VULNERABILITY EVALUATION OF A SECTOR OF GRAN CANARIA EAST COAST AGAINST A POSSIBLE INCREMENT OF SEA LEVEL

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ABSTRACT

An increase of 0,5°C in average atmosphere temperature has been registered over the last century. Based on the current levels of greenhouse gas emission, temperature increases could reach 1,5 to 4,5°C by 2030. A consequence of this phenomenon is the rise of sea level, to which islands are vulnerable. To consider a possible marine transgression is fundamental for island ecosystems management. The island of Gran Canaria has a mountainous west coast, but an alluvial plain dominates its east coast, where urban development is higher. The vulnerability of this area of the Gran Canaria coast against a marine transgression was evaluated. A digital elevation model (DEM) was created from a topographic chart (1:5000) and used to simulate marine transgressions scenarios, based on projections found in literature. Probability charts were then created, where the probability of each DEM cell of being above or below a threshold was calculated according to Bayesian theory, considering errors in database and decision rule. There is 60% probability that the sea will reach the benchmark of 1,13 m, with an increment of 1,5 m ± 1 in its level and the benchmark of 1,52 m, with an increment of 1,9 m ± 1,22. The probability chart superimposed onto a soil occupation chart reveals that the most vulnerable areas, considering human occupation, are the Burrero Beach and Las Palmas Airport.

INTRODUCTION

It has been estimated that atmosphere temperature has increased by a half degree centigrade over the last hundred years as a result of the greenhouse effect (Mahtab, 1989). CO_2, CFC, methane and water vapour are mostly responsible for this phenomenon. In the last decade about 5,4 billion tons of CO_2 where released annually into the atmosphere. Forest fires also contributed with more than 1,5 billion tonnes per year and supposed a biosphere loss of CO_2 recycling capacity. Projections based upon the same levels of greenhouse gas emissions show that the atmosphere could reach temperatures between 1.5 and 4.5°C above present temperature by the year 2030 (Revelle, 1983; Mahtab, 1989). This would be the biggest temperature increase in the whole history of earth (Clark, 1996).

One of the consequences of the global increase of temperatures is the rise of the average sea level due the fusion of glaciers and the Antarctic ice coat. Over the last one hundred years there has been an average increase of 27,7 cm in sea level in open beaches of North American Atlantic coast, reaching 43 cm in Texas (Clark, 1996). There is no expert agreement about what will be the average rise of the sea in the next hundred years or if it will be the same for all coasts of all countries. The only consensus is that this information is of utmost importance for resource planning and management in coastal zone

(Clark, 1996). Mahtab (1989) gives the most pessimistic prediction in which an average atmospheric temperature increase of 3°C for 2030 would raise sea levels by 1.5m. Barth & Titus (1984) after some project revision came to an average value of 1.9m (± 1.22) for the year 2100. In the same way Clark (1996) gives different predictions for the rise of sea level between 50 and 250 cm for the next hundred years (1.5 m ± 1.0).

Perturbations induced by rise of sea level are persistent and provoke irreversible changes in affected ecosystems. In these cases, ecosystems that are structurally more complex can be considered the least stable (low resilience) because they recover their characteristics more slowly along a new coastline (Forman & Godron, 1986; Margalef, 1993). The most vulnerable terrestrial systems are the more densely populated regions and the regions with greater biodiversity, particularly those of lower high ranges and situated on alluvial planes. The most vulnerable marine zones are those with high biodiversity such as coral reefs (Clark 1996). Less structurally complex systems are best able to fluctuate between a varying coastline.

In the case of an increase in sea level, planning of the coastal zone and coastal ecosystems vulnerability assessment starts with a cartographic delimitation of the probabilities of inundation as a function of the topography of a determined area. In order to prioritise and define between the vulnerable areas, it is recommended to cross information relating to the localization of zones with information on relatively higher structural complexes and non-consolidated substrates. Thus, a map model of a segment of the east coast of the island of Gran Canaria was drawn up (Figure 1) applying the technique proposed by Eastman *et. al.* (1993).

