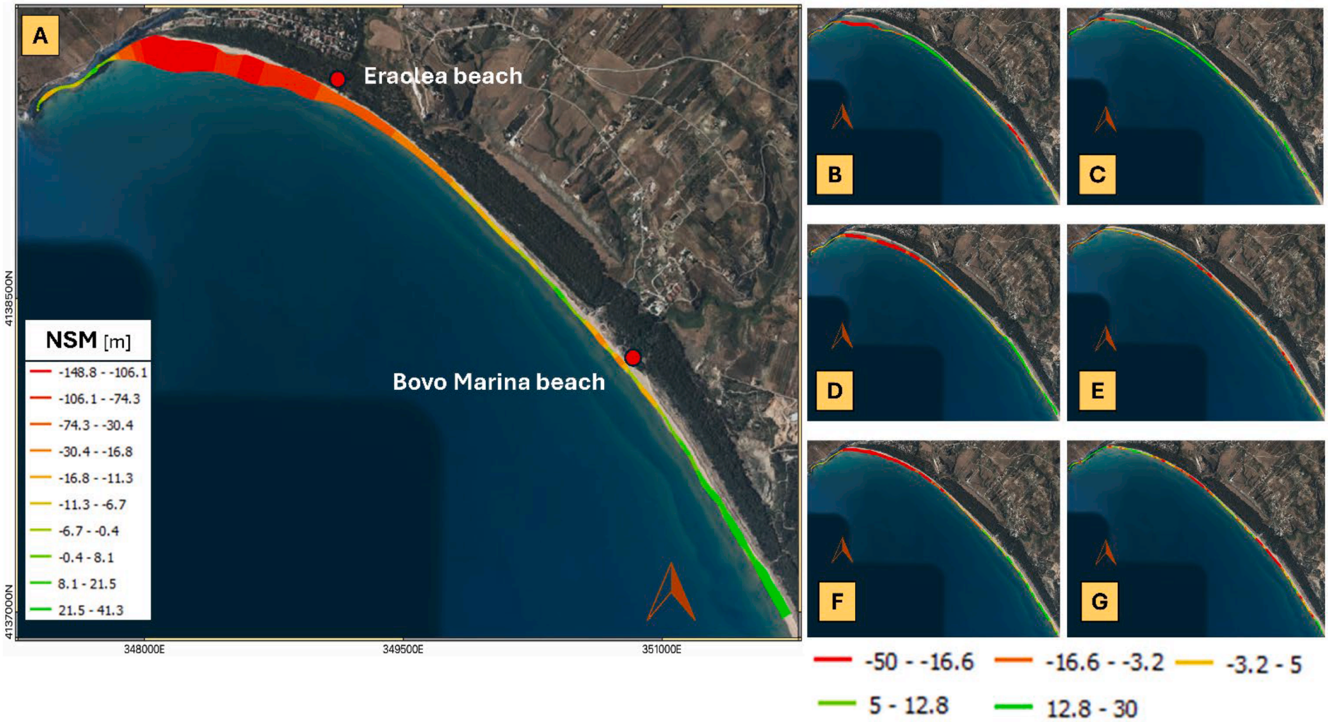

Fig. 8. Maps showing the results of the NSM metrics for the study area. Subplot A shows the calculated NSM for the 1989 and 2020 shorelines. Subplots B through G show the results of the same metric for 1989–1997, 1997–1998, 1998–2005, 2005–2010, 2010–2019 and 2019–2020, respectively.

accretion, with NSM values ranging from −16.8 m to +41.3 m. The Bovo Marina Beach area shows signs of accretion, especially in the terminal part.

In Fig. 8, the areas in dark red show significant erosion rates, with EPR values ranging from −4.8 m/yr to −3.42 m/yr, particularly evident in the northern area of Heraclea Beach. Areas in blue and light blue represent shoreline stability or advancement, with EPR values ranging from −0.01 m/yr to +1.33 m/yr, most prevalent near Bovo Marina Beach (Fig. 9).

The results obtained from the CDA framework are consistent with those described in [22]. Indeed, there is strong agreement between the numerical data obtained in Manno et al., [22] and the results produced by the CDA, confirming the validity of the results obtained from the plugin. The quantitative comparison of the two results is shown in Table 1. Minor discrepancies can be attributed to differences in rounding or interpolation. Thus, both papers confirm that the studied beach is subject to significant erosion, with high values of shoreline retreat, and that the area has undergone large surface changes over time.

Fig. 9. Map showing EPR results for shorelines 1989–2020 thus considering $T = 31$ years.

