A Geospatial Web App For The Visualization And Analysis Of Coastal Erosion Using Remote Sensing Satellite Imagery And Geographic information Systems

by

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Abstract

The internet is a valuable tool to communicate and share information on coastal regions. Nonetheless as it is understood, we haven't gotten to the point where these tools take full advantage of current "Web 2.0" technologies. The capacity of these tools that promote remote information sharing and collaboration are at present not fully exploited applied to coastal erosion management, furthermore these tools are in constant development and are rapidly advancing. For data or information to be useful for coastal management, it must be both comprehensive and accessible. The present research for a web geospatial infrastructure for visualization of coastal erosion addresses Two issues: i) simple access to data and ii) access to information in timely fashion; for anyone involved in the management of coastal areas, these issues represent a strong challenge. The research proposes that a third-party online access tool needs to be developed and be of easy access for data visualization and retrieval so that the data and information available can help in decision-making. This online web infrastructure takes into consideration that the available data is at present not easily accessed by anyone that does not have an academic degree nor wide experience in the use of spatial data hence that particular person has difficulty in understanding and consume the information contained in such data. Earth observation (EO) systems are vital for the assessment and mitigation of the negative effects humanity is having on the environment; because EO tools and products can be used to explore and exploit new opportunities in the sustainable management of natural resources. The goal of this research is to promote the design and implementation of an automated web infrastructure using geographic information systems to analyze remotely sensed coastal imagery and with this, pave the way to generating temporal crust deformation models that can be displayed and published through the internet, making all the data and information accessible to the general public.

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Contents

Abstract		ii
Acknowledgements		iii
Contents		iv
I.	Introduction	1
I.I.	Historical Background and state of the art	2
I.II.	Existing projects	3
I.III.	Research questions and Objectives	8
I.IV.	Methodology	8
I.V.	Contributions	10
II.	Theoretical Foundations	11
II.I	Earth Observation systems	11
II.I.I.	Disaster management	13
II.I. II.	Online resources	15
II.II.	Spatial data	17
II.III.	Open Data	18
II.III.I	Data and Information Policy	18
II.III.	Geographic Information Systems	20
II.IV.	Interoperability	21
III.	Specific Theory	22
III.I.	Problems and solutions	23
III.II.	ArcGIS online	26
IV.	Implementation	27
V.	Results and Discussion	31
VI.	Conclusion and future work	33
References		34
Appendix		38

I. Introduction

All around the world, the marine environment is undergoing unprecedented change due to natural and anthropomorphic phenomena, including climate change, and from human's use of the ocean and its coasts. There are numerous projects for the research and study of the aforementioned phenomena, like the development of many coastal Geographic Information Systems (GIS) applications and experimentation with multiple platforms for web mapping and spatial data catalogs.(meopar, 2016) The internet is a paramount tool allowing global communication and sharing of information on coastal regions. Some resources consist of textual web pages that provide overviews of coastal issues, such as NOAA's Office of ocean & Coastal Resource Management's website. Others serve as data repositories where people can find and download coastal geospatial data of interest, such as Ireland's Marine Data Online web site as well as Canada's Coastal and Ocean Information Network Atlantic. In some cases, coastal web resources provide interactive web maps where users can visualize and query features in the map, like with the Oregon Coastal Atlas and the Marine Irish Digital Atlas (Wright, 2011); there are even other resources being developed like The Marine Geospatial Data Infrastructure, and other services that englobe many EO capabilities; for example the ones being developed by the Group on Earth Observation GEOSS. All the mentioned services and resources are just a few of the ones out there that address today's access to data needs. Nonetheless, we haven't gotten to the point where these tools have taken full advantage of current "Web 2.0" technologies for the promotion of information sharing and very important for collaboration. For data or information to become actionable insight for coastal management, or any other natural disaster management application, it must be both comprehensive and accessible. (meopar, 2016) A major challenge for anyone involved in the management of coastal areas is **simple** access to data and information in a timely fashion. With the present research for a web geospatial infrastructure for visualization of coastal erosion this challenge is addressed. This research proposes that a third-party online access tool needs to be developed and be of easy access for data visualization and retrieval so that the data and information are available and can actually help in decision-making. The envisioned infrastructure takes into consideration that the available data is usually not well suited for easy human consumption. Data is not easily accessible and unless users have an academic degree in the use of spatial data it is difficult to access, understand and consume. Thus, when thinking of implementing an information infrastructure, issues of ownership, privacy, open data and data quality are a concern. EO systems are key for the assessment and mitigation of the negative effects humanity is having on the environment, since, for example, EO tools and products can be used to explore and exploit new opportunities in the sustainable management of natural resources. (Gillespie, 2000) This research is an approach to the design and implementation of an automated web infrastructure using geographic information systems to analyze remotely sensed coastal imagery and with this, be able to generate temporal crust deformation models that can be displayed and published through the internet and can be accessible to the general public.

I.I. Historical Background and state of the art

Earth Observation is the gathering of information about biological, chemical and physical systems that are characteristic of the planet Earth; all to monitor and evaluate the environment due to both natural effects and humankind's impact. (Parkinson, 2006) In recent years, the EO discipline has become increasingly sophisticated with the constant development of satellites for remote sensing, as well as the ongoing development of instruments on site technologies. The instruments for EO are either aerial or ground satellites; These include for example: floating buoys to monitor ocean currents, temperature and salinity; earthbound stations that record the air quality and trends in water; radar and sonar to estimate populations of birds and fish; GPS and seismic stations; and more than 60 satellites for the scanning of the earth from outer space. There are many ways to observe the Earth, there is the use numerical measurements with thermometers, altimeters or seismographs; others capture photographs, radar or sonar images; and ones that perform analysis of samples of land or water; even process information from maps, just to name a few. (Remote Sensors, n.d.) These systems follow the trends of biodiversity and wildlife, measuring land use and changes in the territory, for the purpose of monitoring change processes like for example deforestation. Another application is the response and monitoring of natural disasters (fires, floods, earthquakes, tsunamis, etc.), they can also be applied in the management of energy resources, clean water supplies and agriculture; these are important for responding to emergencies for diseases and other health risks; or to predict, adapt and mitigate climate change. The technologies for EO at present are (and have been for over 30 years) collecting an immeasurable amount of data. EO technologies provide tools that can be used by many social groups for the benefit of all areas of human activity. Specifically, and as an example of the social importance of these tools are groups that put them into use like the: "Group on Earth Observations" (GEO), this group is creating a System of Systems, GEOSS; which is a set of information systems and coordinated independent processing of earth observation, that interact and provide access to information to a wide range of users, both in the public and private sectors. GEOSS links all the systems mentioned in this paragraph.

I.II. Existing projects

As has been stated in the introduction, there are many projects being developed for the integration of data analysis and Web technology capacities. We shall briefly describe a few examples of projects similar to the one proposed in this thesis; One very complete project that integrates systems and that takes advantage of Web Services and Semantic Web technologies for enabling users to share resources and collaborate around these is the **Earth, Life and Semantic Web (ELSeWeb)**.

> With the use of EO and climate change data, the ELSeWeb platform means to enable the modeling of the impact of climate change on animal and plant species. The highly innovative new modelling is done through integrating independently successful initiatives, initiatives that model complex factors associated with biotic change. Models will be able to represent health and infectious disease, that depend as much on climate change as they do on species distributions, and on other human/environmental interactions. Provenance generation capabilities of ELSeWeb services will enable modelers to experiment with many potential future scenarios of human/environmental system, while tracking each computational experiment such that analysts of model output will understand the data, model and parameter choices that were made. These unique capabilities will transform scientists' ability to collaboratively investigate the implications of different climate change scenarios for a wide variety of human/environmental systems, particularly as they relate to the nexus of environmental factors in human health and infectious disease. (ELSeWeb, 2017)

This project is a very complete one that integrates WEB 2.0 tools and the accessible data although it is not in the present research's field of interest and has precisely the downfall that it is a project that requires highly skilled **scientist** for use of the platform. It is a project that is being developed and has identified the capabilities that online web tools offer.

Another project is the **National Earth Observation Data Framework Catalogue (NEODF)**. The NEODF system is one that integrates various project including the NEODF-Cat, these projects are being developed and maintained by Natural Resources Canada.

> The Government of Canada's goal is to allow users to discover and access EO products from a suite of satellites and airborne collections, like the National Air Photo Library. **"**The NEODF-Cat enables public and government users to intelligently search and easily access the GoC EO raw and product archives managed by NRCan. The search capability features advanced geospatial Region of interest (ROI) operators, high-quality Quicklook images, and tools to manage queries and archive access. The National Earth Observation Data Framework is a system concept that illustrates a novel approach to improving

access to Earth Observation (EO) data and products. The goals are twofold: to ensure that valuable EO assets are preserved and made available in a timely manner, and to demonstrate the potential of integrating decision-support tools to help users search and select in a way that best meets their needs. (NEODF, 2015)

Tools like this one addresses the need for accessible data but still requires experts to process and analyze those products.

There are projects that are extensions of remote sensing efforts like The Tropical Rainfall Measuring Mission (TRMM), now called the **TRMM explorer**. The TRMM was a joint mission of NASA and the Japanese Aerospace Exploration Agency (JAXA) to measure precipitation in the tropical and subtropical regions of Earth that was active from November 1997 to April 2015, and the TRMM Explorer extended from that. The TRMM explorer is a Web Service that acts as data mediator, "powering different visualizations and outputs capable of feeding downstream applications."(TRMM, 2012) The project's ultimate goal is to empower users, "especially those with limited access to robust data processing facilities, to realize the full potential of Satellite Rainfall Estimates (SRE) and other, ancillary products." (TRMM, 2012) The TRMM Explorer is a web service and android application for the distribution of rainfall estimates and Earth observation data, the project includes a Python-based web service and Android applications capable of providing data in different intuitive formats with the focus on regional and continuous analysis. The outputs include dynamic plots, tables and data files that can ultimately be used to as raw data for other applications and services. The TRMM Explorer can successfully supplement existing web portals distributing SRE and provide a cost-efficient resource to small and medium-sized organizations with specific SRE monitoring needs, namely in developing and transition countries. (Mantas, 2015) This is a very nice example of technology put to use in a very practical sense and it achieves its goal the only downfall is the not user-friendly design. It is well known that where there is technical knowledge there is a weakness in design and making things user friendly as well as visually pleasing. The two are almost excluding and this is what the proposed platform for coastal erosion analysis means to be, technically useful as well as user friendly with a well-designed interface.

Specifically and as an example of the social importance for the use of technologies for EO, the Group on Earth Observation System of Systems (GEOSS) is a system of systems composed by two systems, an already existing one and future EO systems. The project coming from GEOSS, is a system of systems that enables the combination of information from temporary unlinked sources to address the needs for EO products and services across multiple Societal Benefit Areas (Biodiversity and

Ecosystem Sustainability, Disaster Resilience, Energy and Mineral Resources Management, Food Security and Sustainable Agriculture, Infrastructure & Transportation Management, Public Health Surveillance, Sustainable Urban Development, Water Resources Management). Making those resources available for better informed decision-making. Group On Earth Observations (GEO) was established in 2005 and is a voluntary partnership of governments and organizations that envision "a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations and information."(About GEOSS, n.d.) GEO member governments include 101 nations and the European Commission, and 95 Participating Organizations comprised of international bodies with a mandate in Earth observations. (About GEOSS, n.d.) Projects like this are set in motion to reinforce existing EO system capabilities, they facilitate the exchange of data and environmental information collected from a variety of EO systems provided by worldwide organizations that form part of GEO. GEOSS makes sure the data is accessible, of quality and from identifiable sources. Such that the project increases comprehension of earth processes and improves the predictive capacity from which precise decisions are made. GEO's efforts and projects set the example for data, information and knowledge provision to a wide variety of users. (About us, n.d.)

Efforts to develop projects like the one proposed in this research exist and there are already existing projects that address the needs identified. The ESA funds an online service that promotes a clearer understanding of coastlines, the service would provide access to over 20 years of EO data, Near Real Time (NRT) EO data, non-space data and multi-sensor processing tools. It is a is a project called the Coastal Thematic Exploitation Platform (C-TEP) and it is meant to provide advanced tools and data management resources to easily process and manage large volumes of coastal data; making it easily accessible to users. This vision will support the advancement of scientific insight into complex marine processes and coastal interactions. Doing so specifically by providing the ability to merge in-situ measurements with EO data, rapidly extracting both temporal and spatial information, and conducting statistical analysis. In addition, C-TEP shall provide the scientific community, government agencies and the general public a platform for collaboration on analysis of coastal areas. (Projects, n.d.)

All the mentioned projects in this section are evidence that, as a worldwide community, we are understanding the importance of generating tools for Earth's conservation. Therein exist a complex issue in regards to ease of access, an ideal situation would be for any of these projects to be at any user's reach and not limited to the world's population fortunate enough to have the academic degrees required to take advantage of these tools generated by all these tremendously useful projects. Existing Web services for the distribution of data are rarely focused on specific regional needs and to reach the full potential of data access needs to be timely. In order to accommodate the increasing demand for spatial data and make front to the present limitations of available web portals, it is envisioned that a project must be created for the free access, processing and analysis of existing data.

