One Small State's Preparation for Climate Change: Building an Integrated Socio-Technic Informational Infrastructure

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Abstract
Very few countries can afford to ignore the potential repercussions emanating from climate change. However, few afford to take the steps to ensure the laying of full-coverage groundwork structures that ensure future analytical studies. This paper deals with the stepped-approach taken by a Mediterranean island state, to ensure the creation of a baseline structure that covers all the territory in terms of physical, natural and social environments. Malta has taken on the task to implement a series of measures aimed at integrating environmental, spatial planning and social data in line with the implementation of the Aarhus Convention, the INSPIRE Directive and the SEIS initiative. The implementation of a project entitled "Developing national environmental infrastructure and capacity" co-financed under the 2007-2013 European Regional Development Funds (Structural Funds) Programme for Malta, is targeted to take national environmental monitoring capacity from a semi-analogue state to a fully interactive online system. This initiative has resulted in the creation of tools that scientists and the general public can access for their respective studies. The resultant hardware, software, innovative scans of the terrestrial and bathymetric domains, as well as the freely disseminated SEIS-based systems have created the right scenario for the analysis of climate change.

1. Introduction

1.1 State of Data-Dearth

The Maltese scientific community and the general public have been able to access online spatial and non-spatial data in a dedicated location as late as 1998 through the introduction of a rudimental Census-related Imagemap (Formosa, 2000) and a development planning mapserver (MEPA, 2001). This initial step was taken to ensure the breaking-away from the analogue hardcopy systems that resulted in the retention of data and hoarding. With the introduction of internet services in 1993 the stage was set for the slow implementation of systems and protocols that allowed for the dissemination of information as required for scenario-testing. In early days, the initial attempts were remarkable in terms of their ground-breaking work; however they were limited due to their non-interactive structure. The data was presented as a series of html pages with few imagery options. With few requirements in terms of software, the introduction of online GI services in Malta predated products as Google Maps and even the INSPIRE initiative (MEPA, 2001 and Agius, 2003). The Maltese GIS experts delved into reviews of available technologies in early 1990s and white papers such as produced by Intergraph, Joint Research Center and other entities, proprietary and open-source technologies such as MapInfo, ESRI, Autodesk Map, MapwindowGIS, Vertical Mapper, Quasar, LP360 and Oblivision. The progress made through such early activities as the TC/211 GI committee of the International Standards Organisation (Rowley, 1999) and the OpenGIS Web-mapping Testbed RFT (de La Beaujardière, 2002), leading to the most recent improvements based on the INSPIRE Directive (OJ, 2007) and the Plan4All project (Beyer and Wasserburger, 2009). Such decisions proved their utility since they laid the foundation for subsequent developments as required for Aarhus Convention (OJ, 2003a), the EEA (European Environment Agency) dataflow process (EEA, 2012), the INSPIRE Directive, the Freedom of Information Act (OJ, 2003b), and the resultant international projects requirement data for coherence and integration. With the technology in hand, the main issue that impeded researchers from taking the next step took precedence: the data dearth. Data in the Maltese Islands was created either in line with national report requirements or on an ad hoc basis. With the increasing membership in international fora, the need for a streamlined system of systems where data talks across the different operating systems and scenarios were identified. This conveyor system still needed the implementation of tools for the standardization of the information (ISO and INSPIRE) as well as the free dissemination of the data to researchers and policy makers (Aarhus), without infringing of personal and propriety rights (Data Protection and Freedom of Information Acts). The phased approached set the scene for the next step since it was identified that data availability without a comprehensive and structured coverage left any subsequent analysis both dry and unreliable. Which is where climate change left its imprint on the need for a full coverage which would allow for potential changes in the physical (urban), social and natural environments. Ad hoc projects and data capture exercises were not acceptable in terms of complex analytical exercises required to access climate change impacts on society such as the early sea-level rise study in 2002 (Figures 1a, 1b) (MEPA, 2003) and 2008 (figures 2a, 2b) (Formosa and Bartolo, 2008). The reality identified the need for a fully integrative project that encompasses the different domains and which would deliver baseline data capture, analytical tools and a strategy to monitor the environment: ERDF156 (MEPA, 2009).

