PROF SAVIOUR FORMOSA, DR JANICE FORMOSA PACE
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RISE IN PUBLIC:

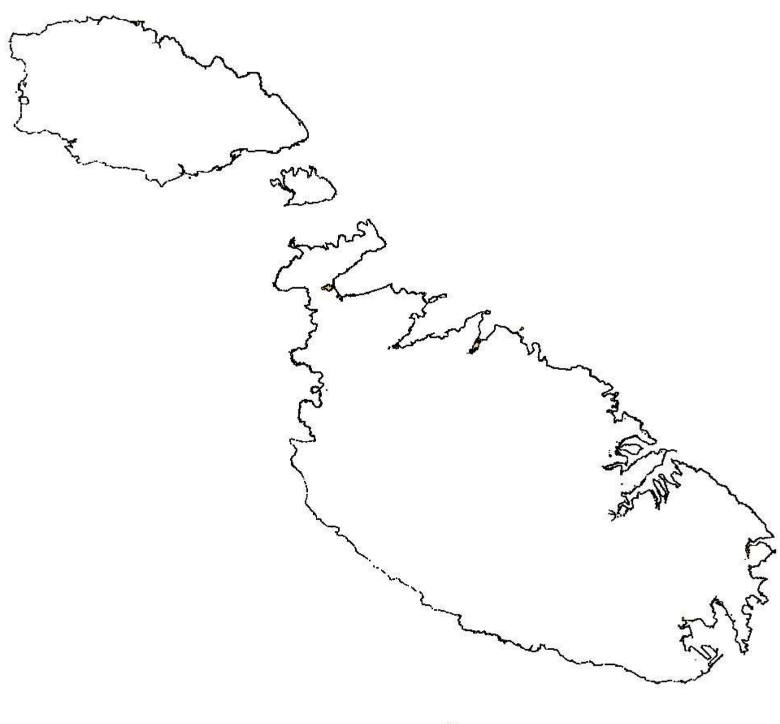
IDENTIFYING THE VULNERABLE PUBLIC AREAS AND ENTITIES

AT 0.5M, 1M SEA LEVEL RISE (SLR)

SUMMARY

An analysis of the 0.5m and 1m sea level rise impact area was carried out to ascertain those areas that will be impacted, covering thematic issues such as transport and public buildings/entities.

The main results show that whilst the road network will be impacted, public amenities will not be affected by such a rise, even when one caters for a 10m buffer extension to compensate for sea surges. The amenities will only be impacted minimally as most buildings falling within the zones pertain to private entities (commercial) and residential zones not analysed within the remit of this study.



Keywords: climate change, LIDAR, spatial data, GIS, 3D, scenario-building, public entities, Malta

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Prof Saviour Formosa, Dr Janice Formosa Pace

University of Malta

Scope

The study scope was twofold: i) to identify those areas that will be inundated by 0.5m SLR and 1m SLR respectively and ii) to identify the entities/infrastructure that will be effected by the SLRs.

Methodology

The methodology employed for this study entailed the conversion of the .las (LiDAR) format data to a TIN (triangulated irregular network) model which rendered a raster output that enabled the identification of those areas that pertain to specific height ranges. Through the use of various GIS tools, the relative target zones were extracted at 0.5m, 1m,. These heights were taken to be consistent with the previous Malta-related studies. An assumption was carried that the models highlight the highest passive sea-level rise, which in turn do not account for storm surges or medicanes, thus once the 0.5m and 1m areas were mapped, a buffer zone of 10m around the boundaries was employed as a surrogate to account for the event of such surges, which surge extent requires further study post this paper.

Figure 1 depicts the resultant topographic changes that would be experienced as sea-level rises, renders at current status (Figure 1a), 2m (Figure 1b). The area loss is visualised in four main areas: the northern part of Mellieha / San Pawl il-Bahar, the Harbour areas, Marsascala and Marsaxlokk zones.