The cited projects integrate systems favoring free access and use of data, nonetheless, to be able to put this data into action a certain degree of know how is required. Many organizations already know this and have made user-friendly e-learning platforms accessible to the public. E-learning systems are very popular means to support the training needed in working with EO products and services. Online learning systems are used mainly by_educational institutions and in Ostrowski ,2015 various popular e-learning platforms were analyzed in Poland and they were found to be very unfriendly for users. The research done by Ostrowski ,2015 points out the importance of the term Design Thinking (DT), which puts a strong emphasis on the end user during the whole design process, so that the final product is easier to use and better adapted to user's needs. Hence the importance that is placed in this research on the design part of user interfaces. In Ostrowski ,2015 found solutions for the design of real systems that are truly user friendly and allow those systems to be exploited in full. It was done by a team of interdisciplinary designers that applied a 5-stage design process. Stages that were identified by the project itself and started with the first stage: Empathizing, in this stage an exhaustive analysis of the problem and its context is carried out. The second stage is that of Definition, by which the information from the previous stage is synthesized and the needs and knowledge of the users are identified. Context and identification of user's knowledge is crucial when designing a tool meant for human manipulation. Next two steps are Ideating and Creation, in the first solutions are generated and in the latter prototypes are proposed and solutions are tested. In the final Design stage, the team used many additional interactive methods which resulted in a prototype for an e-learning platform validated by the final users. This validation confirmed that DT allows the designed product to adapt efficiently to user's needs. (Ostrowski ,2015)

Leaving the discourse for a need of a precise platform design to one side, the envisioned data sharing has been contemplated by various existing projects as well, those are directed specifically for capacity building and resource access. Efforts are being made not only to make data and analysis capabilities accessible online but also for building the skills needed to obtain and use EO products by interested parties. For example, EOPOWER is a capacity building effort, whose goal is to create conditions for sustainable economic development through the increased use of Earth observation products and services for environmental applications. (EOPOWER, 2014) The same scenario is present in the Secure World Foundation a private operating foundation that promotes cooperative solutions for space sustainability and the peaceful uses of outer space. The Foundation acts as a research body, convener and facilitator to promote key space security and other space related topics; and to examine their influence on governance and international development. (Who we are, n.d.) Another example is Eduspace, a project from the European Space Agency (ESA) that is geared towards educating secondary school students and teachers by providing an online learning and teaching tool. It is meant to be an entry point for space image data, in particular, to allow widespread visibility of Earth observation applications for education and training purposes. (Eduspace, n.d.)

To every project and research there are disadvantages and those herein proposed project face challenges of ownership policies for the original spatial data, not all existing data is open data. In recent years we have seen a push for open data and many projects wherein open data is available on database websites especially governmental websites make datasets readily available. (examples of open data websites by province/state) As we were stating above, design of a proper user interface is missing. It is the link between data retrieval, data acquisition and data analysis. Many processes for analysis and even data retrieval can be automated but there is a lack of web infrastructure where all integrated steps can be performed. Updated as well as historical spatial data is crucial for stakeholders in decision making, when taking on the challenges represented by the changes Earth undergoes. It is clear to all skilled in spatial data, the incommensurable potential that data holds and thus we are seeing many projects being developed that harness this potential. The pool of opportunities is just as immense, consequently, most projects tend to be complicated and theory driven, which again makes them not suited for the average layman's consumption. The projects need to go hand in hand with capacity building efforts as well, to allow users of any background the ability to consume and even produce products and services resulting from spatial data. It is naive to propose a platform suitable for both complex data acquisition and analysis and for all the infrastructure to work simply enough that the average public can consume it. Which is why such an infrastructure is proposed but its implementation has gone beyond the scope of a master's degree level research. A lot of work still needs to be carried out for such an ambitious project. This is an area of opportunity which can be exploited for future research and teams.

I.III. Research questions and Objectives

How would a person not trained in the field of EO and spatial data analysis when confronted with a need for data resolve their needs? Probably by hiring academics who have the skills, knowledge and experience in that specific field. Because the decision makers and stakeholders that set policies and social programs into motion, are government officials and local populace who have a high need for spatial data and analysis when confronted with an environmental related challenge. The reality is that correct allocation of human resources can be costly and time consuming, and when it comes to earth sciences time is a pressing factor. This research started out meaning to set up a web access portal for spatial data acquisition, visualization and analysis. Being the scope too broad it was evident that a specific purpose had to be attached. After analysis of potential environmental hazards, it was evident from Mexican news sources that there was an opportunity and need for such a research in the coastal erosion arena. Then it was specified that the first goals were to research and compile temporal satellite imagery from Mexico's coastal areas of interest. From the compiled imagery, it is possible to appreciate the erosion in Mexico's Cancun coast and the challenges it presents in terms of biodiversity and vulnerability to the region; we are also able to explore the resilience of key coastal ecosystems and at-risk populations. With the compiled spatial data going back 30 years we are able to analyze the graphic representation of the observed deformations through the production of graphic/visual models. With a multidisciplinary approach it is possible to develop an automated spatial data infrastructure for online display of the analysis of spatial data. The goal was to publish modelling results online by integrating geospatial web applications and services through a web portal and make it accessible to the general public. Publishing these results online would mean integrating geospatial web applications and services through a web portal. But the most important goal is really the dissemination of web mapping of the generated geographic content and the promotion, access and usability of online geospatial resources.

I.IV. Methodology

The present research objectives can be summarized in four higher goals. To compile temporal satellite imagery, analyze it by producing graphic representations of change in the coasts over time. And the two most important ones that culminate the entire efforts of the research: To display online the observed deformations from the analysis and finally publish these modelling results by integrating geospatial web applications and services. In order to reach these goals first there is a need to acquire the spatial data to work with. For this first step an extensive research of online tools was carried out, it was important to be familiar with all the services available and choose the one that would be best suited for the proposed platform. Once the spatial data was compiled it was analyzed and processed through spatial data analysis software in order to identify the Areas of Interest (AOI) and perform change detection. With these two processes images were produced accentuating the changes in the specific coastal area. Those images were then analyzed visually, and an erosion model was produced. The satellite images and the model were then made accessible online through geospatial services to be then published on a specifically designed web portal.

Data Acquisition

1- About 400 Landsat images from 1984 to 2017, were compiled from the USGS Earth Explorer. Landsat images were used because the acquisition of these from space dates to 1972, this means that it is data that has been collected for the longest, and it is the most comprehensive set of satellite images of Earth's features. Landsat images are used in many research areas and help us make sense of the world when applied and analyzed for example in geography, cartography, history and even sociology.

Data Analysis

2-Use of R programming to run them through a routine where elevation is accentuated, produce graphical models of change detection in the coastal area of interest (AOI). See Appendix for details.

3- Use of animation software to group the processed images and create a visual representation of the erosion process in the AOI. See Appendix for details. The objective of accessibility can be resolved through current GIS tools. There are powerful analysis capacities in GIS tools, but these were not specifically applied because under the ease of access and dissemination, it is visual cues that are most easily consumed. Thus, these are the reasons for an animation of enhanced satellite images which are seen as the best approach to evoke understanding at a glance. The present research is not looking to use or apply complex processes to achieve evident results because complex processes require complex skills and knowledge. The premise is that access to information and data are to be made as consumable as possible.

Data Dissemination

4-Develop backend of a web accessible procedure to download satellite images and make them visible online. Tried python scripting on html framework, didn't work. Many methods to go about the proposed objective. Through extensive research and trial and error of processes across a variety of tools, the research took a turn to discover the Environmental Systems Research Institute (ESRI) online capacities for spatial image display and analysis. ESRI's tools are under ArcGIS online. It does take quite a bit of capacity building and study to achieve the development of such a web infrastructure. This was achieved through ArcGIS online webapp services because they already have done the legwork in pathing the way to data sharing and democratization, in other words making everything open data. At present is the best option for tools in the dissemination of web mapping of geographic content. Albeit not the best tool for specific spatial analysis but it is the best GIS service for the access and usability of online geospatial resources.

6. The final step for a proper dissemination of resources is to design a web visual architecture. This is creating on a visual level the structural design of the pertinent environment for sharing EO information. It involves an intricate understanding of the tools and analysis capabilities so that the model for information analysis of a complex Geographic information systems. This stage is crucial for the success of the proposed EO web infrastructure because it is the way that content is organized and presented to the user. If this stage is not done correctly with the appropriate care of User Experience Design (UX Design) the whole project could render useless. It is not rare in the history of technology that powerful tools are developed, and their use doesn't become widespread due to poor UX design causing difficulties for users. Having a great visual architecture will ensure that the maximum number of users will successfully operate the tools offered.

I.V. Contributions

The approach taken in this research is that of a visual and design discourse due to the presenter's background and experience. Aside from that a visual design approach is the forefront towards new real-time collaboration methods that transcend boundaries; Whether they be of knowledge, skills or geographical boundaries, the research adheres to the online available tools, specifically that of ArcGIS online, due to their power and ongoing technological advancement and allows these services to work in different learning environments. In using the tools readily available by ESRI, this framework is in its first stage of development and can be applied to other various services and embedded in online environments dedicated to spatial data dissemination and consumption. All of which generates skills and knowledge transfer between stakeholders, decision makers and local population resulting in better administration of resources.

II. Theoretical Foundations

When approaching the tasks explained in the previous chapter, there is a need to understand fundamental concepts that are inherent to the study and use of spatial data. This chapter will enlist and explain those concepts, beginning with the general use of Earth Observation, Spatial Data, Open Data, GIS, web mapping, Spatial Data analysis, and many other terms that these topics encompass.

II.I Earth Observation systems

Earth observation is the science involved in learning about our planet's physical, chemical and biological state through the collecting of data made possible by remote sensing systems high above the Earth. Ever since we as a species became capable of monitoring our planet through remote sensing technologies, we came into the Space Age and it made us aware of the wonders and fragility of our home. Ever since these technologies that came into being half a century ago, we have been gathering data and archiving data continuously. The data has an immense potential and value through a diverse kaleidoscope of disciplines from earth sciences, study of ecosystems, disaster management, Energy and Mineral Resources Management, Agriculture, Transportation Management, Public Health, Sustainable Urban Development, and Water Resources Management. EO systems are a powerful scientific tool for the better understanding and improved management of the Earth and its environment. (Observing the Earth, n.d.)

To reinforce the monitoring of the state of the earth, there are services that facilitate the exchange of environmental data and information collected from the wide variety of observing systems. A large project is the outstanding example set forth by GEOSS, which was explained at the beginning of this body of work. In a broad sense, these services are dedicated to ensuring that **EO** data are accessible, of quality and their origin is identified. GEOSS increases our understanding of the processes of the earth and improves the predictive capacity that underpin the process of decision-making. GEOSS is evidence that, as a worldwide community, we are grasping the importance of generating efforts for the planet's well-being, however it is perceived that there is a difficulty regarding these EO services and products; they are only useful for those few who understand the sciences involved to put them into action. It would be ideal to have a scope that is not limited to only the world population with the academic degrees needed to take advantage of the tools generated by groups such as GEO. (GEOSS reference) Earth Observation services and tools is today more important than ever due to the dramatic impact that modern civilizations have on the global environment. EO systems are critical for the assessment and mitigation of the negative effects the human race is having on the environment, since, for example, EO tools and products can and are being used to explore and exploit new opportunities in the sustainable management of natural resources.

An important part of making EO data accessible to the layman is to have a database of all the space data acquisition resources available online. For this purpose, an exhaustive research was carried out to define the services of Earth Observation and Remote Sensing that exist, in order to acquire a specific vision of where and how you can get access to satellite images. There were a variety of technologies, tools and services available, open data is also accessible via the internet that provide both remote sensing data, such as Earth Observation and Geographic Information Services. There is wealth of tools available online that offer spatial data specifically satellite images, vector and even raw data. Each of these services and websites were defined, validated and tested, putting into practice the download protocols of each page. A database with more than 80 records of these technologies was made through SQL language, see Table 1 in the appendix.

To put it in a summarized concept, this research is making a point towards the democratization of data. After the collection of spatial data acquisition from online services it is clear that this democratization is not being addressed there, in the existing tools. The present state of data acquisition accessible tools and processes make the case for the need of democratizing online access to information resources. In fact, in Pratap this growing need for web-based geographic information systems that are easy and fast for the dissemination, sharing, displaying and processing of spatial information is also identified (Pratap, 2013). There is a tremendous growth in the use of web and open-source geospatial resources, and it has inspired the development of web-based projects that address multidisciplinary issues in this arena. The present research is centered in the integration of open-source geospatial tools and web technology to visualize and interact with spatial data using web browsers. We are talking about here of the implementation of a web geospatial infrastructure for visualization and analysis of coastal erosion through crust deformation graphic modelling using remote sensing satellite imagery. To express it another way the goal is to analyze remotely sensed coastal imagery and with this, generate temporal crust deformation models that can be displayed and published through an automated web infrastructure using geographic information systems. What was first envisioned was a web-based mapping service that provides a user-friendly interface with clear instructions in order to encourage interest in maps on the web without any prior technical experience in spatial data acquisition and use. Aside from providing a service for easy access and use of spatial data, there are specific and practical goals to the present research. These goals are to undergo analysis of compiled temporal satellite imagery of Mexico's coastal areas of Cancun, Quintana Roo. With the analyses it would be possible to form a theory on the cause of the area's erosional processes, be it by tectonic subsidence, deforestation, the fragmentation of coastal ecosystems, land use changes or sediment deficits because of infrastructure built along the coast. It is also important to simulate historical erosion in Mexico's Cancun coast, to theorize on the challenges it presents to the region in terms of biodiversity, vulnerability of the region; and explore the resilience of key coastal ecosystems and at-risk populations. All the practical analysis would provide the resources to generate an automated system for crustal movement modelling and deduce the rate of crustal movements on the basis of the differences in temporal satellite imagery.