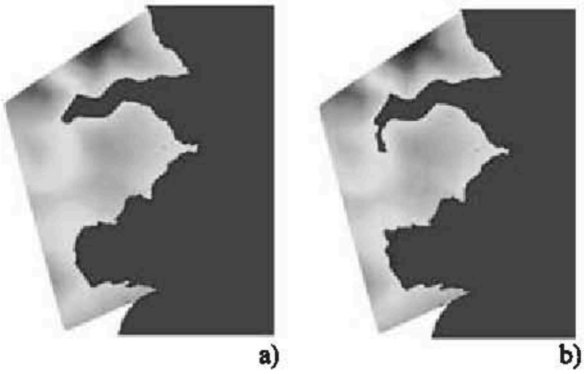

Figure 1: a. Marsascala – 0m rise, 2002, b. Marsascala – 1m rise, 2002

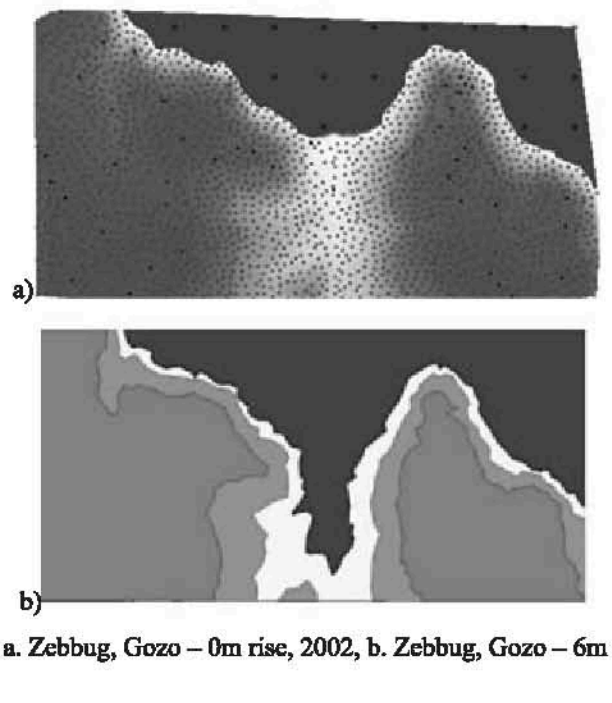

Figure 2: a. Zebbug, Gozo – 0m rise, 2002, b. Zebbug, Gozo – 6m rise, 2002

1.2 Socio-Technics vs Techno-Centrics

The need to understand process requirements for future prediction modeling entailed a sea-change in the logical processing that is more social science friendly. The emphasis on technology in its entirety with low links to the social aspects has gradually given way to a user-oriented approach which allows researchers to analyse and carry out their own spatial-based studies without the need to be knowledgeable of programming. The move from a techno-centric base where programming was the main pivot has migrated to a situation where users can carry out queries on their own without the need to be knowledgeable of the base programming. Languages such as the Structured Query Language (SQL) are easy to learn, whilst advanced tools such as those available in ESRI ArcMap have a whole range of preset queries that drive the user towards choosing the best pre-prepared query for their requirement. SQL is still there but it is hidden behind easily understandable interfaces. Social scientists and natural scientists need not expend major hours on the creation of queries but move towards the use of the technology as a tool for cross-thematic analysis. This, however, entails the need to understand which tools to employ (legislative, operational and informational), and what the infrastructural requirements are for the implementation of such a study as climate change. This need for awareness is evidenced by various studies which employed diverse methods as the technology available for the thematic analysis was enhanced (Goodchild et al., 1996, Feenstra et al., 1998, Klein et al., 2001 and Gardiner et al., 2010).