Table 1
Comparison between results obtained by Manno et al., 2022 [22] procedure and CDA plugin.

Parameter	Manno et al., 2022	CDA
Minimum NSM	−149 m	−148.8 m
Maximum NSM	+41 m	+41.3 m
Minimum LRR	- 4.9 m/year	- 5 m/year
Maximum LRR	+1.8 m/year	+1.9 m/year
Maximum EPR	+1.4 m/year	+1.3 m/year
Minimum EPR	−4.8 m/year	−4.8 m/year
Maximum SCE	170 m	190 m

In addition, the plugin returned the output(s) of each Step on average in 5 s. The times mentioned refer to the shoreline section examined with the resolution already discussed (10 m). The plugin was run on a version of QGIS 3.34.32 Prizren on an Intel(R) N95 1.70 GHz, 16.0 GB RAM V23H2 computer with a 64-bit operating system.

5. Impact and applications

The CDA plugin has the potential to become a valuable tool for the scientific community, industry professionals, and coastal managers.

Its versatility extends across various crucial tasks, making it essential for monitoring coastal change over time, identifying areas at risk of erosion, and evaluating the effectiveness of mitigation interventions.

One of the most significant applications of the CDA plugin lies in its ability to assess shoreline change comprehensively. This includes the analysis of long-term shoreline evolution, which is critical for understanding the dynamics of coastal environments. By utilizing CDA, users can evaluate how coastlines have shifted over time, helping to predict future changes and identify regions that are particularly vulnerable to erosion or accretion [33].

Moreover, CDA proves to be instrumental in assessing the effects of coastal structures on shoreline morphology. Coastal infrastructure, including revetments, seawalls, groynes, and breakwaters, can significantly alter natural sediment transport processes, leading to patterns of erosion and accretion [34].

Ports and other large-scale coastal developments also present challenges and opportunities for shoreline management, as they can drastically affect coastal hydrodynamics and sediment distribution. The CDA plugin can be employed to study these impacts, facilitating the design of more sustainable port infrastructure and the mitigation of negative effects on surrounding shorelines. An example of this application is illustrated in recent research on the interaction between port structures and coastal erosion by Miranda et al., [35], where the tool could be used to assess the long-term consequences of such developments.

Additionally, CDA is invaluable in the context of climate change adaptation. As sea levels rise and extreme weather events become more frequent, the plugin can aid in the planning of adaptive strategies that protect coastal areas from the increasing threats posed by climate change. By providing detailed analyses of shoreline behavior and the effectiveness of various interventions, CDA supports the development of resilient coastal management plans.

In summary, the CDA plugin is not just a tool for analyzing current shoreline conditions, but a comprehensive solution for a wide array of coastal management challenges. Its applications in assessing shoreline change, the impacts of coastal structures, and the effects of large-scale developments like ports demonstrate its utility in preserving and managing coastal environments in the face of both human-induced and natural changes. By leveraging the capabilities of CDA, stakeholders can make informed decisions that safeguard coastal regions for future generations.

6. Conclusions

The Coastal Dynamics Analyser (CDA) is a plugin for QGIS designed to provide versatile and intuitive analysis of coastal changes, focusing on key metrics such as End Point Rate (EPR), Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE) and Linear Regression Rate (LRR). The adoption of transect-based methods (TBA) makes CDA a powerful and accurate tool for assessing coastal dynamics.

The CDA plugin is an efficient and accurate solution for coastal change analysis by exploiting the methodology proposed by Manno et al., [22] already widely discussed and validated. Through its functionalities, it enables the processing, analysis, and visualization of coastal transect data, providing fundamental information for understanding erosion processes and planning mitigation and adaptation interventions. The ability to produce high-quality results with remarkable speed makes CDA particularly suitable for regional studies. The CDA plugin is currently under development and may undergo further enhancements. For more information and to download the plugin, you can visit the project website at the links provided in the *Code metadata* and *Software metadata* sections.

Upcoming versions of the plugin are expected to include the ability to calculate other analysis metrics (such as the Weighted Linear Regression Rate WLR) and to implement Area Based Analysis (ABA).

In summary, CDA offers a robust and affordable open-source alternative to traditional methods, thus supporting a wide range of coastal management studies and interventions.

CRediT authorship contribution statement

Pietro Scala: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Giorgio Manno:** Writing – review & editing, Validation, Methodology, Investigation, Data curation, Conceptualization. **Giuseppe Ciraolo:** Writing – review & editing, Validation, Supervision, Resources, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.softx.2024.101894.

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