II.I.I. Disaster management

Earth Observation and remote sensing products give people crucial information on ocean, ice, land environments, and the atmosphere. This information has the potential to protect the environment, manage resources, and ensure the safety and security of populations, all done by monitoring our planet, as has been the case in many of the efforts in state-of-the-art projects. Satellite imagery and scientific expertise is also at present being used to support global efforts and sustainable development. (Earth Observation Satellites (n.d.)) We are taking for granted that there are many projects that are taking advantage of this data's immense potential, all under a question of how to put together EO systems and international environmental regimes to really take advantage of both data potential and the population's potential for collaboration through the internet. Because there is a real need to enhance the role of satellite observations in solving a variety of large-scale environmental problems. (Mitchell, 2013) Specifically for disaster management they have great capacity for forecasting in this arena, applied EO tools can have an impact in preparing for what's coming. With their growing power to address environmental issues, needs arise for enhanced coordination among major stakeholders. (Mitchell, 2013) As is stated in Mitchell:

"particularly important developments in this regard include the growing capacity of satellite observations to (i) provide crucial information on progress in meeting the objectives of issue-specific governance systems (e.g., rates of sea level rise or ocean acidification in the case of the climate change regime or rates of land degradation in the case of the regime to combat desertification); (ii) assist efforts to prevent or mitigate environmental disasters, through measures such as ice warning systems for maritime shipping, flash-flood alerts, or growth mapping of major crops such as rice, maize and soybeans; and (iii) verify compliance with regulatory arrangements on the part of individual regime members or actors subject to the rules of various regimes." (Mitchell, 2013)

These are just some examples of the importance and power of OE systems; this power is possible thanks to their objective nature and extensive coverage across both space and time. Not all tools and services have this type of democratizing capacity in gathering data from sites across the world, including places too remote or otherwise inaccessible for ground-based data acquisition.(Observing the Earth, n.d.) And because Earth observation satellites are longeval, they can highlight environmental changes occurring gradually. Looking back through archived satellite data shows us the steady changes and processes our planet goes through, a long-term monitoring that enables a reliable assessment of the global impact of human activity on Earth. (Observing the Earth, n.d.) With decades of analyzable data, the inhabitants of Earth are better equipped to comprehend the complexities of it. One of the world's most important Agency sees the growing need for information from satellites that is at an ever-increasing rate. ESA is a world-leader in Earth observation and remains dedicated to developing cutting-edge spaceborne technology to further understand the planet, improve daily lives, support effective policy-making for a more sustainable future, and benefit businesses and the economy. They use cutting-edge space technologies to learn more about the interactions between the atmosphere, biosphere, hydrosphere, cryosphere and Earth's interior, essential how Earth works as a system. Importantly, they address scientific questions that help predict the effects of climate change and address scientific questions that have a direct bearing on societal issues that humankind is likely face in the coming decades. While ESA's missions are fulfilling their original brief, they are all surpassing expectations with their data finding a multitude of uses in real-world applications to improve everyday life. Observing the Earth, n.d.

There are many different types of disasters and increasingly Earth Observation is used for other types of disasters, such as industrial calamities, explosions, terrorist attacks, and others. But this work refers to the natural disasters that are for example: volcanic eruptions, earthquakes, landslides, floods, tsunamis, droughts or wildfires. Under this category, coastal erosion is a very important issue that local governments should prepare for the effects and earth observation can play a supporting role to help authorities improve resilience of the population. Another trend is the increase in use of open-source software. This trend is universal and not exclusive to disaster management, but disaster management is an area where the benefits of the use of open-source software can be seen most clearly. Access to affordable software and data helps local governments to better prepare for disasters. Historically, disaster management has been the responsibility of organizations that were more focused on emergency response than on prevention or resilience. It is a big step that the approach towards disaster management is now more inclusive. Some countries, after centuries of development and cooperation, have now reached a stage where adequate protection against certain disasters has been achieved.(Cannata, 2016)

II.I.II. Online resources

Collaboration of populations along with integration of emerging online GIS tools, is what empowers communities. Specifically, online communities are mapping the world as we speak and are publishing the resources on the internet, this is possible through participatory individuals that are increasingly pushing for openness and accessibility. Which in turn enables local decision-making applications with respect to early warning for disasters. An example of emerging technologies and important tools for this research are online mapping resources like web repositories that provide access to datasets, web maps are also very important and useful for collaborative online communities, as are Web atlases. In earth observation for disaster management we can distinguish services for risk assessment and simulation models, forecasting and early warning, monitoring, damage assessment, and prevention and planning; each applicable to a specific type of disaster. All categories are interrelated and related to decision-making. In April of 2013 the workshop "Risk and environment management: the added value of satellite applications", was held in Brussels hosted by the Committee of the Regions, and organized by Eurisy in cooperation with the GEONetCab consortium; and it was there that was stated that for decision makers, early warning is of fundamental importance. That same workshop also expressed concerns about the persisting gap between technological capabilities and the availability of operational services for the end-users. (Eurisy , 2013) The latter is precisely the point of the present body of work. Communication and comprehension between specialists and decision makers is of the utmost importance. At that same workshop it was stated that "decision-makers and professionals need tangible services that are easy to assess and that are compatible with their existing systems and work processes". (Cannata, 2016) The challenge is to provide these services, in cooperation with the end-users, it would seem intuitive but to find a common ground where technological capabilities and the end-users meet is very difficult to achieve. There are few tools available that provide operational services for non-academic end-users. There always has to be a certain degree of capacity building for the tools to be exploited to the fullest.

Repositories and Datasets

Going forward, web repositories and datasets are compilations of spatial data, or any data for that matter, that is allocated on a web server and can be accessed online. The repositories for spatial data can be and are mostly free access and are where users can find datasets, which are collections of spatial data that is files that are related under a given uniform parameter (usually location) throughout the data set. When doing an internet search for spatial data repositories and data sets there are thousands of resources out there and the challenge doesn't lie in access to them, the challenge is finding the specific data that is useful for a specific project or research. As an example of an extensive repository is the home of ESA Earth Online data: https://earth.esa.int/web/guest/data-access, where it is possible to browse data products. But there are many websites and online resources that have access to data products. To list a few:

http://www.nrcan.gc.ca - Natural Resources Canada that provides access to satellite imagery and related products to other government users and the general public.

For specific sources of data on remote sensing of coastal and marine environments there exists a directory for Remote Sensing Internet Resources: http://www.ncl.ac.uk/tcmweb/msc_tcm/rs.htm

The Common Metadata Repository is NASA's Earth Observing System Data and Information System (EOSDIS) which provides full and open access to more than 17.5 petabytes of Earth observation data: https://earthdata.nasa.gov/the-common-metadata-repository. The EOSDIS provides end-to-end capabilities composed of systems for data acquisition going forth to infrastructure for data distribution. Their website gives a very useful diagram to understand its structure.

Earth Observation Data is accessed for example in: https://earthdata.nasa.gov/earth-observation-data

Access to datasets can be found on: https://globalchange.nasa.gov/

This same website has access to tools as well, at: https://earthdata.nasa.gov/earth-observation-data/tools of which the Earth Explorer is part. Another tool is the Earth data Search which is an application that allows you to search, discover, visualize, refine, and access NASA Earth Observation data. If you are new to this application, please follow the brief tour to get an overview of the features that will help you achieve your goals. https://search.earthdata.nasa.gov/search

ESA earth observation mission data can be found on: https://earth.esa.int/web/guest/data-access/how-to-access-eo-data/earth-observation-data-distributed-by-esa

Web atlas

A Web atlas is basically they are atlases that use the power of the WEB. They "provide a system for organizing, managing, and visualizing libraries of geospatial data. This framework allows producers to easily create and manage libraries of electronic map products through a graphical user interface. The resulting web atlas provides end users with an easy-to-use interface for browsing and visualizing geospatial data. Like the traditional atlas of paper maps, its function is to present a large amount of spatial information in an organized fashion. However, the web atlas extends the conventional atlas concept by providing a variety of methods for static and dynamic visualization of spatial information." (Influences, 2010) A coastal web atlas is defined as "a collection of digital maps and datasets with supplementary tables, illustrations, and information that systematically illustrate the coast, oftentimes with cartographic and decision-support tools, and all of which are accessible via the Internet" (O'Dea, 2007)

Web Maps

An example of a web map is "Worldview" This application allows for interactively browsing, saving and sharing global satellite imagery within hours of it being acquired. (Welcome to Worldview, n.d.) Web maps visually display geographic information through GIS on the World Wide Web. They have interactive capabilities and are used to *consume* maps. These web maps usually contain navigation tools to pan and zoom and may be composed of layered maps with different sets of data. Web maps may be used for specific purposes and as such can have different levels of complexity and analytical power. They may be used only for viewing data or collecting information, editing features, or making comparisons. Many maps are being developed by many users across the globe and many of these capabilities are possible thanks to ESRI/ArcGIS web map applications. Of the three tools, web maps are the tool that allows users to interact and get results from data.

II.II. Spatial data

Regarding EO, spatial data is acquired through spaceborne remote sensing, this is spacecraft mounted sensors that are orbiting the earth. (Roddy, 2001) Since 1972 there have been 8 LANDSAT missions launched for the acquisition of spatial data, these missions have been managed by NASA and the U.S. Geological Survey. At present only LANDSAT 7 and LANDSAT 8 satellites are still active. Nonetheless, the amount of spatial data acquired by these satellites is immeasurable and in the last three sections a limited amount of resources were mentioned and there actually is a world of spatial data available that can take up someone's lifetime if they were to review and validate all of the available resources. The huge volumes of high-resolution images exceed the capacity of the users to access and analyze it. If we only look at the sheer quantity of data, we realize that it also exceeds the existing methods for extraction and analysis calling methods to be updated, renovated and improved. (Mihai, 2006)

II.III. Open Data

Open data is an international trend that a growing number of stakeholders widely promotes, emphasizes and implements and in doing so procuring benefits of their applications.(Goodchild, 2007) Although it is a trend that is widespread, it is a complex task to achieve due to its regulatory framework. The difficulties are accentuated because of the multiple actors that are involved and their interests when generating and using such data. The nature of EO data and their usefulness are the major factors that cause dispute for this information, leading to restrictions on sharing and use. All of which causes varying legal conditions and restrictions on access and use of data. GEOSS is the most ambitious initiative to set up a platform to provide gateway and access to widest possible amount of EO data on the international level. It is designed to become a global network connecting data, information and other geographically referenced content from multiple providers. With their system of systems, it aims at offering decision-support tools by linking together national and international EO satellites and systems. It is set up to promote common technical standards to achieve interoperability and coherence of data generated from different sources. GEOSS is the perfect example of the spirit of Open Data with their primary goal being to enable "open data exchange across different legal traditions and jurisdictions and reducing institutional, legal, and cultural impediments to data sharing." (GEO Report, 2010)

II.III.I Data and Information Policy

Data policy are the terms and conditions of supply and use of data. They are usually set separately by the different entities and there is no unified mechanism for data authentication and validation. The data policies concerned are the framework addressing the access and pricing for public benefit, commercial distribution and intellectual property rights. Considering the current EO trend, issues are always being raised regarding accessibility of data in terms of different uses. It becomes increasingly complex when considering the rights of all parties concerned over the data and derived products. Also, we cannot overlook the reliability and quality of data and the liability of the supplier and its use. For example, incorrect data may generate problems to the users as well as to third parties that rely on the data. Or another instance is when use is given to the data in a manner that is detrimental to the interest of a supplier. In addition, when talking about data available on the internet, users can easily infringe the rights of the data suppliers. Consequently, the role of a legal framework is quite critical in order to regulate the supply and use of spatial data. (Harris, 2002)

The issue of managing data derived from EO satellites, in terms of access, pricing, data rights and the aforementioned aspects, is referred to as EO data policy. It covers a range of issues including international and national laws and regulations; intellectual property rights; security; socioeconomic benefits of free and open data; public-private partnership; and pricing policy. Data policy is a combination of various concerns and interests of the operators and users. Policies globally follow the rules of the UN Remote Sensing Principles, while fostering commercialization through licensing or contractual agreements. Protection of data rights under applicable legal terms include copyright, database protection, confidentiality clauses, or non-redistribution clauses, and extra-legal means such as encryption or secrecy. Protection of data implies recovery of cost through its sales; open use of data suggests widespread use of public information. The policies and practices of respective states are diversified, mainly due to the different attitudes toward the nature of the activity and, in particular, commercialization. (Ito, 2011)

Earth observations (EO) represent a growing and valuable resource for many scientific, research and practical applications carried out by users around the world. Access to EO data for some applications or activities, like climate change research or emergency response activities, becomes indispensable for their success. However, often EO data or products made of them are (or are claimed to be) subject to intellectual property law protection and are licensed under specific conditions regarding access and use. Restrictive conditions on data use can be prohibitive for further work with the data. Global Earth Observation System of Systems (GEOSS) is an initiative led by the Group on Earth Observations (GEO) with the aim to provide coordinated, comprehensive, and sustained EO and information for making informed decisions in various areas beneficial to societies, their functioning and development. It seeks to share data with users world-wide with the fewest possible restrictions on their use by implementing GEOSS Data Sharing Principles adopted by GEO. (Earth Science Reference Handbook, n.d.)

II.III. Geographic Information Systems

Many Geographic Information Systems (**GIS**) today are opening up possibilities to do exactly what is described in the previous paragraph and much more. GIS are valuable planning tools that assist in the development and administration of scientific programs based on geographic needs; companies, communities and individuals are realizing that they must have geographical information to understand their world. (Boyles, 2002). As such, mapping is a requisite for safety against any natural disaster like erosion related misfortunes. The data used in the analysis for the present research is represented by satellite images and complex environmental modelling, which represent large amounts of data or requiring complex processing procedures. As a consequence, the computational power needed for dealing with such resources requires advanced technical knowledge. (Reich, 2012) Thus when wanting to provide access and empowering populations who could benefit from EO technologies a specialized tool is crucial, a tool that allows operations like the proposed analysis to be performed through a simple, yet powerful interface. The diagram below represents the flow of the data from the web infrastructure which allows spatial data to be stored and displayed, which is the visualization step and then the user is able to analyze and manipulate the data using the GIS capabilities through online apps; until finally the user has the liberty to create their own data, see diagram 1.

