SOFTCOPY PHOTOGRAMMETRY AND LIDAR AS SOURCES FOR COASTAL MORPHOMMETRIC 3D SURVEYS (TIDAL MARSHES AND COSTAL DUNES): SPATIAL ANALYSIS CAPABILITIES IN A GIS ENVIRONMENT

Ojeda Zújar, J.[1], Vallejo Villalta, I.[1], Hernández Calvento, L[2]. y Álvarez Francoso, J[1].
[1] Dept of Physical Geography. University of Sevilla
[2] Dept of Geography. University of Las Palmas de Gran Canaria

INTRODUCTION

The use of new data sources and spatial analysis tools in coastal research is increasing during the last years (Saye et al, 2006; Mitasova et al, 2005; Stephenson y Branderb, 2003; Brown y Arbogast, 1999). As a result of this process, now it is possible to incorporate volumetric and coastal features evolution analysis (beaches, dunes, marshes…) in the research scheme, as well as the detailed modelling of some critical processes in coastal geomorphology (flooding, erosion, etc…). In order to carry out these tasks there are two essential methodological steps: the development of accurate DEMs and their treatment in a GIS context.

Due to the tree-dimensional nature of coastal natural processes and their related morphologies, it seems reasonable the interest in morphometric data sources which are able to provide spatially-continous and almost-synoptic temporal information. The decreasing prices of digital photogrammetry softwares and present accessibility to airborne LIDAR data, give geomorphologists news possibilities in coastal research. Digital data provided by these technologies and the spatial analysis capabilities of GIS, point to the latter as the natural context for integration, analysis, visualization and modelling of these geo-referenced information.

OBJECTIVES

Main goals of the paper are two fold: (i) to show some specific results of the application of these technologies and data sources to topographic 3D surveys and volumetric change analysis on tidal marshes and coastal dunes systems; (ii) mainly based on these results, to reflect on the wide range of classical coastal geomorphology issues where these new tools could be applied.

Among different research works by the authors, tree different coastal issues have been selected in tree distinct study areas (FIGURE 1):

- Areal and volumetric evolution of the Doñana National Park coastal dune system using softcopy photogrammetry.
- Detailed 3D topographic characterisation of Isla Cristina tidal marshes using airborne LIDAR data.
- GIS-algorithm development to model aeolian dynamic at the Maspalomas coastal dune system (Model Builder -ArcGis 9.2).

METHODOLOGIE AND RESULTS

1. The active dune system of Doñana Nacional Park (Huelva, Spain)

From a methodological point of view this work is based in the join analysis of 3 DEMs extracted by softcopy photogrammetry; corresponding photogrammetric flights dated from 1956, 1977 and 2001 (FIGURE 2).

Tree main steps are emphasized from the whole research process. The first one is mainly methodological and the other two are focused on results:

A) Digital restitution based on geomorphological interpretation.

All restitutions (stereocorrelation and structure lines) were made at Stereocarto Ltd, where our team dealed with capture of all those geomorphological features (mainly dune toes and slip faces) which are essential in DEMs dune generation. Afterwards, elevation data could be edited by softcopy restitution software (StereoCaptor) in order to improve their quality before DEMs were build up.

B) Digital orthophotos generation for areal change analysis and dune advance rates estimation

As derived information of the complete photogrammetric work, tree orthophotos were produced dated from 1956, 1977 and 2001. Common geometric and correction parameters for these tree sets of data allow multitemporal change analysis based on two different approaches: (i) differences in surfaces distribution of dunes and interdune depresions, and (ii) differences in slip faces positions as indicator of dune movement.

Two different periods were defined for both approaches (1956-1977 and 1977-2001), in order to evaluated differences between them. So, results show a clear change in dune system behaviour. On the one hand, it is detected a widening process of interdune depresions surfaces, in front of a narrowing process at dune ridges. On the other hand, slip faces are gradually slowing down; so, in 1956-1977 mean rate of advance is 2,7 mts/yr, whereas in 1977-2001 this rate drops to 1,7 mts/yr (FIGURE 3).