1.3 Preparing for Change Requirements: The Legislative Scope

The Maltese Island's process required a review of the environmental obligations for Malta's adherence to environmental reporting and sought to ensure that society should undergo changes the technologies would be in place to ensure the understanding of the resultant occurrences as well as enable continuous monitoring and reporting. The focus was on seven themes: five environmental (air, water, noise, radiation and soil), one social and one concentrating on the technologies required to deliver baseline and real-time parameter monitoring from remote and in-situ sources. The themes were chosen as per Malta's Acquis Communautaire and the relative legislation (Borg and Farrugia, 2010). These included the need to analyse the current situation, carry out baseline studies and propose future changes to legislation and operational requirements aimed at identifying the respective monitoring requirements and outlining the institutional roles and responsibilities with respect to the monitoring of hundreds of reporting parameters. This exercise led to a detailed outlining of the technical and legislative requirements pertaining to each theme. It also resulted in a feasibility study and cost-benefit analysis study pertaining to the post-project upkeep. In addition the output also featured a report on the needs to build a bottom-up series of Management Information Systems and Executive Information Systems that would enable ongoing reporting of the environmental data. The final outputs of the project would be to enable the transmission of knowledge and tools for cross thematic data analyses and models which would be required for the forecasting of the environmental themes in potential scenarios created for early-warning impact analysis emanating during climate change (figure 3).

1.4 Initial Thematic Targets: Environmental

Each of the thematic targets were identified for their potential impact on climate change due to their explicit as well as inherent data-cycle requirements that would impinge of the analysis of climate change. Each theme was chosen for its potential impact on climate, for the actual data cycles (gathering, analysis and output) and for the indirect data that effect or would be effected by climate change such as sea level rise, water contamination, dispersal of chemicals in soil, radiation dispersal monitoring, seepage of seawater onto the freshwater aquifers and meteorological data, amongst others. The thematic data would then be integrated into a model that includes spatial planning datasets for such analysis as seepage of seawater onto contaminated sites, impacts on industrial zones such as the power-generation plants. The relevant hardware and software were marked for acquisition within each theme. The themes are briefly outlined below:

1.4.1 Air

Whilst the main emphasis was placed on the monitoring of ambient air quality and the diverse variables as required for national and long-range monitoring aimed at understanding the changing air quality in urban and rural areas, the output also includes compliance monitoring for industrial operations requiring an environmental permit - IPPC Directive (OJ, 1996). Another requirement was based on the need to develop a conceptual modelling system, which system would be able to monitor the effectiveness of air quality and emission control policies, design and test pollution level projections, as well as develop custom made models on energy, transport and meteorology with regards to climate changes as they occur. This would be a dynamic model aimed at monitoring of real-time incoming data.

1.4.2 Water

Still in its early stages of the development of a strategic plan for water resources, Malta is implementing the EU Directives pertaining to the Water Framework Directive (2000/60/EC), as well as the Nitrates and Urban Wastewater Treatment Directive. These instruments serve as the launching pad to analyse climatic changes on the biological, physico-chemical and hydromorphological quality elements. The project aimed to become compliant through the generation of a baseline survey of the coastal waters to be within 1 nautical mile from the baseline coast. In effect, the data will serve as a first baseline data layer aimed at setting the reference dataset for the subsequent analysis of climate change impact on: i) the biological parameters (angiosperms (posidonia oceanica), benthic invertebrates, macroalgae, phytoplankton, and chlorophyll; ii) the physico-chemical parameters that support the biological quality elements (pH, temperature, salinity, and nutrients in water and sediments); iii) direction and speed of predominant currents and wave exposure; and iv) pollutants in water and sediments.