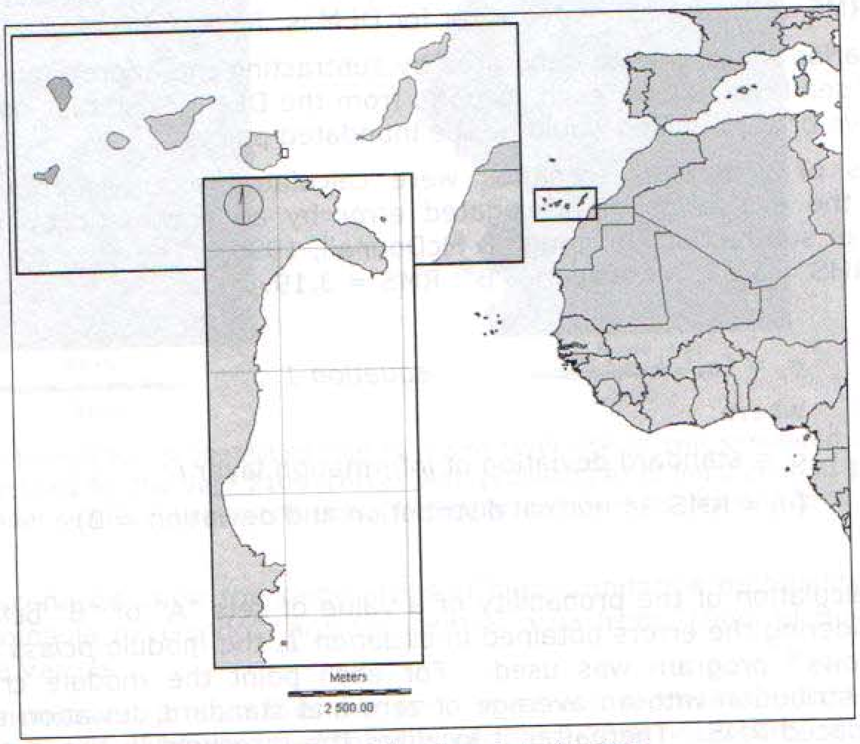

Figure 1: Localization map of Canary Island and study area.

The result for each value of the digital elevation model (DEM) of the area express its probability of being higher or below a determined level, taking into account errors inherent to the values matrix and to the rule of decision.

METHODOLOGY

Two guidelines were established for the evaluation of the modelling results ("A" and "B" sets), based on projections on sea level increase found in literature. Set "A" was established according to Clark's (1996) projection (an increase of 1.5±1 m in 2100). Set "B" was based on Barth & Titus (1984) projection (1.9±1.22 m in 2100). Set "B" was considered as a conservative estimate for the year 2030, if the projections of Mahtab (1989) were found to be real.

The hypotheses (H_0: height of point > 0; H_1: height of point ≤ 0) where evaluated using the *Bayesian Theory of Probabilities* for both scenarios. This permits the relation between the probability of an event and the feasibility of evidence, which depends of the existing doubt in the DEM and in sets "A", and "B" (Eastman *et. al.*, 1993).

A DEM is a *raster* image obtained by interpolation of digitalized level curves with 5 m intervals at scale 1:5.000. The existent error was estimated considering that 90% of the sample points are inside of the interval of contour (5 m), that the distribution of these points is normal (RMS = standard deviation) and that the deviation is zero (average = real value). For a normal distribution with a confidence interval of 90% the samples points should have a standard deviation of 1.645 from average (statistic table value). Since confidence interval is equivalent to map contour interval (1.645 RMS = C), the estimated error for DEM is: RMS = 3.03 m.

Scenarios A and B were generated by subtracting the appropriate average value of sea level rise for each scenario from the DEM. Resultant points with a negative or zero values would be the inundated points.

Errors of generated scenarios were calculated after *equation 1* that permits the evaluation of propagated error by an arithmetic operation of addition or subtraction (Burrough & McDonnell, 1998). The error for scenario A was: RMS = 3.27; for scenario "B": RMS = 3.19.

$$\sigma_z = (\sigma_x^2 + \sigma_y^2)^{1/2} \qquad \textit{equation 1}$$

where:

σ_i = standard deviation of information layer *i*

(σ_i = RMS $_i$ in normal distribution and deviation = 0)

For calculation of the probability of a value of sets "A" or "B" below zero and considering the errors obtained in *equation 1,* the module *pclass* of *Idrisi for Windows®* program was used. For each point the module creates a normal distribution with an average of zero and standard deviation equal to the introduced RMS. Thereafter it localizes the threshold in the distribution and integrates the area under the curve. This last function is interpreted as the probability in question (Eastman, 1993).