Figure 1a: Topographic - Current

Figure 1b: Topographic – 2m SLR

The next step in the data preparation process entailed the conversion from raster to vector formats which was carried out in order to extract the zones under inundation potential. The vector model was partaken to due to the fact that most spatial data created in Malta pertains to this format which also allows for various queries, not readily available in raster format. Each of the resultant vector files were combined to ensure that the individual 'pixel' output from the raster was aggregated into homogenous polygons. The data was then cleaned through the removal of boats (higher than 0m above the sea-level) residual from the TIN, where the process entailed the re-disaggregation of the polygons and through a cookie cutting exercise in conjunction with a layer of non-land polygons created for the boat zones, the 'pixel' polygons were eliminated. This resulted in a layer that contains solely land-based polygons that was combined to render a single polygon layer for that height. All other layers were in turn aggregated.

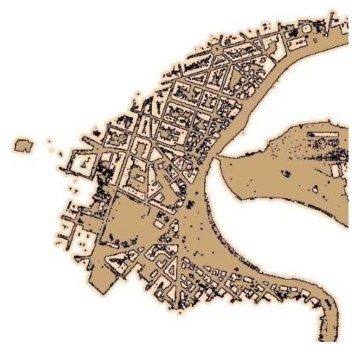
The final step entailed the creation of a buffer of 10m which data allows for the potential 'flood zones' that are impacted by surges and other streets effected by the closures emanating from sea-level rise. The buffers were aggregated into one workspace and the relevant inundated layers were created.

The buffer zone areas were calculated as based on the actual inundated zone and the potential buffer zones pertaining to that zone. As the spatial capture is based on the height under study, the higher infrastructure is not captured as the LiDAR data posits the highest elevation of any point. Thus if a building has a height of 15m and the rise under study is that of 5m, whilst the street and open spaces would be captured in the analysis, the building footprint would not as in the Gzira case depicted in Figure 2a. A buffer query (Figure 2b) was employed to enable the capture of the area falling within the building footprint since it is assumed that any building that experiences inundation in its lower floors would be abandoned or rendered unusable. Figure 2c depicts the overlay of the build areas and the buffer which covers the area under study ensuring that point-in-polygon queries are made possible.

Figure 2a: Actual capture build

Figure 2b: 10m buffer

Figure 2c: Build plus buffer overlay



A depiction of the Marsa zone shows that overlaying all the potential sea-level rise (SLR) heights under study is best served by the buffer layers as they have less ‘holes’ and are more structured to employ in the layering processing. Figure 3a depicts the Marsa pixelated output as resultant from the TIN extraction, whilst Figure 3b depicts the homogenous buffers for each SLR.

Due to the projection incompatibility that Malta has yet to implement, all data was converted to a common projection to ensure cross-thematic analysis, which projection pertained to the European Datum 1950 (ED50 Malta). Maltese data is available in a non-Earth projection and has to be converted to a real projection in order to allow overlaying of the thematic data over real-space data such as is the LiDAR output. In terms of the data analysis process, various spatial tools were employed, inclusive of cookie-cutting, overlays, point-in-polygon and SQL querying. In addition, 3D analysis on the TIN files was carried out to render the potential area changes.

The findings depict the analytical outputs for the zones falling within the 0.5m and 1m SLR, which were chosen to gauge how far the SLR will effect Maltese society. This decision was taken in order to gauge how far Malta will be effected as against an incremental change analysis based on each SLR..