1.4.3 Radiation

Malta currently implements a monitoring plan entitled the First National Environment Radioactivity Surveillance Plan (FNERSP) targeting air and water monitoring system. The outcomes of the review as based on Commission Recommendation 2000/473/Euratom Articles 35 and 36 will deliver a baseline marine and soil survey employing gamma spectrometry as well as allow for real time gamma monitoring.

1.4.4 Noise

Although not as directly related to climate change as the previous themes, ambient noise still forms a substantial component due to its indirect input into analysis of parameters such as pollutants in air as it measures agglomeration (population density, soil sealing, building density), road traffic (peak time and continuous emissions) and industrial activity (zones, airports, seaports).

1.4.5 Soil

Soil monitoring is deemed essential for its chemical storage potential and subsequent indicators for accumulation over time as industry, extreme events and other changes occur. The project brings in the soil component for its monitoring strategy, baseline and real-time data collection.

1.4.6 Social themes

The above themes relating to the natural environment could only exist within a wider framework, one which encompasses the real target for such studies: the social environment. The theme includes population studies (population density, cities on coast, dwelling density, soil sealing), and its impact on the socio-economic scenario. In addition, the studies include the creation of datasets outlining the urban and rural infrastructure (residential, industrial, social and community, retail, utilities).

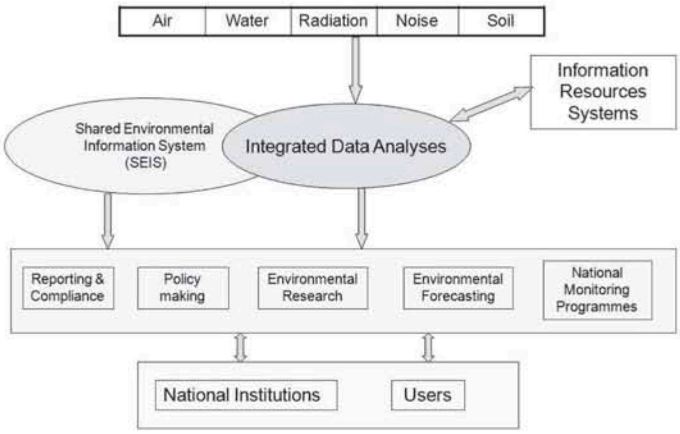

Figure 3: Integrated Model

2 Deus ex machine: The Informational Resources

The different theme requirements at all point towards the need for integrated information systems that are designed to create the necessary data capacity within a spatial structure setup; systems that are essential but not necessarily seen by the final users: the ghost in the proverbial machine!. The initial studies identified specific resources comprising hardware and software such as the installation of a permanent positioning system and the acquisition of spatial imagery and digital elevation models (DEMs) that serve to prepare the foundation for a precise data gathering structure. In addition, geospatial software and corresponding hardware were deemed essential in order to enable analysis of the collected geodata and to contribute towards meeting the environmental monitoring obligations. In summary, Malta's climate change analysis benefits from the following setup.

2.1 Software

The various software licenses comprise Geographical Information Systems (GIS) and image processing software. These are crucial for the processing of the satellite imagery acquired and for the spatial display, modelling and analyses of the monitoring data collected. Such software also enables an integrated analytical approach towards assessing the cross-thematic monitoring data and enables the necessary environmental reporting.

2.2 Hardware

Hardware includes a storage area network, servers and computer workstations for the geographical processing of the environmental monitoring data acquired. A 3D colour printer, a handheld 3D scanner and an A3 colour laser printer were installed to enhance landscape modelling and environmental analysis and corresponding outputs.

2.2.1 Data capture systems

- GPS handheld receiver and accessories Portable mapping device for the collection of monitoring data and location information on-site enabling efficient asset management in the field. Receiver and data collected will be fully compatible with GIS software acquired for the project.
- Global Navigation Satellite System Permanent Station

Geodetic and topographic surveying is used for environmental monitoring, including georeferencing of sampling locations and delineation of boundaries of nature protection and conservation zones. Using this network, the geographic locations of environmental data are referenced to a unique system which enables measured geographical data to be comparable with similar data from other member states.

