Total Quality Measures for Environmental Coastal Monitoring Using Remote Sensing, Lidar Bathymetry, Radar Altimetry and GIS Techniques

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Key words: GIS, Remote Sensing, Radar Altimetry, Accuracy, Environmental, Quality, Coastal Management, 3D, Surface, Geodatabase, Lidar, Bathymetry.

SUMMARY

Unlike conventional methods for topographic or hydrographic mapping, many times certain environmental remote sensing monitoring and mapping issues remain incomplete, due to simply neglecting quality measures, and the trailed effect of the quality status.

Similar to other issues, efforts such as time, money, work, and knowledge used for monitoring environmental issues are sensitive to the final quality of the results. Total Quality issues can not be simply neglected as it is the case many times, since the quality means the level of goodness of the data and maps, their reliability and validity, how accurate the data or information is, and is it possible to depend on the information for making decisions concerned with a range of particular facts, and how far this dependency can go.

This paper is intended to represent the issues and results of a research work executed to assess the different quality measures related to environmental coastal monitoring using GIS and Remote Sensing, as much as comparing Lidar and Radar Altimetry versus conventional methods, providing a introductory classification of the major coastal monitored factors, their relation to the environment, and the level of usefulness of the collected and geo_ processed information, considering the elements used for the process in relation to what its meant to be used for.

The level of usefulness of monitoring coastal factors such as, erosion, turbidity issues, ocean color, productivity, salinity, temperature, coral reefs, water quality, oil slick, etc, and the reliability, and dependency of the remotely sensed data, the interpretation issues, also the level of automation of the repeated monitoring process and interpretation issues, along with their accuracy issues are assessed.

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1. ENVIRONMENTAL COASTAL MONITORING & THE QUALITY TOTALITY

We are seeking to provide a solution where coastal environment can be monitored and managed properly using GIS solutions, so as to sustain coastal life and protect it from the misuse which has a tremendous impact on the production and subsequently the economy and life style of the nation.
Total Quality on the other hand means that the solution mentioned above, should be well balanced. Balancing the solution provides a way of making an almost perfect decision, and reducing the miss management of the coastal environment due to the neglect of certain issues comprising the total solution of environmental management or coastal environmental management as it is instanced for this particular case study aiming to protect and sustain the coastal environment while allowing activities to take part in a regulated and supervised manner.

The elements comprising environmental coastal management, analyzed and represented through GIS using data captured, interpreted and classified using remote sensing combined with in-situ field measurements, should be subjected to total quality rules and should comply with standards and regulations.
This should be implemented through built-in procedures and functions within a web application for example, which is used day by day for managing coastal environmental issues and related decisions.
A selected example for expressing the procedure flow is provided below using the effect of mapping sea water surface, sea bottom line and geoid as factors for setting the base map for managing the environment, showing that having a correct up to date base map of the coast at a standard scale, has an effect in the analysis of other mapped/Monitored environmental features such as the distribution and type of coastal activities in relation to the degradation of marine habitats, or as well be further analyzed below the effect of suspend matter movement and distribution to health and growth of coral reefs.

However, if we are to address the analysis of a certain marine habitats in relation to the activities of a coastal area, and want to represent this in a correct measures for the decision makers to decide the variations of managing those activates, total quality rules are to be implemented, tested and perhaps enforced, as much as the result should have a measure of confidence factor and a proper reference plotting or standard scale.
The standard reference scale for a certain mapping issue sets the rules for the minimum amounts of works and data to be collected as much as time for that specific mapping theme.

2. ENFORCING QUALITY RULES AND STANDARDS

In favor of leading the management and planner to make the correct decisions for the coastal environment, total quality rules exempted from the sensitivity of a coastal element in hand to the element of total quality are to be implemented to GIS analyses, interpretations, classification and presenting the result.

2.1.1 Elements of Environmental Coastal Management

Here some elements comprising environmental coastal management issues are to be mentioned as an example for those elements which are to be subjected to total quality rules, and as a result to that decisions get a confidence factor, and presented GIS data get a standard reference scale.