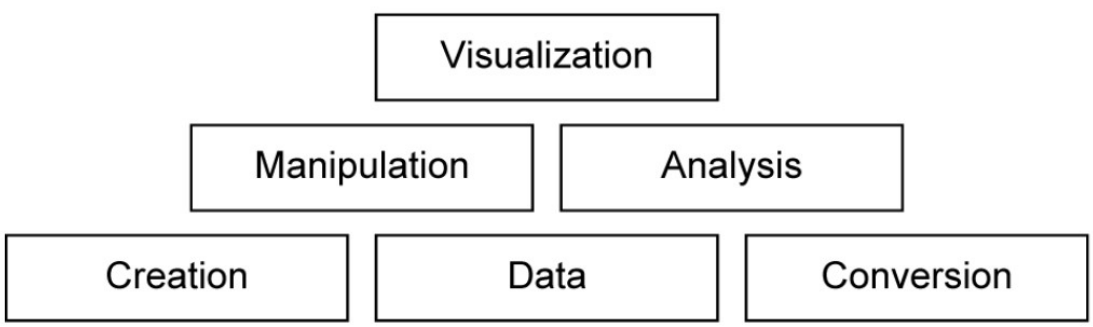

diagram 1

(Coastal Informatics: Web Atlas Design and Implementation: Web Atlas Design- edited by Wright, Dawn)

Geographic information systems (GIS) are systems for input, storage, manipulation, summarizing, editing, querying and visualizing geographic information. Geographic information is the collection of information about places and events that occur on the Earth's surface. Geographic information science (GIScience) is the study of organizations and tools associated with the process of collecting and disseminating geographic information. GIScience research includes topics that relate to cartography, remote sensing, photogrammetry, web mapping and spatial data organization. Digital data management of spatial information is also associated with GIScience. As we have seen throughout this book, there are a wide range of ways in which GIScience can help solve real-world problems. In this section, a range of tools associated with the collection and distribution of spatial data. (Dodge, 2008) Geographical Information System (GIS) and geospatial library services represent major opportunities for data curation and services to universities, communities and society. As an emerging issue, geospatial literacy can be seen as a data science of the global citizen. This framework may aid the data dissemination and advance geospatial literacy by making aspects of its use within the reach of a mobile devices and by embedding it into surroundings such as university learning environments. (Branch, 2013)

II.IV. Interoperability

Over the past four decades many hundreds of formats have been devised and implemented for spatial data. Some are open, while others are proprietary. The development of an effective spatial data infrastructure requires extensive efforts to achieve interoperability, in other words the ability of systems to exchange and use data without major effort. The standards that make this possible have been devised and widely disseminated by several organizations, including national mapping agencies, international standards bodies, and the Open Geospatial Consortium (OGC): http://www.opengeospatial.org. (Smith, 2015)

There are numerous software and analysis tools that can assist the use of geographically referenced data in population research. Spatialanalysisonline.com has a thorough, regularly updated list of them here, as well as a number of other resources specifically designed to assist in GIS analysis. Another compilation of spatial analysis tools can be found here: http://gispopsci.org/software/. Given the vast range of spatial analysis techniques that have been developed over the past half century many topics in the arena of spatial analysis, GIS and software tools can only be covered to a limited depth. Making it a rapidly changing field and increasingly GIS packages are including analytical tools as standard built-in facilities or as optional tool sets or add-ons. In many instances these tools are provided by the original software supplier, but in other cases they have been developed and are provided by third parties. Many products offer software development kits (SDKs), programming languages and language support, scripting capabilities and/or special interfaces for developing analytical tools. In addition, a wide variety of web-based or web-deployed tools are available, enabling datasets to be analyzed and mapped, including dynamic interaction and drill-down capabilities, without the need for local GIS software installation. These tools include the widespread use of Java applets, Flash-based mapping, AJAX and Web 2.0 applications, and interactive Virtual Globe explorers. This online workflow is the direction in which online GIS and their service providers are taking. (Smith, 2015)

III. Specific Theory

After centuries of ground surveying and paper maps, in just a few decades, geoscientific technologies such as remote sensing, global navigation satellite systems (GNSS), and GIS have completely revolutionized how we explore the geography of places, cultures, environments and processes. Geospatial technology mediated mapping and spatial analysis has become critical in an incredibly wide range of professional and everyday decision making. Be it the prediction of climate change or forest fires, planning a city or modeling its growth, monitoring diffusion of information or disease vectors, tracking terrorists or salmon migration, mapping landforms or tornadoes — the application of geospatial technologies and spatial analytical methods continues to expand at a phenomenal pace. Putting a focus on EO and geographic information science is the ideal arena for the present objectives which use to a large extent the computational aspects of mapping and geographic analysis. (Abhisek, 2016)

Developments in sensor and web technology have led to a vast increase in acquisition of EO data and quality geo-spatial information. To process this available ***big*** geo-data and have it support decision making, an advanced methodology is needed for interpretation and integration. A methodology with the capacity to deal with such data puts a strain on users, who require high speed image analysis to continuously monitor global and local geo-spatial processes. Considering the increasing heterogeneity of big geo-data as well as the need for automated analysis of those data, it is pertinent to propose a unified platform with the specific requirements to adapt to the ever-changing spatial data landscape. (Services, n.d.) This research focuses on automated processes for spatial data access and analysis in an aesthetic and user-friendly way. The research is conducted in three overlapping fields focusing on graphic design, visual modelling and EO semantics.

Earth Observation satellites are the only source that provides a continuous and consistent set of information about the Earth's land and oceans. These satellites produce massive amounts of data, but only a fraction of that data is effectively used for scientific research and operational applications. Furthermore, current methodologies for putting this information to use, are far behind the population's capacity to build sophisticated and integrated user-friendly services. Hence, from any perspective it is apparent that there is a central scientific dilemma: How to use science methods and techniques to substantially improve the access and dissemination of available spatial information from Earth Observation data sets in an open and user-friendly way. This is a challenge far too ambitious and this project has only conceived a possible solution, to build and implement a WEB 2.0 capacity Geo infrastructure to offer the available knowledge in the form of spatial data on a platform for organization, access, processing and analysis of big Earth Observation data. This of course is too great a goal to achieve in a mere master's level thesis and as has been corroborated it has not been concluded. There are as many projects as there are data out there and it would take years to construct something that is authentic, unifying and unique. (Battle, n.d.)

III.I. Problems and solutions

Coastal Erosion is rapidly becoming the most important environmental challenge facing mankind. Small changes may seem inconsequential, but a small change to the vast volume of oceans covering our earth represents immense changes in energy. These energy changes can become concentrated and focused, resulting in massive hurricanes and storms. Concurrently, the changes in temperature can trigger outbreaks of insect pests or disease vectors, which can destroy entire landscapes, forests, or croplands. Everything in nature is related, so outbreaks or changes in one area trigger changes in other areas or organisms and the cycles expand. At critical periods, changes in the earth's crust becomes a source of increasing losses and human impacts. (Planet action, n.d.)

The coastline, which includes tourist resorts, ports, hotels, fishing villages, and towns, has experienced threats from many disasters such as storms, cyclones, floods, tsunami, and erosion. Both conventional and remotely sensed data were used and analyzed with the aid of the remote sensing and geographic information system tools. Zones of vulnerability to coastal natural hazards of different magnitude can be identified on a map and specifically on the maps produced in this research. The area in question is highly vulnerable, showing the majority of coastline has been subject to erosion.

The coastal zones of Latin America have many landforms and environments that respond differently to the expected changes in climate and associated sea level rise, all of which produce coastal erosion. Erosion is not yet a serious threat, although it is widespread, and it is severe in some parts. The research means to address coastal erosion in Mexico's coast, specifically Cancun and the challenges it presents to the region in terms of biodiversity, vulnerability of the region and finally analyzing the resilience of key coastal ecosystems and at-risk populations. It is proposed that the analysis be done through crustal movement modelling and development of an automated spatial data infrastructure. This should carry out investigations to deduce the rate of crustal movements on the basis of the differences in temporal satellite imagery. The research is being based on graphic representation of the observed deformations by producing crustal deformation models. These models can be published online by integrating geospatial web applications and services for web mapping dissemination of geographic content. By facilitating access and promoting usability of online geospatial resources, the proposed research may empower the general public in exploring strategies to overcome erosion and ensure resilience thus sustain economic growth, minimize population risk and maintain biodiversity.

The main goal of this research was to produce a platform as a bridge between scientist and end-user communities, going far beyond a conventional bridging. The Platform will be supported by the development of a web geospatial infrastructure and the set of sustainability assessment tools required for making multi-scale integrated assessments in the coastal zone by supporting and creating local geo-nodes in order to deliver data sets accessible through an Internet viewer. Implementing this platform will allow to use spatial data, generated within the project as well as external, through an interactive viewer. One of the major challenges of the project is to tangibly share the data with all the stakeholders and beyond. (Masser, 2005) Some literature resources define a Cyberinfrastructure (CI), a combination of data resources, network protocols, computing platforms, and computational services that brings people, information, and computational tools together to perform science or other data-rich applications in our information-driven world.

Geospatial analysis, feature relationship calculations, geospatial modeling, geo-visualization, and geospatial decision support are all areas of the science at hand in this research and most platforms employ detailed geospatial principles for large amounts of geospatial data processing. These principles are necessary to make any type of geo infrastructure useful. Geospatial CI (GCI) refers to a CI that involves geospatial principles and geospatial information to transform EO research and analysis. GCI is based on the most up to date advancements in the geographic information science with information technology, computer networks, sensor networks, and Web computing. Our research efforts would in theory contribute to building a GCI with the objective of supporting technologies, communities, and future research. GCI is a new area of the science which provides significant improvements and signals how geospatial information will advance. The evolution of GCI is producing platforms for geospatial science domains and communities to better conduct research; to better collect data, access data, analyze data, model and simulate phenomena, visualize data and information, and produce knowledge. (Chaowei , 2010) The case is made for the importance of developing a system to maintain and provide access to the most current spatial data where multiple remote users can access and integrate data in real-time from multiple sources whether they be local, regional, state, federal, academic, or non-profit entities. The value of visualization and virtual globe tools in in the promotion of a more intuitive understanding of coastal issues. All the tools available address coastal hazards resilience and more effective implementation of comprehensive plans in coastal communities. The contributions herein evidence the scope of computer-based analysis fostering a better understanding of the synergistic relationships between built and natural environments, their spatial scope and their dynamics. Application areas include infrastructure and facilities management, physical planning and urban design, land use and transportation, business and service planning, coupled human and natural systems, urban planning, socio-economic development, emergency response and hazards, and land and resource management. This research emphasizes the importance of the development and enhancement of computer-based technologies for the analysis and modeling, policy formulation, planning, and management of environmental and urban systems that enhance sustainable futures. (Stone et al., in press).

In the southern state of Quintana Roo beaches are at present severely eroded, news sources report it is due to sand extraction, construction of hotels and meteorological phenomena. Permanent erosional processes are caused by tectonic subsidence, deforestation and the fragmentation of coastal ecosystems, land use changes and sediment deficits because of infrastructure built along the coast. In recent years, all around the World but especially in the Caribbean, there have been happening different natural disasters such as hurricanes, earthquakes, tsunami, etc. which have damaged deeply various coastal tourist destinations. Examples of these disasters are Cancun and similar tourist destinations in the Caribbean after the devastation caused by the hurricanes Ivan (2004), Wilma (2005), Dean (2007) and Gustav & Ike in 2008. As a consequence of such disasters, different research has the proposal is in analyzing coastal erosion in Mexico's coast, specifically Cancun and the challenges it presents to the region in terms of biodiversity, vulnerability of the region and finally analyzing the resilience of key coastal ecosystems and at-risk populations. It is proposed that the analysis be done through crustal movement modelling and development of an automated spatial data infrastructure. This should carry out investigations to deduce the rate of crustal movements on the basis of the differences in temporal satellite imagery. The research would be based on graphic representation of the observed deformations by producing crustal deformation models. These models can be published online by integrating geospatial web applications and services for web mapping dissemination of geographic content. By facilitating access and promoting usability of online geospatial resources, the proposed research may empower the general public in exploring strategies to overcome erosion and ensure resilience thus sustain economic growth, minimize population risk and maintain biodiversity.

III.II. ArcGIS online

ArcGIS is developed by ESRI, a GIS developer that works closely with information technologies and maintains environmental studies. Their geomatic analytics is widely user based and user expanded, they provide the tools and services and the user (mostly skilled in the geosciences) develops and expands their applications. ESRI is the go-to service for web mapping and app development because their tools and databases are readily available online. Their infrastructure and platform are constantly pushing for more user-friendly interoperability. ArcGIS online is the most widely used product from ESRI and it is powered by web maps. Maps are embedded in websites and shared through apps that can be used modified and created. One can say ArcGIS online is a web mapping tool for delivering the current power of GIS at the world's fingertips. It takes spatial analytic tools connecting data mining for the exploitation of data applications. It is geo processes are done in real time which makes for a true interaction and interoperability with data to analyze and relate the information. Which makes for example risk assessment a seamless and easy process. The use of ArcGIS online tools and services has been of great help and actually solved most infrastructure problems presented throughout this research but after putting it into practice, the same weakness is still able to be identified. This is that it is necessary for the ESRI user to have a certain level of knowledge regarding geoprocessing and spatial data. The reason ArcGIS online is mostly user guided is because there actually are many scientists that use their services and develop very useful applications. Nonetheless it is an amazing proposal and it is going in the precise direction that has also been already identified in this work. This is ESRI works on a premise of open cloud and pushes towards open data principles.(ArcGIS online, n.d.)

As a precursor of the new WEB 2.0 era ESRI launches services that accommodate the needs of the end users. Take for example ARCGIS ENTERPRISE, it's a framework for deploying web GIS applications, which allows s a GIS practitioner, to provide end users with a web GIS application that enables them to get their work done without having to learn a lot about GIS. By necessity, the user of the ESRI services must have a full grasp of the concepts of each web GIS application and their understanding is more complex than the end users' expertise. (ArcNews, 2013) In short ArcGIS online is an excellent developer's tool but not a geoweb platform in itself and provides sufficient solutions for the geospatial online portal proposed in this thesis.

