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Sea cliff instability susceptibility at regional scale: A statistically based assessment in southern Algarve, Portugal.

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Mass movements are the dominant process of sea cliff evolution, being a considerable source of natural hazard and a significant constrain for human activities in coastal areas. Related hazards include cliff top retreat, with implications on planning and land management, and unstable soil or rock movements at the cliffs face and toe, with implications mainly on beach users and support structures.
To assess the spatial component of sea cliff hazard assessment with implications on planning, i.e. the susceptibility of a given cliff section to be affected by instabilities causing retreat of the cliff top, a statistically based study was carried out along the top of the sea cliffs of Burgau-Lagos coastal section (Southwest Algarve, Portugal). The study was based on bivariate and multi-variate statistics applied to a set of predisposing factors, mainly related with geology and geomorphology, which were correlated with an inventory of past cliff failures.
The multi-temporal inventory of past cliff failures was produced using aerial digital photogrammetric methods, which included special procedures to enable the extraction of accurate data from old aerial photos, and validated by systematic stereo photo interpretation, helped by oblique aerial photos and field surveys.
This study identified 137 cliff failures occurred between 1947 and 2007 along the 13 km long cliffs, causing the loss of 10,234 m2 of horizontal area at the cliffs top. The cliff failures correspond to planar slides (58%) mainly in Cretaceous alternating limestone and marls, toppling failures (17%) mainly in Miocene calcarenites, slumps (15%) in Plio-pleistocene silty sands that infill the karst in the Miocene rocks, and the remaining 10% correspond to complex movements, rockfalls and not determined cases.
The space distribution of cliff failures is quite irregular but enables the objective separation of sub sections with homogeneous retreat behavior, for which were computed mean retreat rates between 5x10-3m/year in strong sandstones to 5x10-2m/year in Miocene calcarenites with frequent karst sinkholes filled with Plio-pleistocene silty sands, reflecting the strength variations of the rock masses that compose the cliffs. The maximum value of local retreat of the cliff top was up to 33m, in man induced failure, with more frequent values in the range of 2m to 6m.
For the susceptibility assessment a set of predisposing factors was studied using two statistical methods, the bivariate Information Value method, and the multi-variate Logistic Regression method, along successive constant length stretches of cliffs. The predisposing factors included: a) major lithostratigraphical units adapted from existing geological surveys; b) rock mass structure based in field observations; c) cliff height measured in 1:2,000 scale aerophotogrammetric surveys; d) general cliff slope angle generated from photogrammetric stereoploting of cliff top and toe; e) maximum cliff slope angle derived from the 1:2,000 scale aerophotogrammetric surveys; f) presence and type of cliff toe protection (plunging cliffs, fallen blocks, beaches, wave cut platforms) obtained in aerial photo interpretation and field work; g) land use; h) cliff exposure; i) cliff face aspect; j) presence of faults or dykes.
The two instability assessment models produced were validated using standard Receiver Operator Curves using the cliff failures inventory, and provided very promising results, indicating that these methods are adequate to assess cliff instability susceptibility at regional scale, enabling an objective and validated assessment in this highly complex natural environment.