RESULTS AND DISCUSSION

Considering the *meta-stability* concept (Forman & Godron, 1986), which assumes that equilibrium is an oscillation state around a position that can change to another depending on perturbations, there can be long periods of small variations in sea level and followed by small periods of higher variation. In this context, the Mahtab projection (1989) for the year 2030 is feasible. Thus it is necessary to know the perturbation level responsible for causing an alteration of the meta-stable state. On the other hand Clark (1996) points out the necessity of taking note of the rise of sea level in every protection study, development or planning of coastal zone, without waiting to refine prediction models in order to avoid possibilities of risk. As Figure 2 shows, the inundation probabilities obtained for both simulated scenarios do not differ greatly.

Figure 2: Inundation probabilities due to a sea level rise in two simulated scenarios after projections for the year 2100. (Areas with probabilities of inundation of 100% are already under sea level in present days). More information is available in text.

Both scenarios show the same areas of high inundation probability: north, near "Peninsula de Gando", and the central area from "Playa el Burrero" to "Playa de Vargas".

The inundation probabilities for each level are represented in Figure 3. According to the database used there would be a 60% probability of sea level rising 1.13m above its actual average in scenario "A". On the other hand, a more conservative view (scenario B) indicates that there is a probability of about 60% of the sea level to reach 1.53 height

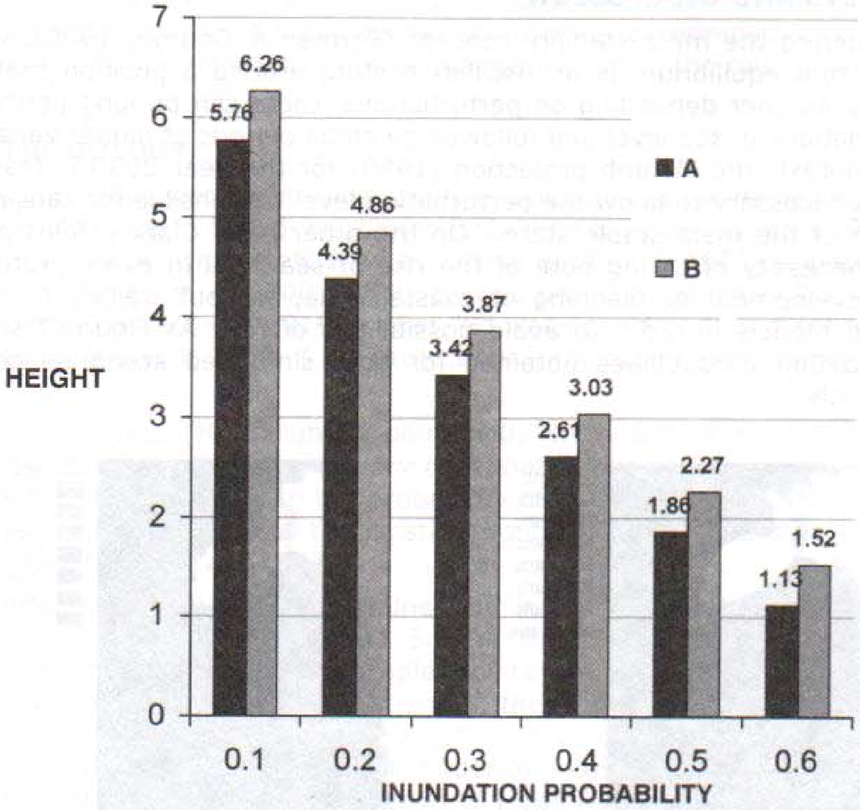

Figure 3: Inundation probabilities against heights over ground for scenarios A and B

The inundation probabilities for each level are represented in Figure According to the database used there would be a 60% probability of sea le rising 1.13m above its actual average in scenario "A". On the other hand more conservative view (scenario B) indicates that there is a probability about 60% of the sea level to reach 1.53 heightThe surface corresponding a 60% of probability of inundation calculated for set "B" is 7.7 hectares, larger area than that calculated for set "A". This demonstrates grea topographic variation at lower elevations in relation to higher elevations this DEM, which increases uncertainty for these areas. To avoid risks, in t case it would be prudent to adopt decisions based on more conservati probability values.