Enabling web-based gis tools to improve and expand data accessibility and analysis functionality has been an effort that began a couple of decades ago, it eventually involved collaboration between partners of certain industries for example with universities to make improved data products available over the internet. This resulted in improved web portals that aimed to make data sets readily available. The usage of these tools has grown exponentially throughout time. The success of the web has seen, in the last few years, a change in the user requests for more geographically based information. This coupled with recent changes in web site security procedures that reduced capabilities of the current site, warrants a significant upgrade for continued data dissemination. These improved GIS tools enable the visualization and data analysis that provide a more convenient way to access and use the data for individual needs and decision support systems. A growing number of government and industrial agencies use GIS tools for data analysis and there are many new tools for mobile GIS applications. (Earth Data, 2017)

IV. Implementation

The goal of this research is to promote the design and implementation of an automated web infrastructure using geographic information systems to analyze remotely sensed coastal imagery and with this, pave the way to generating temporal crust deformation models that can be displayed and published through the internet, making all the data and information accessible to the general public. The solution for implementation for the proposed web geospatial infrastructure was given by ArcGIS online tools and developed through web app builder, it already had the spatial data in an online cloud-based database that can be accessed through the built apps. Also, ESRI is improving the spatial analysis tools and have been integrated in the web app which can be accessed through https://tuadmiradora.000webhostapp.com/.

The ESRI services used for developing geospatial platforms is **Web AppBuilder** for ArcGIS is an intuitive, custom web mapping WYSIWYG application with powerful tools to configure fully featured HTML apps. The Developer Edition of the Web AppBuilder provides an extensible framework for developers to create HTML/JavaScript apps that can run on any device and allows for custom widgets and themes. It is Integrated with the ArcGIS Online and ArcGIS Enterprise platforms using ready-to-use widgets, such as Query and Geoprocessing. (ArcGIS for Developers, n.d.) There are 3 different editions of Web AppBuilder for ArcGIS: Embedded in ArcGIS Online; Embedded in Portal for ArcGIS; and Developer Edition and conceptually they all have the same capabilities. To use Web AppBuilder embedded in ArcGIS Online and Portal for ArcGIS for creating new web app with custom functionality it is necessary to download the code for the web app and deploy it on a web server. Then by editing the app's configuration files it is possible to add custom widgets within the web app. Web AppBuilder supports Web GIS patterns. Data content for Web AppBuilder is defined and based on web maps, which are one of the mechanisms that promotes and facilitates sharing and collaboration in the ArcGIS platform. The Web maps embedded in the resulting application, are first created within ArcGIS Online and Portal for ArcGIS. However, Web AppBuilder's widgets can be configured to work directly with web services by specifying the properties of a widget. ArcGIS for Developers, (2017)

Under the concept of "openness", there is a big contradiction to working with ArcGIS tools, in that it does require a desktop license and an ArcGIS for Developer Plan Subscribers, which is difficult to navigate when depending on educational institutions for resources. This aspect has caused the research to come to a standstill on several occasions and makes a strong case for analogous tools and services but that are open source. Of course, open source software often requires developer skills that contradict the design premise that this thesis is being built upon. Nonetheless ArcGIS online is a powerful service and has its workarounds that allowed the building of a decent infrastructure.

At present, the tool that was developed with this research allows for several spatial analysis to be performed. The specific tools can be identified by icons on the left side of **image 1** and each spatial analysis tool looks for a specific spectral signature. Depending on the specific analysis tool chosen, it will look for a specific spectral index and will modify the image on the screen such that the user will see the desired characteristics of the land enhanced visually by color. For example, if the icon of the "leaf" were to be chosen the tool will run an analysis of the satellite images stored in the local database to match the Normalized Difference Vegetation Index (NDVI) and output an image that has these bands enhanced and that can then be easily identified by a green tint on the AOIs.

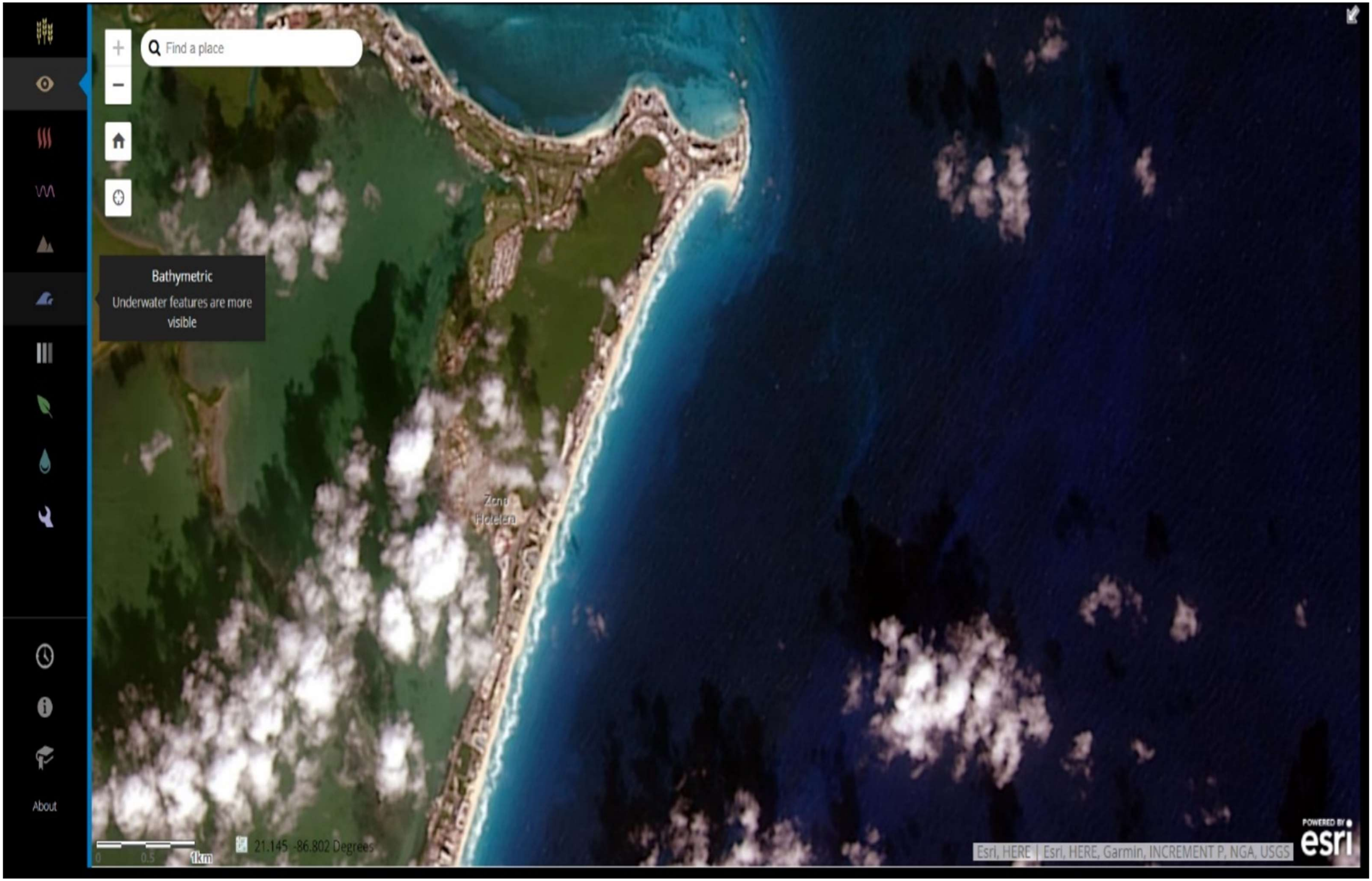
Find a place
Bathymetric
Underwater features are more visible
About
Zona Hotelera
21.145 -86.802 Degrees
1km
Esri, HERE | Esri, HERE, Garmin, INCREMENT P, NGA, USGS
POWERED BY esri

image 1

Image 2 and image 3 show the web infrastructure with spatial analysis tools that have been specifically programmed in the framework of this research to find more specific data that can be more closely related to coastal erosion. **Image 2** for example allows the user to run analysis on specific bands of their choosing, making the resulting visual analysis to adhere to their specific needs. **Image 3** is an example of the power of the tool when analyzing an image for which users can directly query a specific point in the spatial data (satellite image).

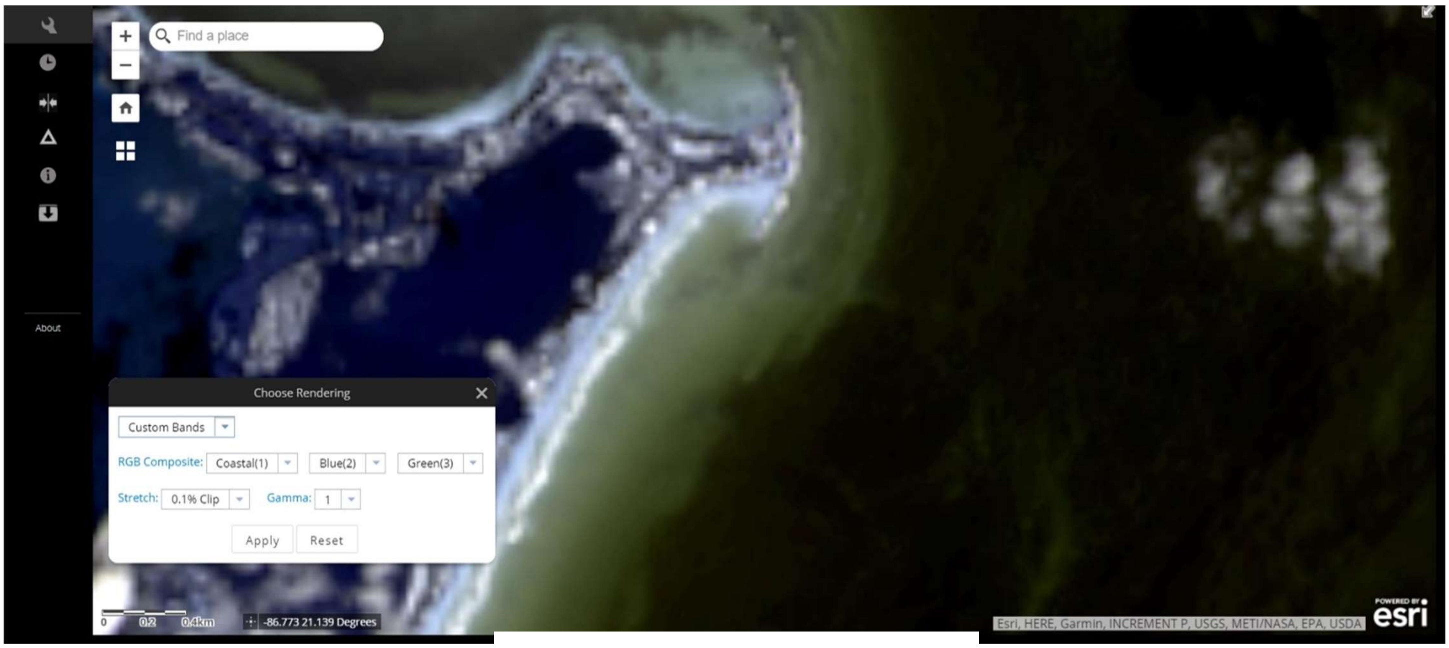

image 2

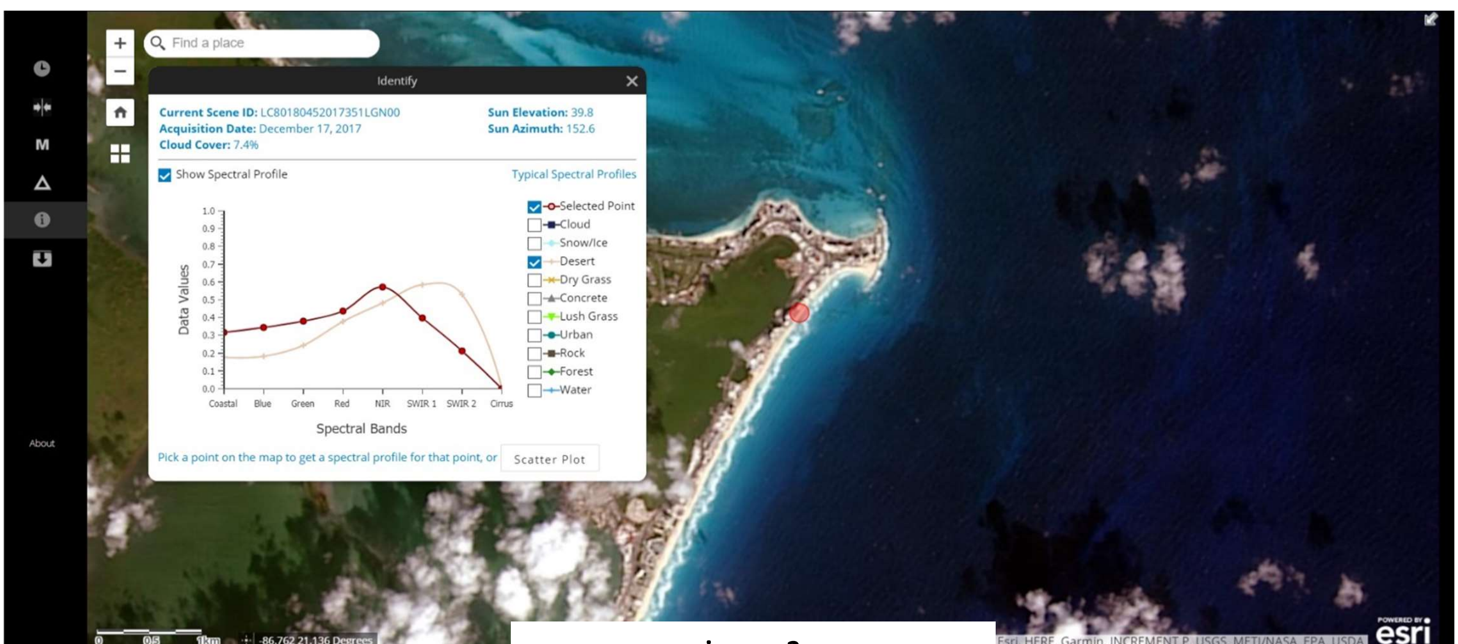

image 3

V. Results and Discussion

As can be seen from the previous chapter the web infrastructure is far from finished. Several technical and institutional issues surfaced as the projects moved from discovery, acquisition, and integration of spatial data from multiple sources to analyze regional coastal issues to the development of interoperable web mapping services and spatial data catalogs. These issues are associated with the following research topics: web portal design and evaluation, choosing appropriate web mapping technologies, GIS cartography, domain spatial data infrastructures, geospatial data archives, and spatial ontologies**.** Before mass use of the Internet and its technologies, and still today to a large extent, spatial data for a particular location have been stored in different physical locations, and often using different formats. This makes it difficult for a user to access and utilize the data. Which is why Schmitz defines "islands of data" as organizations that cannot afford to acquire data on their own and have a need for EO services to provide them access to spatial data stored somewhere else. This is exactly the need for the sharing of data is so important and also sharing means saving resources, time and effort, by avoiding the duplication of effort required to acquire and maintain the data (Schmitz, 2008)