- Marine habitat conservation
- Coral Reefs Conservation
- Sea surface water level and bottom line mapping.
- Maintaining Water quality
- Phytoplankton and oxygen issues
- Waves, tides, wind directions and speed.
- Off shore geoid, marine navigation lines and sea shore line.
- Coastal activities, harbors and structures.
- Fishery and potential areas

Now each of these factors or elements are sensitive to a number of specific issues which have a certain measure on the elements of total quality (mentioned below)

2.1.2 Elements of Total Quality Management

Example of quality elements are:

- Cost / Time and quality
- Validity
- Accuracy and precision
- Flexibility and Permissibility
- Accessibility

2.1.3 Sensitivity Between the Elements

The sensitivity between a coastal environmental element in-hand and the different elements of quality in relation to the theme has to be investigated, for the rules to be further set.
The sensitivity has to result a relationship which will be afterwards translated to a tangible quoted rules that should be implemented on GIS data at the analyses stage, or the results of the analysis has to be validated against some or all of the rules.
For instance, what of quality rules can be sensitive to the GIS data of sea bottom line oceanography.
The bottom line GIS data is sensitive to:

- Accuracy
    - (for a certain mapping purposes certain scales are categorized and the accuracy assessed).

    Example Rule 1: If zoom is grater than x value then send a warning message to the user.

    Example Rule 2: If the standard mapping scale is smaller than 1/x value then prohibit a list of actions or analysis commands, or warn the analyst and reduce the confidence level of the results.

- Validity
    - (this type of GIS data is varying in time, meaning that it can be valid for only a limited period, after which it has to be updated partially or totally).

    Similar rules can be set here.
- Cost
    - (cost should be considered when mapping or updating taking into consideration the availability of older data and its validity as much as how important it is to map specific features and what is the optimum scale suitable for mapping it).

    Similar rules can be set here.

Once these relations are determined they have to translated to practical rules and regulations and then implemented on the GIS data for preserving and enforcing the total Quality rules.

2.1.4 Implementation and Validation of Rules and Standards

This stage follows the design stage of the rules. Once a rule is set it has to be inserted into the application where it becomes life once a certain action or a function of analyses is used

2.1.5 Further explanations

For further clarification and explanation of the process this paragraph will show an example which was selected to show total quality measures on one element from the elements of environmental coastal management.

The element is: "Suspended Matter"

This element is important for the quality of the sea water, which intern affect the Coral health and the potential production areas of fisheries and marine habitat sustainability.
Further, for protecting marine life habitats and the production, we map, monitor and model the suspended mater for determining the concentration, and distribution of the particles in time (dynamically) and in a 3D manner, meaning that information dose not only reflect the situation of the surface but also some deeper layers.

We determine and analyze the sources which are for this particular case:

- Dredging of artificial structures.
- Erosion of the sea shore.
- Deposition areas

The factors that affect the change among others are:

- Currents
- Waves
- Wind speed and direction

The high risk factors are:

- Closeness to coral reefs
- Threatening of habitat (such as analyzing the type of marine habitat in the area and how they react to suspended mater concentrations)
- Erosion areas of the sea shore
- Effected of the production

Management factors are:

- Reducing dredging
- Regulating dredging time
- Creating prohibited zones
- Regulate, limit or prohibit some coastal activates
- Curing or maintenance actions
- Rules and fine.

However, for designing and testing the importance of the elements to the elements of total Quality the upper mentioned procedures are to be followed. So if for example we consider the Validity factor for this particular example of monitoring suspended matter then we check the following factors:

If the GIS map was created to show the areas of concentrations of suspended matters say as an average for one month period.

- What is the level of importance of the data validity for monitoring suspended matter?
- If this data is to be checked for the closeness and effects to coral reefs, then the speed of variation factor in time should be considered.