- Remote capture GPS receiver

Such refers to a GPS receiver capable of capturing positional information remotely from any location. This will enable the operator to determine the location of environmental monitoring targets which cannot be accessed easily. This ensures the operator can collect positional data safely and significantly reduce field time.

- Satellite imagery for land cover monitoring

High resolution colour image maps of the Maltese Islands acquired from satellite imagery on separate dates. The image maps will act as base maps onto which monitoring data will be plotted. Furthermore, land cover maps will be derived from the satellite images using image classification techniques and analyze assessment of land cover changes. Land cover data will form part of the data input for modelling of environmental monitoring data.

2.3 Terrestrial 3D Surveys and Coastal Water Bathymetric Surveys

- 3D scan capture - LiDAR (terrain) Light Detection and Ranging (LiDAR) is a remote sensing laser system used to collect topographic data. In this case, an aerial survey using LiDAR technology will be used to capture topography over land areas. The end result would be a 3D model of the terrain (i.e. incorporating height data). This digital terrain model and topographic maps created are crucial datasets for 3D modelling of environmental data.

- Oblique aerial imagery

Oblique aerial photography technology allows multiple perspectives of the terrain. High-resolution images can be visualised from multiple views thereby enabling better analysis of the terrain. Such imagery can be incorporated into the GIS and combined with the environmental datasets produced.

- Bathymetric scans capture (0-15m in 1 nautical mile)

Aerial LiDAR survey targeted to measure bathymetry (water depths) of coastal waters. Bathymetry will be measured between 1m and 15m water depths within 1 nautical mile from the

Maltese coastline which are required as part the data requirements for the Water Framework Directive and for modelling of water monitoring data.

- Bathymetric scans capture and seabed surveys (15-200m in 1 nautical mile)

Bathymetric survey of coastal waters captures data between 15 and 200m water depths and within 1 nautical mile from the Maltese coastline. Sonar survey equipment will be used as mounted on a vessel. This seabed survey comprises an acoustic scan and grab sampling survey so as to provide an assessment of the seabed's physical and biological characteristics. Both the bathymetric data and seabed characteristics data within 1 nautical mile are required as part the data requirements for the Water Framework Directive and for modelling of water monitoring data.

2.1 Data Cycles and Spatial Technologies: Initial Outputs

The results show that as the data is integrated into one system, the outputs aid the researchers to carry out detailed analysis such as the identification of vulnerable areas affected by climate change. This secludes analysis of urban areas that will be effected due to their topographic location using oblique imagery (figure 4), building 3D models of the zones and the infrastructure in order to identify those areas that will experience sea level rise employing DEM (figure 5) and LiDAR (figure 6), employing height/depth interpolation and slope analysis (figure 7). These initial outputs show that with the setting up of an integrated system which adheres to official environmental requirements, results are readily available, pending the further scenario testing as new knowledge is made available.