Besides the technical components that connect data 'islands' via the Internet, other aspects such as licensing agreements, data transfer standards, and data access policies must also be put in place to ensure consistent and reliable access. Consequently, a spatial data infrastructure is not only a technical facility, but a complete framework that includes political, technical, business and social aspects. If you do an online search for free data, many government institutions all around the world provide access to data from their specific area. So much so but so specified that it becomes a full-time job to go through all the resources to find the specific resource that is the best fit for the task at hand. In this day and age where user friendly interfaces are a priority this mindset can and should be adopted in the sciences. The current projects and efforts mentioned in the introduction of this work is proof that it is happening. Currently we encounter two trends within the broader GIS community: one that is on the move to web-based applications based on open standards as defined by the Open Geospatial Consortium (OGC) resulting in more flexible and interoperable solutions. The other is the raise of the prosumer-oriented GeoWeb2.0, with its user generated content (a prosumer is a consumer that has professional skills). Goodchild (2007) gives an overview of these global collaborations with respect to geographic information. He calls the phenomenon Voluntary Geographic Information (VGI). One of the most striking examples of VGI is the OpenStreetMap (OSM) project. It aims at creating and collecting free vector geodata covering the whole planet. While the quality is still heterogeneous, we see already potential for real applications using this data. (Goodchild, 2007)

The issue to solve is how to get all people all data needed at any time. An extensive research was done reviewing the tools and resources that exist and it has been evident that the company ESRI is already gaining ground in making resources readily available online efforts. The phenomenon of volunteered geographic information (VGI) is part of a wider transformation related to the use of geographic data in the different field of applications. Among these, participation, commercial uses and natural or anthropogenic risks assessment could be highlighted. Considering the rising difficulties faced by agencies, authorities and private users in the collection and distribution of new geographical information, a well-conceived VGI could constitute a valuable tool. The growing facility to gather spatial geographic information by users through the use of portable devices is going to bring the crowdsourcing philosophy for geographic knowledge production into evidence. All those who are interested in the generation of maps from sources other than the authoritative could be potentially involved. Not only that but, crowdsourcing could be particularly useful in the generation of geographical knowledge where geographic data are not in common use or where existing maps are not updated.

The emerging ubiquity of geospatial information is providing an unprecedented opportunity to apply GIS-based multiple criteria decision analysis to a broad spectrum of use cases. Volunteered geographic information, open GIS software, GeoService-based tools, cloud-based virtualized platforms, and worldwide collaboration of both domain experts and general users have greatly increased the quantity and accessibility of geospatially referenced data resources. Currently, there is a lack of tools that integrate this decision-driven process within a widely accessible, robust GeoFramework environment, designed for user-friendly interaction. A Web-based platform that leverages open-source geotechnologies to incorporate a wide variety of geospatial data formats in a common solution space to allow for spatially enhanced and time-relevant decision analysis is always identified as a need in all the literature that was reviewed. (Hamilton, 2016) It covers not all relevant data and depends on issues like the willingness (and resources) of organizations to participate in such efforts - only to mention a few issues. Only within the last few years another type of solution appeared on the Web. People collect all kinds of data in a collaborative way on the Web2.0. Well known examples include Wikipedia, Flickr or YouTube, to name only a few. In fact, they are not experts, but "ordinary" Web-users that are interested in practical and easy solutions and not necessarily aware or interested in any professional specifications or formal standards. Interestingly geographic information and maps play an important role in this approach as maps/space/coordinates provide a universal framework for organizing all types of most heterogeneous content. The majority of examples for this phenomenon are so called Mashups of existing (or new) data sources with suppliers of a base maps on the Web such as Google Maps / Earth and similar. But very recently also this is changing with the increasing success and (therefore coverage and quality) of user-generated geodata as a free source.

VI. Conclusion and future work

To develop an automated web infrastructure using geographic information systems. By facilitating access and promoting usability of online geospatial resources, the proposed research may empower the general public in exploring strategies to overcome erosion and ensure resilience thus sustain economic growth, minimize population risk and maintain biodiversity. GEOSS is evidence that, as a community, we are understanding the importance of generating efforts for the good of the planet, however it is perceived that there is a difficulty regarding these EO services and products; they are only available to those few who understand the science involved in this area. It would be ideal to have a scope that is not limited to only the world population with the academic degrees needed to take advantage of these tools generated by groups such as GEO. Earth Observation services and tools is today more important than ever due to the dramatic impact that modern civilizations have on the global environment. To make use of the power of these tools it is important to know them thoroughly, and this is the first part of the thesis project. EO systems are crucial for the assessment and mitigation of the negative effects the human race is having on the environment, since, for example, EO tools and products can be used to explore and exploit new opportunities in the sustainable management of natural resources. In short, the goal is to design and implement an automated web infrastructure using geographic information systems to analyze remotely sensed coastal imagery and with this, generate temporal crust deformation models that can be displayed and published through the internet and can be accessible to the general public. The premise is that there is a world of data available for use and not enough knowledge on how to get and use it. It amazes me how the internet has all this data available and just the people involved in the hard science know it. When these data can be used by anyone and its applications are immense. And as such there is a lot of work still to be done being as the research done here was limited by time and the overwhelming breadth and depth of the area.

REFERENCES

MEOPAR. (2016, November 30). Retrieved from http://meopar.ca/about-meopar/

Coastal Informatics: Web Atlas Design and Implementation, 1st edition 2011, Publisher: Information Science Reference, Editors: Dawn J. Wright, Ned Dwyer, Valerie Cummins, pp.10-27

Remote Sensors (n.d.) Retrieved from https://earthdata.nasa.gov/user-resources/remote-sensors

Gillespie Randy, Butler Michael , Anderson Neil , Kucera Henry, and LeBlanc Claudette (2000): "MGDI: An Information Infrastructure to Support Integrated Coastal Management in Canada": retrieved from: https://pdfs.semanticscholar.org/47b9/3288c7925740a418eedef3816d62d0c911c8.pdf

Boyles D., "GIS Means Business," ESRI, Redlands, 2002

Earth, Life and Semantic Web (ELSeWeb): An Earth observation-driven, Semantic Web system for computational modeling of the impact of changing climate on ecosystems and human/environmental health system. (Aug 10, 2017). Retrieved from https://earthdata.nasa.gov/community/community-data-system-programs/access-projects/elseweb

National Earth Observation Data Framework & Catalogue. (Jan 27,2015) Retrieved from http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/neodf/11003

Tropical Rainfall Measuring Mission (TRMM) Precipitation Data and Services for Research and Applications 1 September 2012 http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-11-00152.1

Mantas V.M, Z., & Liu, Pereira A.J.S.C. (2015). A web service and android application for the distribution of rainfall estimates and Earth observation data. Computers & Geosciences, 77(April 2015), pp. 66-76. doi:10.1016/j.cageo.2015.01.011

About GEOSS (n.d.) Retrieved from http://www.earthobservations.org/geoss.php

About us (n.d.) Retrieved from https://www.earthobservations.org/index.php
Who we are (n.d.) Retrieved from https://swfound.org/about-us/who-we-are/?

Projects - Earth Observation at UCC (n.d.) Retrieved from http://earthobservation.ucc.ie/current-projects/

Ostrowski Sławomir & Rolczyński, Rafał & Pniewska, Joanna & Garnik, Igor. (2015). User-friendly **E-learning** Platform: A Case Study of a Design Thinking Approach Use. Retrieved from https://www.researchgate.net/publication/283355538

EOPOWER, (2014) Retrieved from http://www.eopower.eu/

Parkinson Claire L. Ward Alan & King Michael D. (2006): Earth Science Reference Handbook https://atrain.gsfc.nasa.gov/publications/2006ReferenceHandbook.pdf

O'Dea, L., Cummins, V., Wright, D., Dwyer, N., & Ameztoy, I. (2007). Report on Coastal Mapping and Informatics Trans-Atlantic Workshop 1: Potentials and Limitations of Coastal Web Atlases. Cork, Ireland: Coastal and Marine Resources Centre, University College Cork.

Atmospheric Science Data Center (n.d.) Retrieved from https://earthdata.nasa.gov/about/daacs/daac-asdc

Observing the Earth (n.d.) Retrieved from http://www.esa.int/Our_Activities/Observing_the_Earth/ESA_for_Earth

Welcome to Worldview (n.d.) Retrieved from https://worldview.earthdata.nasa.gov/

Atsuyo Ito (2011). Legal aspects of satellite remote sensing: Leiden ; Boston : M. Nijhoff Pub.

Influences of physical and social landscapes on the health of rural communitites, 2010 retreived from http://globalmonitoring.sdstate.edu/projects/obesity/index.php

Roddy D., 2001."Satellite Communications".3rd Edition, McGraw-Hill Companies, Inc.

Mihai Costache, Mihai Datcu (2006) "Learning - unlearning for mining high resolution EO images", Geoscience and Remote Sensing Symposium 2007. IGARSS 2007. IEEE International, pp. 4761-4764, 2007, ISSN 2153-6996.

Goodchild, M.F. (2007): Citizens as sensors: the world of volunteered geography, In: GeoJournal, Vol. 69.

GEO Report on Progress (2010), Retrieved from https://www.earthobservations.org/documents/ministerial/beijing/MS2_The%20GEO%20Report%20on%20Progress.pdf

Harris R.(2002):Earth Observation Data Policy and Europe: CRC Press

Earth Science Reference Handbook (n.d.) Retrieved from https://atrain.gsfc.nasa.gov/publications/2006ReferenceHandbook.pdf

Dodge, (2008)M., McDerby, M. & Turner, M. 2008, Geographic visualization : concepts, tools and applications, Wiley, Chichester, England ; Hoboken, NJ.

Branch, Benjamin D. and Rousi, Antti M., "An International GIS and Data Curation Dissemination Framework Using Mobile Devices: A Purdue-Aalto University Example" (2013). Libraries Faculty and Staff Presentations. Paper 74.

Smith, Goodchild (2015): Geospatial Analysis - 5th Edition: Longley

Services, (n.d.) Retrieve from https://www.itc.nl/services

Abhisek Santra (2016): Remote Sensing Techniques and GIS Applications in Earth and Environmental Studies: IGI Global

Battle, Robert, and Dave Kolas. "Enabling the geospatial semantic web with Parliament and GeoSPARQL." Semantic Web

Masser I. (2005) The Future of Spatial Data Infrastructures, ISPRS Workshop on Service and Application of Spatial Data Infrastructure, Oct.14-16, Hangzhou, China

Planet action, (n.d.) Retrieved from http://www.planet-action.org/web/137-domains.html

ArcNews, 2013: Retrieved from http://www.esri.com/esri-news/arcnews/fall13articles/implementing-web-gis

ArcGIS online, n.d. Retrieved from http://www.esri.com/software/arcgis/arcgisonline

Hamilton Michelle C., John A. Nedza, Patrick Doody, Matthew E. Bates, Nicole L. Bauer, Demetra E. Voyadgis & Cate Fox-Lent (2016) : "Web-based geospatial multiple criteria decision analysis using open software and standards, International Journal of Geographical Information Science": 30:8, 1667-1686

Earth Data, (2017): "Enabling Web-Based GIS Tools for Internet and Mobile Devices to Improve and Expand NASA Data Accessibility and Analysis Functionality for Renewable Energy and Agricultural Applications": Retrieved from https://earthdata.nasa.gov/community/community-data-system-programs/access-projects/enabling-web-based-gis-tools

ArcGIS for Developers, n.d. Retrieved from https://developers.arcgis.com/web-appbuilder/guide/xt-welcome.htm

ArcGIS for Developers, (2017):"Development overview" Retrieved from https://developers.arcgis.com/web-appbuilder/guide/developer-s-guide-overview.htm

Arseneau, Carole (2017, June 21): "With Esri's building blocks, creating web apps is easier than you think": Retrieved from https://resources.esri.ca/arcgis-online/with-esri-s-building-blocks-creating-web-apps-is-easier-than-you-think

APPENDIX

Image 4: An example of the online tool that was developed in which the capability of the tool to look at satellite images over time is shown. The user selects any time frame and a visual progression of erosion is shown animated one by one using various images stored in the database.

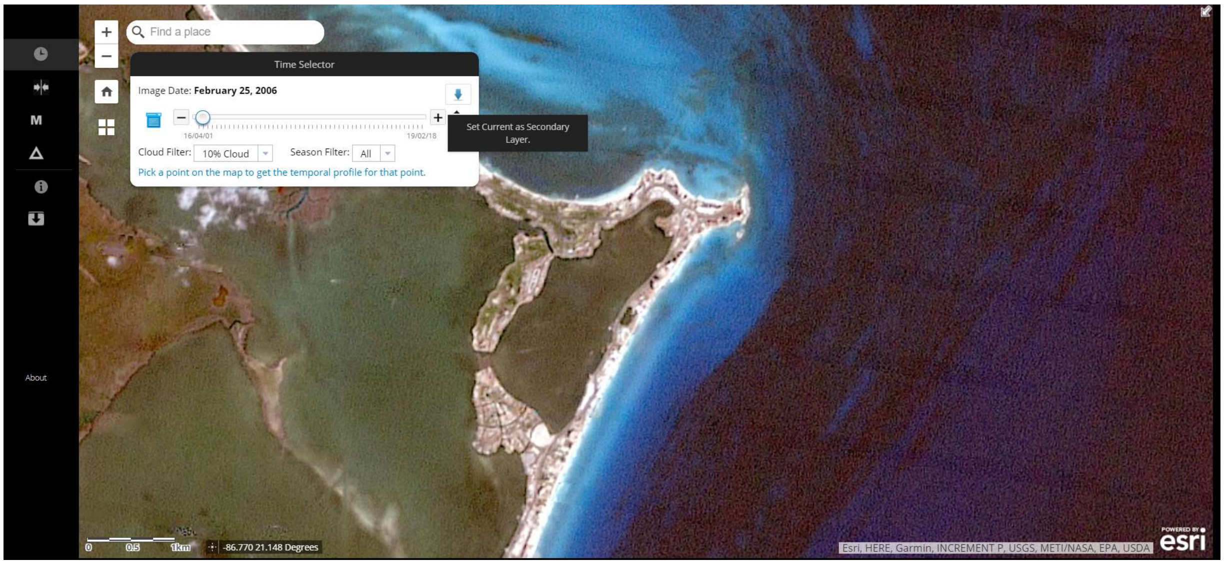

Image 4

Image 5: In the beginning of the research a web app was developed using ESRI services and with it we show the story of coastal erosion in the specific area in Quintana Roo.