The total area corresponding to a 10% of risk of inundation is 103. hectares for set "A" and 144.51 for set "B" representing only 8.26% a 11.51% respectively of the total area of 1.254, 5 hectares in the DEM. T area up to 50% of risk represents only 1.14% and 1.72% respectively. The values are not of great concern, but in order to correctly evaluate t vulnerability of zones in question, it is necessary to cross this informati with others that represent the spatial complexity of the landscape (Forman Godron, 1986). For human systems, this complexity can be qualitative represented by the territory occupation.

Superimposing a cartographic base of the occupation of territory with t probability charts reveals that the most vulnerable places of the studi zone, considering the DEM and the decision rules adopted are "Playa c

Burrero" (Fig. 4) and the area near the "Aeropuerto de Las Palmas" and "Base Aérea" (Fig. 5). In "El Burrero" there is a 30% probability of inundation (scenery B) up to the second block of buildings.

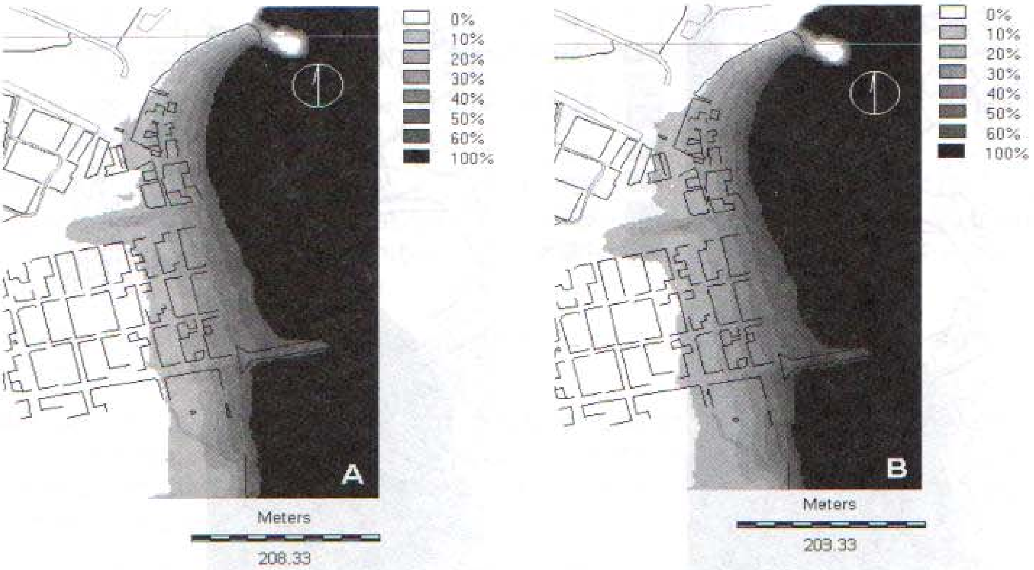

Figure 4: Probabilities of inundation in Playa del Burrero.

In both scenarios, the probability of sea invading about 50m of the "Base Aerea de Gando" is 30% (Fig. 5). The area comprising 10% is close to one of the runways of "Aeropuerto de Las Palmas" and inundates some buildings. Although considered low risk, this strategic area should be considered as vulnerable since it is situated in alluvial sedimentary ground.

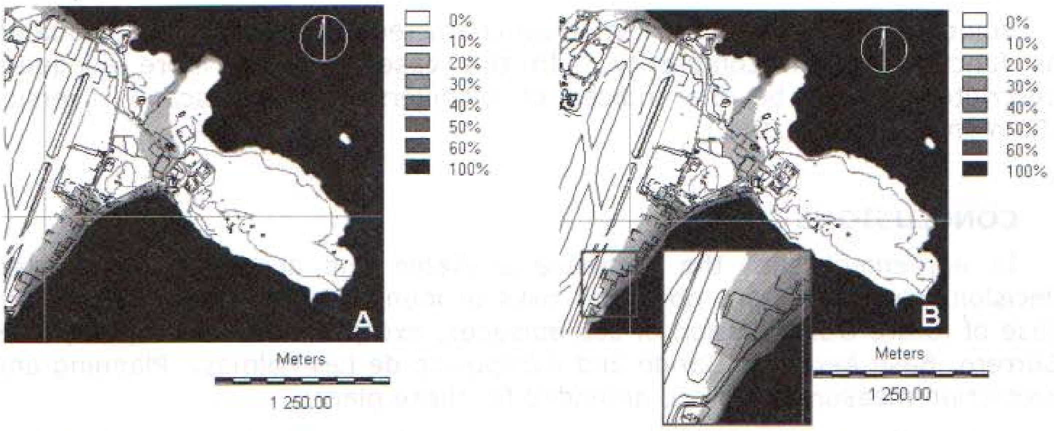

Figure 5: Probabilities of inundation in the surroundings of the Base Aerea and Aeropuerto de Gran Canaria.