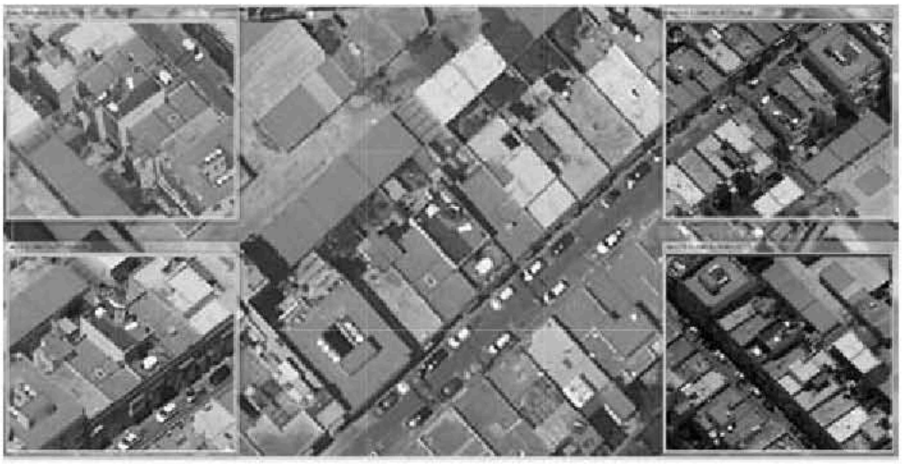

Figure 4: Satellite and oblique imagery

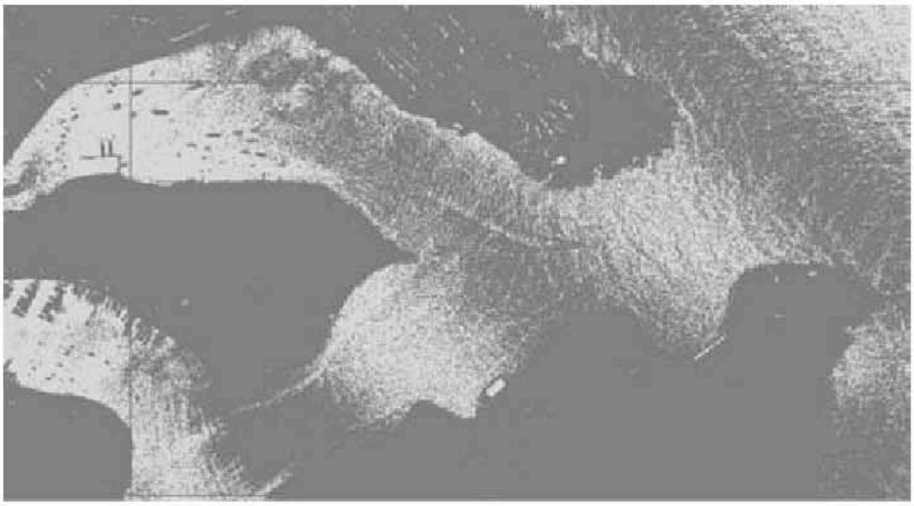

Figure 5: DEM


Figure 6: LiDAR

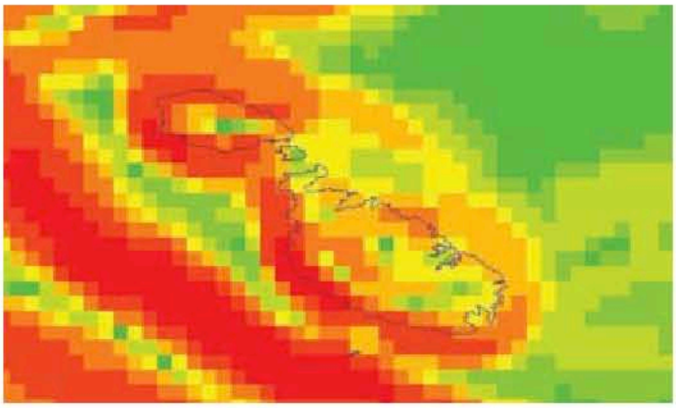
Figure 7: Slope analysis

Figure 8: SEIS interface

3. Disseminating the Deliverables
The Malta case study serves as a best practices approach towards the setting up of a system that facilitates scenario-testing within and across the different themes. The Malta initiative went further to ensure that the information is freely disseminated

over the web through the implementation of an online tool that integrates web-mapping as its basis, with a spatial interface and a solid database backend (figure 8). The Shared Environmental Information System (SEIS), which is an EU initiative emanating from the Commission of the European Communities in 2008 (Borg and Farrugia, 2010), aims to acquire all the reporting requirements and streamline them in a single system. Malta is creating one of the first tools that is based on the INSPIRE Directive implementation rules and also employs the SEIS principles ensuring wide use of the environmental data, in turn using the Aarhus dissemination protocols as a conveyor.

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