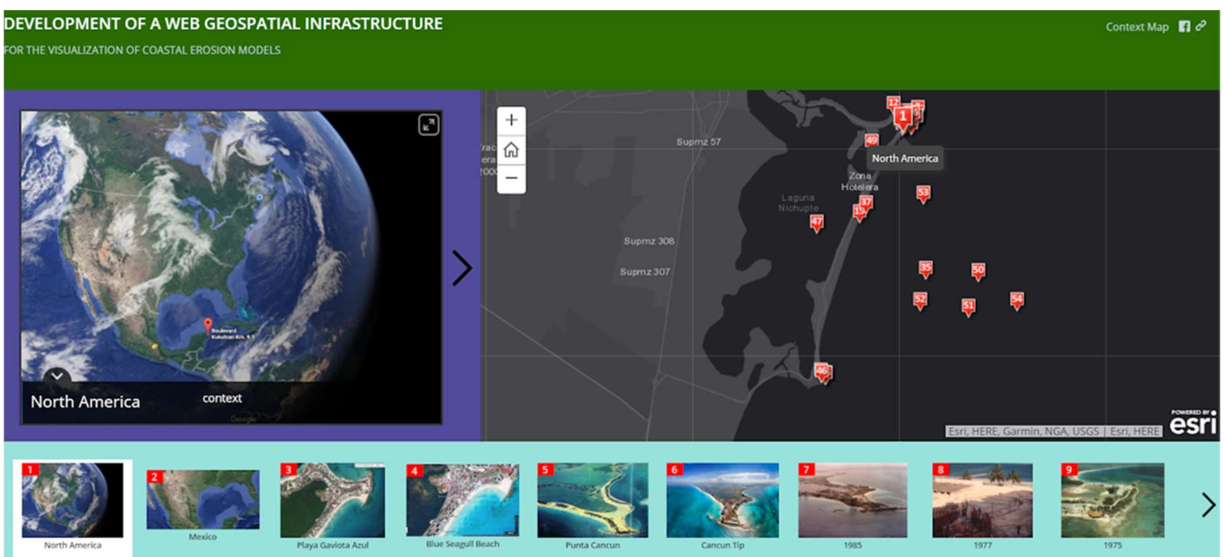

Image 5

Image 6: A first approach at a web portal that allows accessing the text of this thesis as well as the online tool for spatial analysis. Image 6 is the home page.

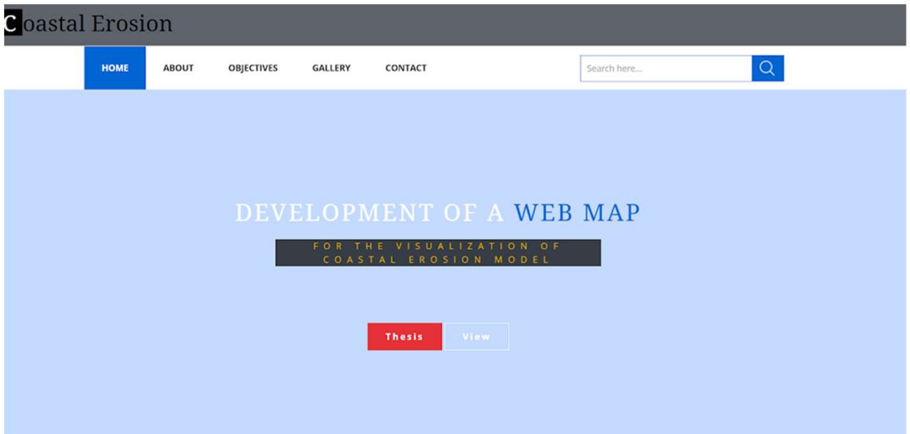

Image 6

Image 7: Is the section "About" of the above-mentioned web portal.

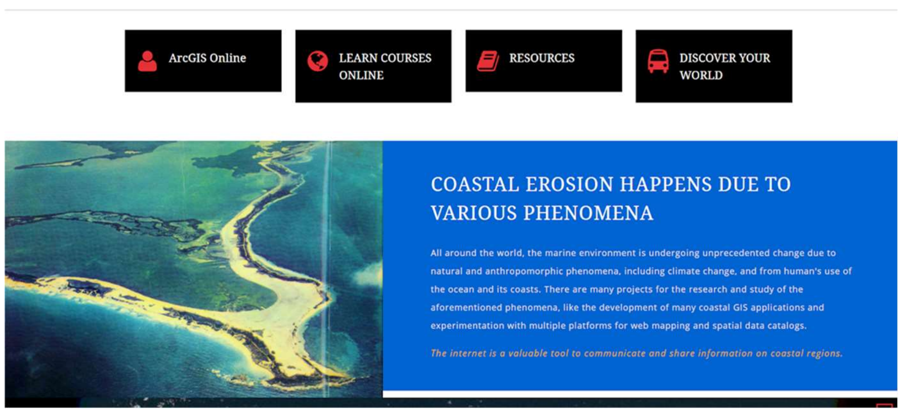

Image 7

Image 8: Is the section "Objectives" of the above-mentioned web portal.

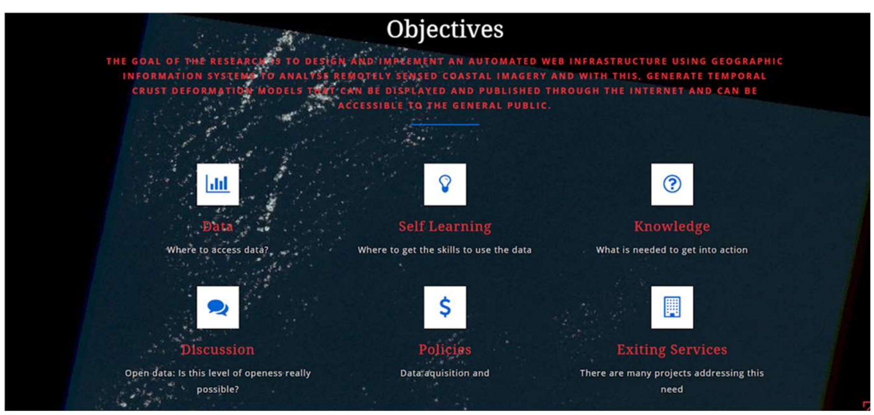

Image 8

Image 9: Is the section “Gallery” of the above-mentioned web portal.

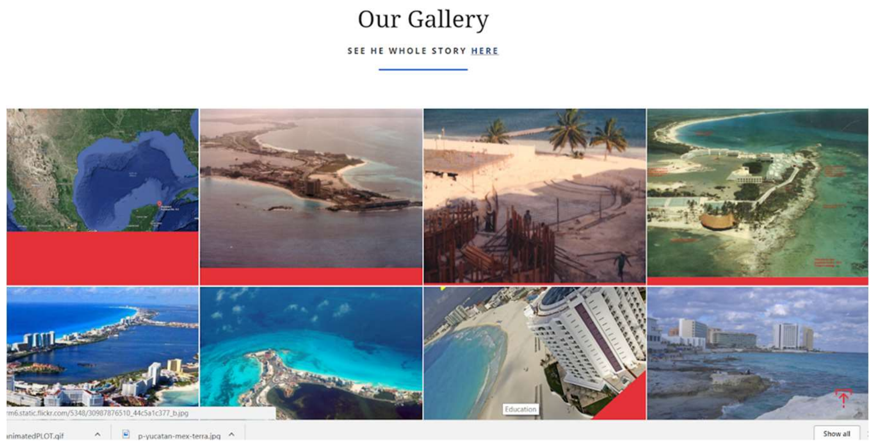

Image 9

Image 10: Is the Python routine used in the online tool that downloads Landsat images automatically from the USGS website for generating the database of satellite data used to run the spatial analyses.

AutomaticDownload.py - C:\Users\Yessica\Desktop\ThesisDefense\AutomaticDownload.py (2.7.12)

File Edit Format Run Options Window Help

```python
import os,sys,math,urllib2,urllib,time,math,shutil
import subprocess
import optparse
import datetime
import csv
import re

class OptionParser (optparse.OptionParser):

    def check_required (self, opt):
      option = self.get_option(opt)

      if getattr(self.values, option.dest) is None:
          self.error("%s option not supplied" % option)

def connect_earthexplorer_proxy(proxy_info,usgs):
    print "Establishing connection to Earthexplorer with proxy..."
    cookies = urllib2.HTTPCookieProcessor()
    proxy_support = urllib2.ProxyHandler({"http" : "http://%(user)s:%(pass)s@%(host)s:%(port)s" % proxy_info,
    "https" : "http://%(user)s:%(pass)s@%(host)s:%(port)s" % proxy_info})
    opener = urllib2.build_opener(proxy_support, cookies)

    urllib2.install_opener(opener)
    data=urllib2.urlopen("https://ers.cr.usgs.gov").read()
    m = re.search(r'<input .*?name="csrf_token".*?value="(.*?)"', data)
    if m:
        token = m.group(1)
    else :
        print "Error : CSRF_Token not found"
        sys.exit(-3)
    params = urllib.urlencode(dict(username=usgs['account'], password=usgs['passwd'], csrf_token=token))

    request = urllib2.Request("https://ers.cr.usgs.gov", params, headers={})
    f = urllib2.urlopen(request)
    data = f.read()
    f.close()

    if data.find('You must sign in as a registered user to download data or place orders for USGS EROS products')>0 :
        print "Authentification failed"
        sys.exit(-1)
    return

def connect_earthexplorer_no_proxy(usgs):

    cookies = urllib2.HTTPCookieProcessor()
    opener = urllib2.build_opener(cookies)
    urllib2.install_opener(opener)
```

Image 10

Image 11: Is an output image of the first trials for the spatial analyses desired using **R Studio**. These trials involved trying to identify erosion by change detection and comparing various Landsat images and their differences in spectral reflectance.

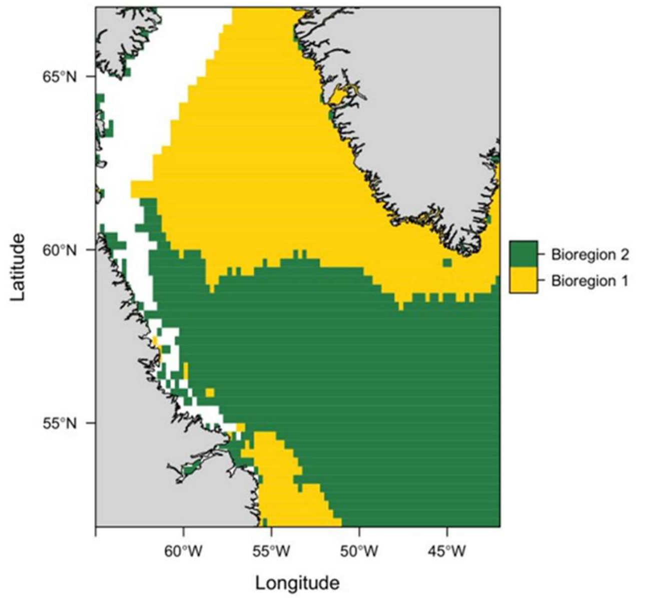

Image 11

Image 12: Is another output image of the first trials for the spatial analyses desired using **R Studio**.

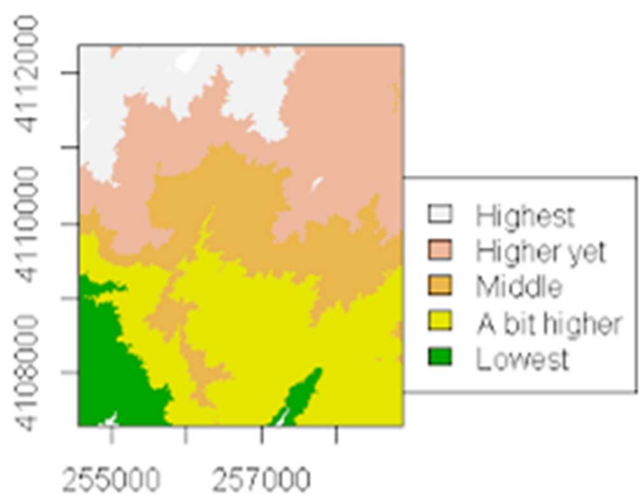

Image 12

Image 13: Is a 3D model generated in **R Studio**, in an effort to translate the above change detection analysis into a more visual style.

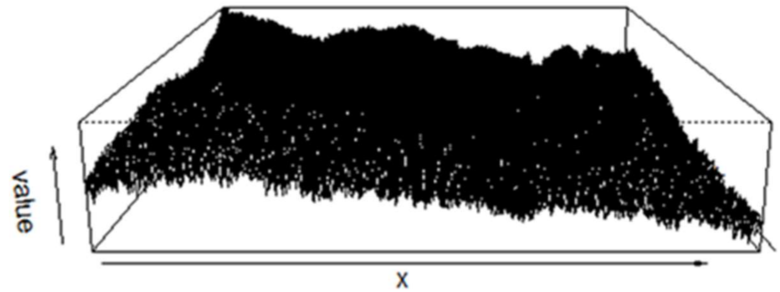

Image 13

Image 14: Is another 3D model generated in **R Studio**.