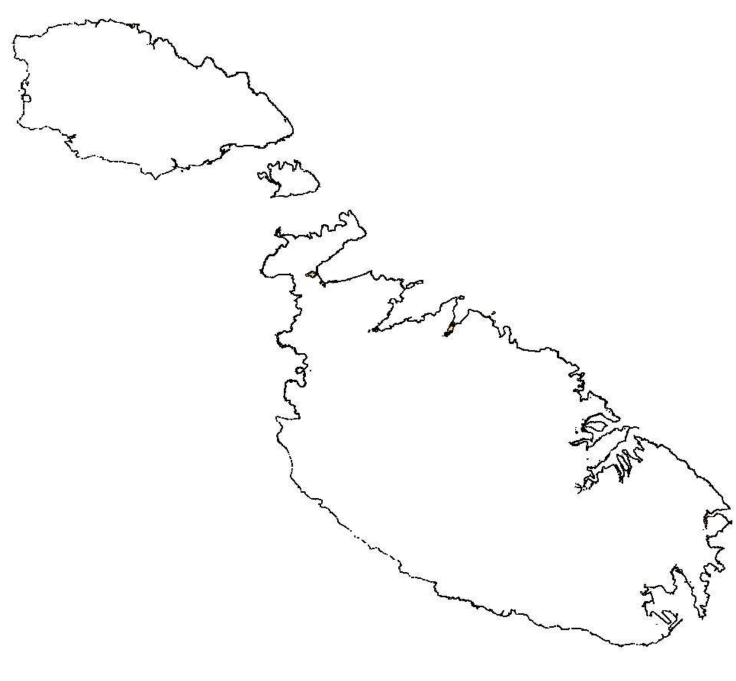
Findings - Spatial

The initial analysis to identify the zonal extent of the sea-level rise as based on the two heights under study (0.5m and 1m) took into account the buffer zones as detailed in the earlier section, where the zones ranged from a minimum of 0.6 km.sq for the TIN 0.5m SLR, the effected buffer zone renders an area of 6.1 km.sq which area includes all the building footprints and the adjacency area that could potentially fall within the surge zone. Table 1 depicts the relative effected zones, where the area range up to 1.3 km.sq for the TIN area and 7.4 km.sq for the 1m buffer zone. The TIN 0.5m SLR and the 1m SLR show relatively low areas being effected, which is extenuated when the buffers are brought into account.

Table1: Buffer zone areas

Height (m)	Area (km.sq)	
SLR	Area in TIN	Zone Buffer
0.5	0.6	6.1
1	1.3	7.4

Figure 4: Sea level rise at the different potential rates



Findings – Thematic: Zoning Categories

In terms of thematic analysis, the results show the following aspects:

i) Transport: - Arterial and Distributary Roads

The roads impacted are in general not affected by such rise, though in some areas as detailed below intervention is required to ensure that mitigation is possible.

Gozo road infrastructure (arterial and distributary network) will not be affected. Malta, on the other hand will be affected in various zones, mainly:

Ghadira Bay that will be affected by 1m SLR (Figure 5a), as currently the road serves as a barrier, Pwales will also be affected by both 0.5m and 1m SLR (Figure 5b), Msida and Marsaskala will be affected by both 0.5m and 1m SLR (Figure 5c and Figure 5d).

Legend for Figures:

Figure 5a: Ghadira Bay

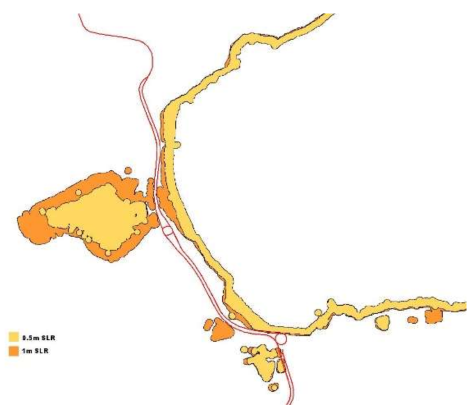


Figure 5b: Pwales Bay

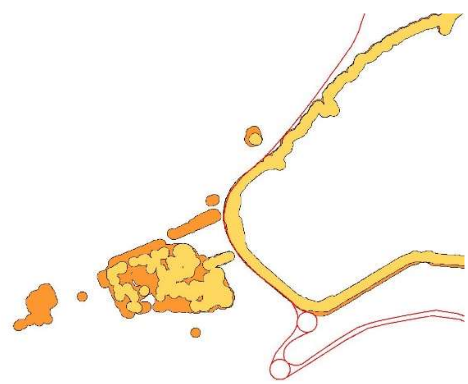


Figure 5c: Msida

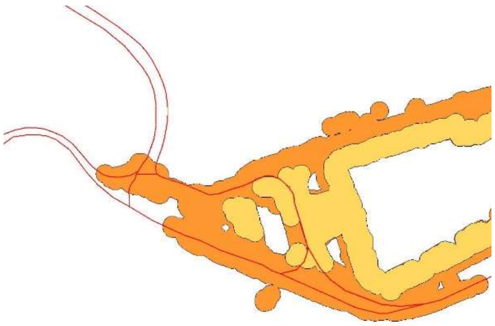
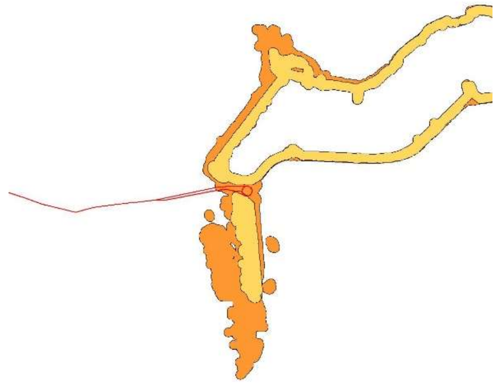