Vs: the validation value of suspended material is a function of the rapidity or speed of change Cs.

$$Vs = f\,(Cs)$$

Cs: on the other hand is a function of the “model” (meaning many factors are considered within the model such as wind speed and direction, sources of suspended matter, currents, etc)

Now here, we have to consider a factor for validation of suspended material which is of acceptance to the rules of sensitivity set, which is a result of the equation or the model itself.
In other words geographic distribution maps of suspended matter can be considered for coral analysis, if the data is not older than a certain period of time "t" such as one month, and it must be an average data of "x" number of data collection times, and more than that should not be older than one month "t2".
These rules shall be set in the application and the level of satisfying these rules will determine the confidence level of the results of analysis.
Further, exceeding these set of object oriented rules will produce a validation error or warning prior to producing the results of the analysis.

2.2 Considering Bathymetric Lidar & Radar Altimetry

In spite of the advanced technology and GIS information provided by these technologies for mapping coastal variations such as oceanography, waves, currents, and geoid among others, the quality of the resulted information has to be considered so as to decide the most cost effective and valuable method to use for a certain mapping purpose.

Deciding the aim of mapping coastal variations, leads to the useful scale, and thus the accuracy, or it leads to deciding the accuracy of mapping and thus to sat the optimum standard scale.

Having set the scale, accuracy and the elements to be mapped and collected provides a measure of reference for the type of technology to be used and perhaps the amount of in-situ works to be combined with a certain method.
On the other hand, when mapping for setting the base map of the coastal environment we should consider a range of accuracies as this would create the base for mapping different range of features and topics.

The validity period of base information produced by bathymetric Lidar for example, depend on the types of ongoing activities such as dredging, as much as other factor such as currents erosions and the migration of the suspended material.
Again similarly using radar altimetry for geoid determination is subject to that chosen period where the average data is collected and used for analysis, causing an accuracy measure on the produced geoid, after which the process of refinements is decide according to the required an d accepted accuracy of the geoid.

These elements are base elements for mapping, meaning having an accurate and up to date base coastal GIS map provides the foundation of further building the correct environmental GIS.

Thus finally the quality measures of the derived base data should be known and inserted as factors which will be further used by the sensitivity modeling rules, which afterwards will create the basis for presenting the GIS analysis results and the confidence of the derived for conserving and protecting the coastal environment.

3. CONCLUSION

Considering automated built-in web based total quality measures within GIS applications, for GIS environmental coastal analysis is of great importance, and lead to reducing the risk of miss management which may affect conserving coastal zones as much as offshore marine areas.
This is most perfectly done using investigating the elements of environmental coastal zone management against the elements of total quality for setting the sensitivity rules of analysis. These rules are to be translated into equations and conditions, inserted into the applications to enforce or lead the analysis towards conservation and protections. Validating GIS data against the rules and conditions clearly lead to guide the results of analysis to consider quality measures, and make sure to present the data according to standers as much as providing a level of confidence of the results for decision makers, planners and environmentalists.

Implementing such a method for enforcing total quality measures for environmental remote sensing is sophisticated due to enormous variations of the issues to be analyzed. But main headlines and working steps can be set for users to follow and verify according to the GIS theme in hand. Further follow up and investigations are to be performed which are expected to result in a useful sophisticated web based GIS applications.

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BIOGRAPHICAL NOTES

Achieved BSc (DTM experiments and change detection using GIS). and MSc (Environmental Impact Assessment using Remote Sensing and GIS), from Budapest University of Technology & Economics. Started and completed 3 years of PhD studies in the department of Photogrammetry and GIS within the same university.

Assisted the management of mapping the 3rd district of Budapest in GIS, and programmed intermediate GIS software for assessment and analysis using, Delphi and C++ Builder. (other computer languages are Pascal Fortran and Basic)

Took par as a developer GIS engineer in the project for mapping fiber glass cable through Hungary

Engineered and sub designed the photogram metric project 2001 for Dubai. Designed the Photogrammetry of the Dubai Base Map project 2003. Designed the Lidar project for Dubai Municipality. Designed and currently engineering and technically managing an Environmental monitoring project for Dubai.

Former member of IEEE IGRAS and the author of more than ten papers dealing with the Total Quality of GIS and Remote Sensing topographic and environmental data.

Research and area of Interest other than the one mentioned above is Modeling 3D surface data

Currently occupying the post ”GIS Senior Specialist ” at the GIS Center of Dubai Municipality.

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