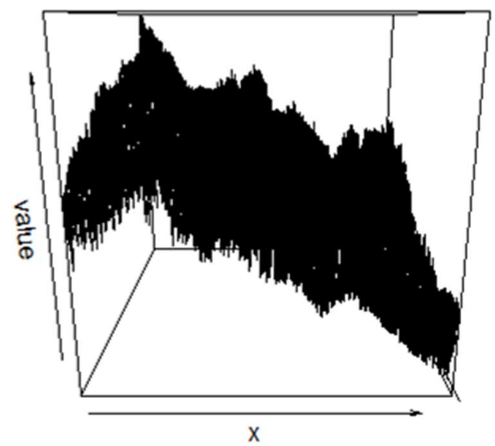

Image 14

Image 14: Is a final 3D model generated in **R Studio** using color coding after this all efforts were moved to using ESRI products and services.

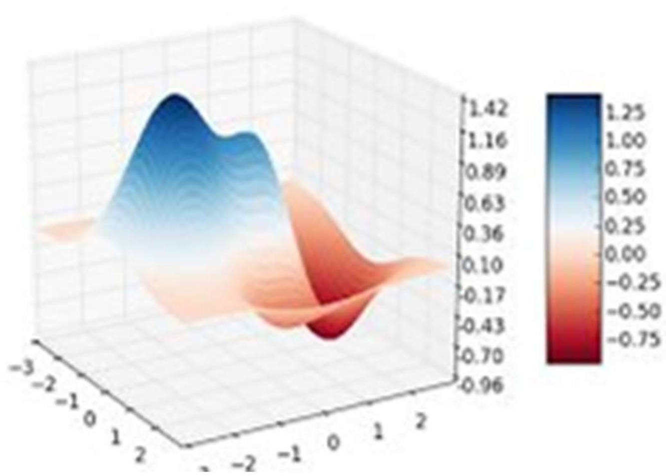

Image 15

TABLE 1:

Id	Name	Web_site	Format_or_description	Satellite_instrument_name	Requires_r egistration
1	Open street map	Http://www.openstreetmap.org/	.osm	Open street map, map	No
2	Natural earth	Http://www.naturalearthdata.com/	Vectors and raster	Data sets	No
3	Usgs earth explorer	Http://earthexplorer.usgs.gov/	.tif	All(landsat,spot,ikonos,ceos,aster,lidar,etc.)	Yes
4	Socioeconomic data and applications center	Http://sedac.ciesin.columbia.edu/	.png, .pdf,goetif,csv,.xls	Data sets	Yes
5	Google earth	Http://googleearthforchromebook.com/	Compressed image files	_	No
6	Unep environmental data explorer	Http://geodata.grid.unep.ch/	Several	Data sets	Yes
7	Fao geonetwork	Http://www.fao.org/geonetwork/	Shape files	Data sets	No
8	Nasa earth observations	Http://neo.sci.gsfc.nasa.gov/	.jpg,.png,geotif,csv	Data sets	No
9	Moderate resolution imaging spectroradiometer (modis)	Http://modis.gsfc.nasa.gov/data/data prod/mod01.php	From earh data	Data sets	No
10	Terra	Http://terra.nasa.gov/	Hdf	Aster,ceres,misr,modis,mopitt	No
11	Sentinels scientific data hub	Https://scihub.copernicus.eu/	Geotif	Sentinel	Yes
12	Diva-gis	Http://www.diva-gis.org/data	Boundaries, railways, roads	Data sets	No
13	International steering committee for global mapping	Http://www.iscgm.org/	.png	Images	No
14	Earth resources observation and science center	Http://glovis.usgs.gov/	Several	Landsat, hyperion, ali	Yes
15	Reverb	Http://reverb.echo.nasa.gov/	.tif	Several	Yes
16	Golbal landcover facility	Http://www.landcover.org/	Geotif	Landsat	No

17	Coastal topographic lidar	Https://coast.noaa.gov/dataregistry/ search/collection/info/coastallidar		Data sets	No
18	Earth observation monitor	Http://www.earth-observation-monitor.net/datasets.php		Data sets	No
19	Eye find	Http://eyefind.rapideye.de/	Hdf		
20	Image generation division (brazil)	Http://www.dgi.inpe.br/cdsr/	_	_	Yes
21	Esa third party missions data by copernicus users	Https://spacedata.copernicus.eu/web/ cscda/data-access/access-to-esa-third-party-mission-data	_	Data sets	Yes
22	Esa earth observation data by copernicus users	Https://spacedata.copernicus.eu/web/ cscda/data-access/access-to-esa-eo- data	_	Data sets	Yes
23	Open topography	Http://www.opentopography.org/	Geotif	Lidar	Yes
24	Eoli (earth observation link)	Https://earth.esa.int/web/guest/eoli	European space agencys client for earth observation catalogue and ordering services.	Browse the metadata and preview images of earth observation data acquired by the satellites: envisat, ers, Landsat, ikonos, dmc, alos, spot, kompsat, proba, irs, scisat.	Yes
25	Landcover & surface data group	Http://www.bu.edu/lcsc/data-documentation/	_	_	_
26	Global forest change	Http://earthenginepartners.appspot.com/science-2013-global-forest	_	_	_
27	Earthenv	Http://www.earthenv.org/	Global, remote-sensing supported environmental layers for assessing status and trends in biodiversity,	_	_

			ecosystems, and climate		
28	Topical rainfall measuring mission	Http://trmm.gsfc.nasa.gov/data_dir/data.html	_	_	_
29	Worldclim	Http://www.worldclim.org/	Worldclim is a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer.	_	_
30	Lp daac	Http://gdex.cr.usgs.gov/gdex/	_	Aster	_
31	Golbal landcover facility strm	Http://glcf.umd.edu/data/srtm/	Raw data	Space shuttle endeavor	Yes
32	Fire risk system	Http://firerisk.conservation.org/index.php	Calculates moisture content of litter on the forest floor by modeling moisture exchange between the litter and surrounding air	Data sets	_
33	Biodiversity studies	Http://www.dpi.inpe.br/ambdata/engli sh/download.php	You can download environmental data usually used for modeling species distribution, considering brazil and Brazilian legal Amazonia geographical limits	Data sets	_
34	Vmerge data portal - emerging viral vector borne diseases	Http://www.edenextdata.com/?q=content/global-gis-datasets-links-0	_	_	_
35	World soil information	Http://www.isric.org/data/data-download	A selection of the isric dataholdings is available for download as zipped datasets	Point/profile, polygon and raster/grid	_
36	World pop	Http://www.worldpop.org.uk/	Provision of	_	_

			detailed and open access population distribution datasets		
37	European union open data portal	Https://open-data.europa.eu/en/data	_	_	_
38	Global change master directory	Http://gcmd.nasa.gov/	Discover data and services	_	_
39	Freegis database	Http://freegis.org/database/?cat=1	Complete list of data services	_	_
40	Geocommons archive	Http://geocommons.com/	A community contributed collection of open data from around the world. Uploaded by the public, data are often from public and open government website and sources.	_	_
41	The world bank	Http://maps.worldbank.org/p2e/mcmap/ index.html	Information from the world bank projected on world maps	_	_
42	Map cruzin	Http://www.mapcruzin.com/download- free-arcgis-shapefiles.htm	Download free gis maps, ArcGIS shapefiles & geospatial data for digital cartography	_	_
43	Dienstleistungszentrum	Http://www.geodatenzentrum.de/	Des bundes für geoinformation und geodäsie	_	_
44	Open weather map	Http://openweathermap.org/weathermap	Openweathermap is developed by team of it specialists who have 10+ year-long expertise in development of telecommunication and big data solutions.	_	No
45	Open government data platform india	Https://data.gov.in/catalog/liss-iii-data-download-indian-remote-sensing-satellite-resourcesat-1	Provides free download of indian remote sensing	_	_
			The eduspace website		

46	Eduspace	Http://www.esa.int/specials/eduspace _en/sem9nipt1kg_0.html	is meant to be an entry point for space image data, and, in particular, to a widespread visibility of earth observation applications for education and training.	_	_
47	Visible earth	Http://visibleearth.nasa.gov/view_ca t.php?categoryID=1495	A catalogue of nasa images and animations of our home planet.	_	_
48	Canadian space agency	Http://www.asc- csa.gc.ca/eng/satellites/default- eo.asp	_	_	_
49	Aviris	Http://aviris.jpl.nasa.gov/alt_locat or/	2006-present aviris flight locator tool	_	_
50	Product distribution portal	Http://www.vito- eodata.be/pdf/portal/application.htm l#home	_	_	_
51	Apex, airborne prism experiment	Http://www.apex- esa.org/content/free-data- cubes	The first apex (airborne prism experiment) imaging spectrometer data set available to the remote sensing community.	_	_
52	Spectir	Http://www.spectir.com/free-data- samples/	Hyperspectral sample data sets	_	_
53	Arcgis online	Http://www.arcgis.com/home/webma p/vi ewer.html?featurecollection=http%3a %2f%2flandsatlook.usgs.gov%2farcgi s %2frest%2fservices %2fsentinel2%2fimageserver%3ff %3djson%26option %3dfootprints&supportsprojection=tr u e&supportsjsonp=true	Map viewer	_	No
54		Http://www.sat.dundee.ac.uk/	_	An up-to-date archive of	Yes

	Dundee satellite recieving station			images from noaa, seastar, terra and aqua polar orbiting satellites.	
55	Congo basin satellite imagery resources	Http://carpe.umd.edu/geospatial/satellite_imagery_resources.php	_	Landsat, modis, aster, spot, cbers, radar, lidar	No
56	Grass gis	Https://grass.osgeo.org/download/sam ple-data/	Data sets in grass gis format ready for use with grass.	Data sets	No
57	Esa lansat 8	Https://landsat8portal.eo.esa.int/portal/	_	Landsat 8	Yes
58	Noaa	Https://www.nodc.noaa.gov/	High-value environmental data and information	_	No
59	Land processes distributed active archive center-data pool	Https://lpdaac.usgs.gov/data_access/data_pool	A more direct way to access files by foregoing their retrieval from the nearline tape storage devices.	_	No
60	Geogratis	Http://www.geogratis.gc.ca/geogratis/en/search	Search, discover and download free maps, data and publications.	_	No
61	Polaris	Http://nsidc.org/data/polaris/	Earch and customization of nsidc data with immediate downloads	_	No
62	Modis	Http://modis.gsfc.nasa.gov/	Modis data	Data sets	No
63	Great lakes mapping and gis	Http://gis.glin.net/	Public access to map-based tools and gis data layers	Data sets	No
64	Earth resources observation and science (eros) center	Http://eros.usgs.gov/find-data	Aerial photography,digitized maps,elevation products,fire science,land cover,satellite imagery	Data sets	No
65	Usgs the national map	Http://viewer.nationalmap.gov/launch/	Data download and visualization services	_	No

66	Usgs tnm download	Http://viewer.nationalmap.gov/basic/	_	_	_
67	Usgs hazards data distribution system viewer	Http://gisdata.usgs.gov/website/eo/	Eo inventory query tool,annotate/ measure,earthquakes ,e levation,gazetteer,me tadata,scale,xy/usn	_	_
68	Earth observing system project science office	Http://eospso.gsfc.nasa.gov/	_	_	_
69	Indian remote sensing and gis	Http://www.indiaremotesensing.com/ 20 12/10/list-of-important-sites-to-download.html	List of important sites to download free satellite images and gis data	_	_
70	Ilwis world institute for conservation & environment, wice	Http://www.ilwis.org/data_acquisitio n.htm	Free and low-cost satellite images for gis and ilwis	Aster	No
71	Indian geo-platform of isro	Http://bhuvan.nrsc.gov.in/data/downl oad/index.php?c=s&s=l3&p=&g=	_	_	Yes
73	Geocab	Http://www.geocab.org/	Earth observation capacity building portal	Access information	No
74	Airbus defence and space	Http://www.geo-airbusds.com/	Data acquisition and processing, to data management and hosting	Pléiades,terrasar-x & paz,spot 6/7,spot 5,dmc constellation,formosat-2,kazeosat-1	Yes
75	Un-spider	Http://www.un-spider.org/	Access and capacity to all types of space-based information for support of full disaster management cycle	_	Yes
76	Global mapper	Http://data.geocomm.com/catalog/in de x.html	A valuable online source for all resources in their respective vertical market	_	No
77	Maps analytics	Https://cmapsconnect.com/data/#gsc .t ab=0	_	Csv	Yes
78	Share geo open	Https://www.sharegeo.ac.uk/	The uk open source	_	Yes

			for your free geodata		
79	Geo fabrik	Http://www.geofabrik.de/geofabrik/g e ofabrik.html	Free geodata created by projects like openstreetmap	Osm and shapefiles	Yes
80	Remote sensing for biodiversity & conservation	Http://remote-sensing-biodiversity.org/resources/terrestrial-rs-data/	Information about workshops, conferences, publications and data portals	_	Eventua
81	University of toronto map & data library	Http://mdl.library.utoronto.ca/collections/geospatial-data/remote- sensing-resources	List of remote sensing resources	Information	No
82	Landsat science	Http://landsat.gsfc.nasa.gov/?page_id=2370	More free data	Information	No
83	Esa earth online	Https://earth.esa.int/web/guest/data-access/browse-data-products	Browse data products	Information	No
84	Esa earth online	Https://earth.esa.int/web/guest/home	How to access eo data	Information	No
85	Esa earth online	Https://earth.esa.int/web/guest/data-access/how-to-access-eo-data/how- to-access-earth-observation-data- distributed-by-esa	How to access eo data	Information	No
86	Land remote sensing program	Http://remotesensing.usgs.gov/index. php	The usgs is fostering the use of land remote sensing technology to meet local, national, and global challenges.	Information where to get data	No

Table 1