C) Temporal volumetric analysis (DEMs comparisons)

This second group of techniques are based on spatial analysis (map algebra) between DEMs, in such a way we got sedimentary budget for the same two periods (1956-1977 and 1977-2001). Obviously, negative values represent deflation areas, whereas positive values represent deposition areas (FIGURE 4).

Results are quite consistent with those derived by previous areal analysis. So, it is evident a reduction of the surface which represent depositional processes at the dune tops, whereas deflation areas from the toe of the dunes are progressively wider. As a direct effect, dune ridge show such a different profile: stoss faces (upwind) become convex, while dune top rises at a new join crest-brinck sector. Figure 5 shows a synthetic representation of these processes.

2. Isla Cristina tidal marshes (Huelva, Spain)

In this second example LIDAR data is used (TOPOSYS II) dated from 2003 to build up a DEM. Only the first return obtained by the sensor was used.

A) Geomorphological maps

Shadows and slopes DTMs were easily generated from the original DEM (2 mts pixel and 0,15 mts for elevation accuracy) once it was integrated in a GIS (ArcGis 9.2). GIS tools applied to the three surfaces (elevations, slopes and shadows) allow creating a wide range of maps, specially useful for morphometric and geomorphological characterization of tidal marshes (FIGURE 6).

B) Flood processes mapping

High elevation accuracy of DEM is an essential factor for tidal and marine levels mapping. In this case, flooding area maps were drawn for different tidal coefficients levels; these levels are essential for many ecological processes, including vegetation distribution patterns. Chosen levels (FIGURE 7) include mean lower low water MLLW (0.2 tidal coefficient and 0,5 mts over mean sea reference level —MSRL Alicante—), mean low water MLW (0,45 tidal coefficient and 0,93 mts over MSRL Alicante) and mean high water MHW (0,70 tidal coefficient and 1,32 mts over MSRL Alicante) (Fraile, 2005).

3. Maspalomas dune system (Canary Islands, Spain)

High dynamics of this system has been pointed out by different works where differential GPS was used to dune monitoring and rates of advance estimation. The join use of satellite images, aerial orthophotos and a DEM based on LIDAR data allow calculation of rates which reach 30 mts/yr at several places.

Main goal of the present analysis is to calculate the required time for dunes to travel all across the dune field, assuming present advance rates and directions.

A) From punctual to surface advance rates data

Used advance rates data were derived from orthophotos interpretation dated from two different periodods (2000-2003 and 2003-2006). Digitized slip-face lines were divided in equal spaced points for which displacements between different dates were measured. From these points two distinct surfaces were obtained by interpolation techniques (FIGURE 8).

B) GIS-algorithm development for dune displacement modeling

Once mean advance rates surfaces were created for the whole period (2000-2006) a simulation algorithm (FIGURE 9) was designed by using *Model Builder* (Arcgis 9.2); results obtained are show on figure 10.

CONCLUSIONS

Morphometric characterization and volumetric (sedimentary) evolution in tidal marshes and dune systems clearly reflect the great potential of digital photogrammetry and LIDAR data in coastal geomorphology. Different points have to be emphasized to explain these successful applications and their probable expansion in the next future:

On one hand, incorporation of the 3th dimension (z) it is essential in coastal geomorphology for two main reasons:

- Firstly, due to the great forms and processes dynamics (dunes, beaches, tidal process…) and to their huge spatial variability (in spite of their low elevation ranges).
- Secondly, due to the critical role of elevation in geomorphological (flooding, waves, deflation…) and ecological processes control (first line of vegetation on beaches, halophytic plants…).

Based on previous remarks, we conclude that it is essential to integrate elevation data sources in coastal geomorphology works, mainly when these sources provide spatially continous and temporary synchronic data (digital photogrammetry and LIDAR).

On the other hand, results show undoubtly that LIDAR is unrivalled when high precision elevation data is needed (flooding hazards). Join use of LIDAR, INS (Inertial Navigation System), and D_GPS, guarantee high geometric accuracy data even when we deal with extensive study areas.

Lastly, a wide range of morphometric information can be derived from all these used data sources. This type of information enlarges different kind of thematic applications, as its spatially-continous nature allows treatments by many analytical techniques (interpolation, map algebra, spatial correlation, modelling…), for which GIS is the most convenient context.