Figure 5c: Marsaskala



In terms of all other roads, a significant number will be affected within the zones under study, which incidence is actuated by the fact that the 10m buffer analysis was taken into account.

As an example, B'Bugia will experience a number of roads (144 in total) that will fall within the SLR buffers (Figure 6), however such have to be treated individually in a further analysis as some, whilst falling within the buffer may be higher than the expected rise due to a sharp gradient from the 0.5m/1m actual area and the relative buffer. It would be best if these roads would be listed for potential change, however the main emphasis should be on the arterial and distributary roads.

Figure 6: Birzebbugia all roads

ii) Public Buildings

In terms of an analysis of public entities that would fall within the 0.5m and 1m SLR buffers, an analysis was carried out on the addresspoint data emanating from WSC addresses through a query pertaining to the WNRES (Non residential) category that includes all public entities. Subsequent queries relate to the identification of those entities that fall within the 0.5m and 1m buffer zones.

The results show that the infrastructure falling within such areas is very low in count and pertains to offices (police stations, customs and agricultural and fisheries), which infrastructure may be moved over the period within which the SLR is expected to occur.

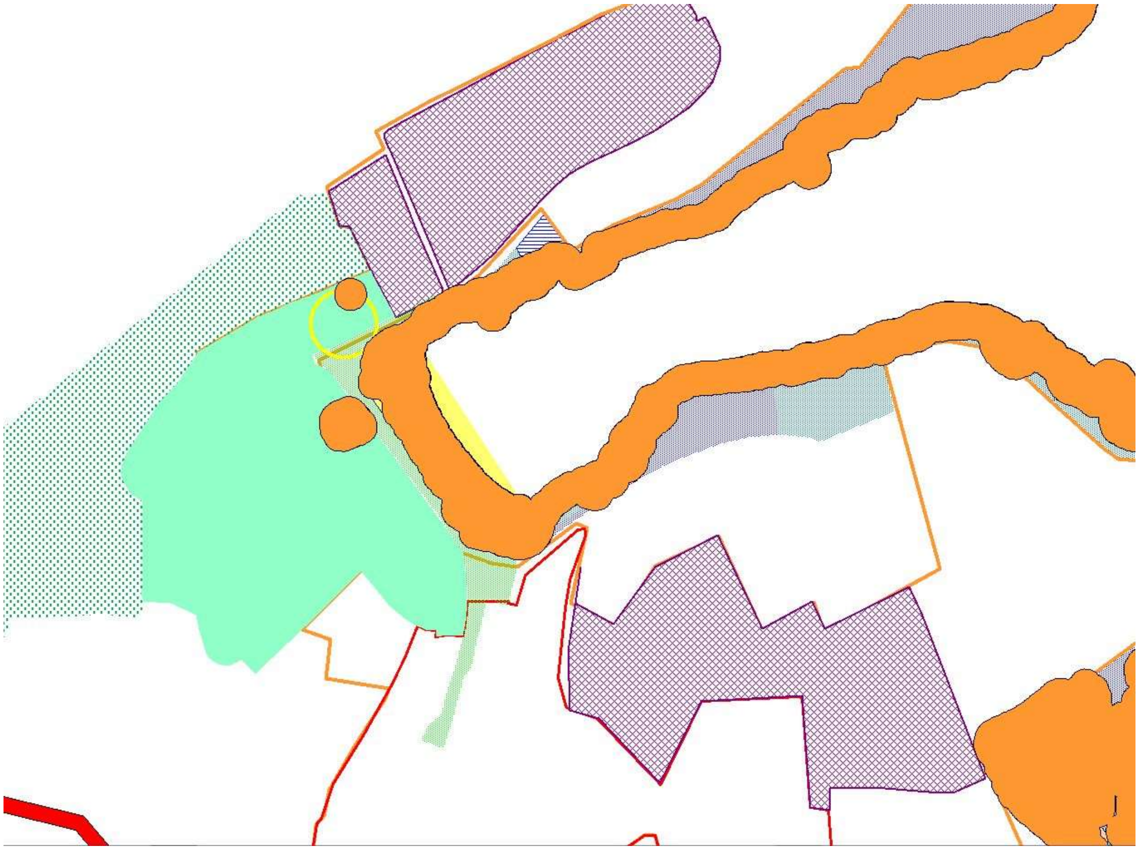
Category	0.5m SLR Buffer	1m SLR Buffer
All non residential entities (Public and Private)	40	137
Public	5 (1 Police department, 2 agricultural, 2 customs for 1m)	7 (2 Police department, 3 agricultural, 2 customs for 1m)