Inundations are also probable in Playa Vargas, however this area is less vulnerable due to the low level of anthropogenic activity and human occupation, except for the area of Salina (Fig 6).

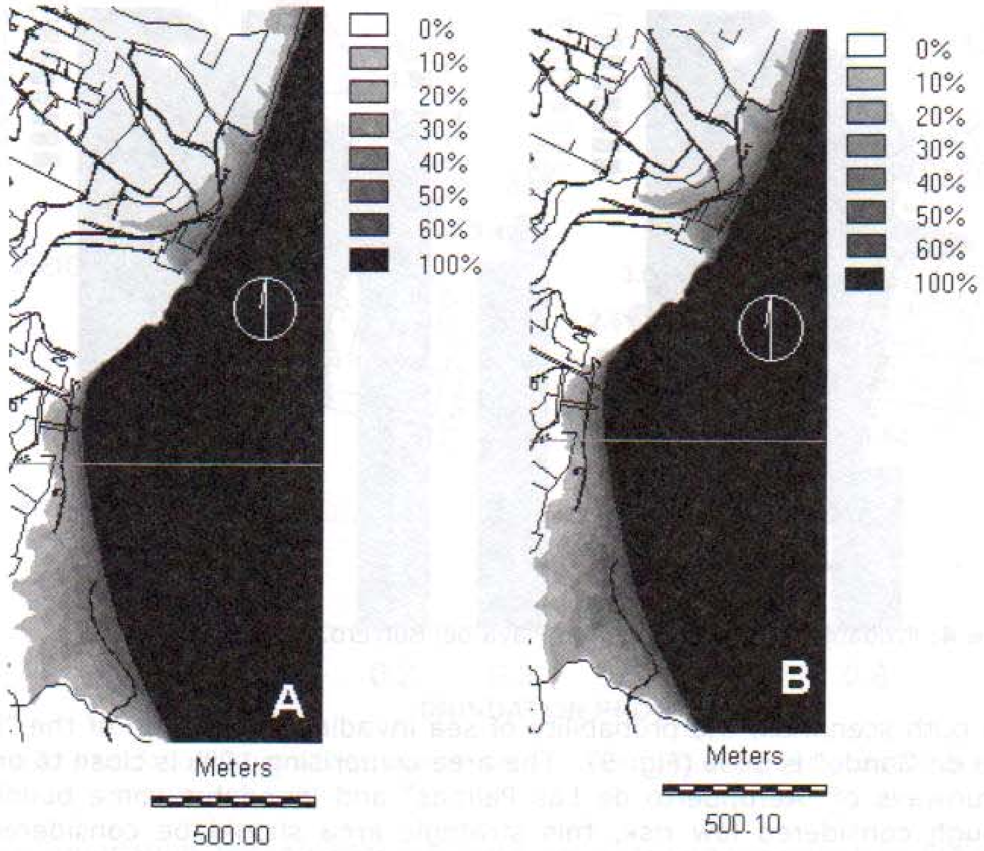

Figure 6: Probabilities of inundation in Playa de Vargas.

Vulnerability in relation to biological characteristics can be also evaluated as function system complexity. In this case however, more adequate descriptors would be the indices of biodiversity or landscape diversity (Forman & Godron, 1986).

CONCLUSIONS

In agreement with the database available and according to selected decision rules, there are no major risks of inundation in the study area, in case of future transgression of sea episodes, except in the zone of Playa del Burrero, Base Aerea de Gando and Aeropuerto de Las Palmas. Planning and protection measures are recommended for these places.

New studies to delimit vulnerable areas in other sides of the island of Gran Canaria are recommended. Some places in the south of the island are potentially vulnerable, especially large tourist complexes, situated in low lying areas formed by sedimentary deposits. Similarly a considerable area of Las Palmas, the island's capital, could be at risk to flooding caused by rises in sea level.

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