iii) Other thematic issues

An analysis based on policy mapping shows that all sandy beaches will be affected and each beach needs to be individually analysed through high definition scanning to investigate the morphological changes wrought by SLR. As an example San Giljan Bay (St George's Bay) as depicted in Figure 7 will be affected in its entirety due to the low gradient and the narrow width of the sandy part. Beach replenishment constitutes 3 areas that will be affected.

In terms of an analysis of other thematic issues, such as those identified in the Policy Maps that include constraints mapping, one needs to discuss whether to include them in such an analysis since they refer to constraints and as such may yet be implemented, does each development/process can be evaluated on a case by case basis. In terms of zones, the areas affected are predominantly those related to residential, protected areas, coastal uses, entertainment priority areas, open space and environmental uses that in sum total 30% off all uses.

Figure 7: San Giljan Bay (St George's Bay)



Conclusion and pointers for further study

This exercise sought to understand which areas will be impacted by Sea-Level Rise at 0.5m and 1m respectively, which shows that the main themes that will be impacted will be those arterial and distributary roads that have been identified as Ghadira, Pwales, Msida and Marsascala. The other roads that fall within the zones primarily fall within the lesser categories of such infrastructure and need to be investigated further in the future to enable analysis of the actual lengths that will be inundated, steepness of slope and other aspects.

Public infrastructure that falls within the zones were identified for their import and show that the main categories that fall within both the 0.5m and the 1m SLR buffer and are comprised of small edifices that could be transferred to other streets. However, it is to be noted that there are other edifices in the areas under study and that such are comprised of private entities.

For further analysis, this study could be extended to cover the risk maps pertaining to the critical infrastructure that have yet to be mapped.

References

Briguglio L. (2000). Implications of accelerated sea-level rise (ASLR) for Malta, proceedings of SURVAS expert workshop on European vulnerability and adaptation to impacts of accelerated Sea-Level Rise (ASLR). Hamburg. Germany. 19 -21 June 2000

European Environment Agency (2005). The European environment — State and outlook 2005. Copenhagen

Farrugia M (2011). Perceptions on sea level rise in small Mediterranean islands with special reference to the Maltese islands. Unpublished MA dissertation. University of Malta

Feenstra J. F., Burton I., Smith J. B. and Tol, R. S. J. (1998). Handbook on Methods for Climate Change Impact assessment and Adaptation Strategies. UNEP. Vrije Universieit Amsterdam.

Formosa S. Magri V., Neuschmid J. and Schrenk M. (2011). Sharing integrated spatial and thematic data: the CRISOLA case for Malta and the European project Plan4all process. Future Internet 2011, 3(4). 344-361

Formosa S. (2013). Future-Safe Malta. Think. Winter 2013. Issue 4, 26-33. University of Malta, Msida

Formosa S., (2015), Rising waters: Integrating national datasets for the visualisation of diminishing spatial entities, Xjenza Online, Vol 3(2), 105-117, doi: 10.7423/XJENZA.2015.2.02

Tol R.S.J., Klein R.J.T., Nicholls R.J. (2008). Towards successful adaptation to sea-level rise along Europe's coasts. Journal of Coastal Research. Vol. 24(2), p.432

Walker-Leigh V. (2006). Climate change and Malta, future climate change policy: looking beyond 2012. International workshop 11-12 October 2006. Ljubljana