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MULTISENSOR DATA INTEGRATION AND GIS ANALYSIS FOR NATURAL HAZARD MAPPING IN A SEMIARID AREA (SOUTHEAST SPAIN)

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ABSTRACT

Natural Hazards are mostly related to the actuation of active geomorphological-geological processes that condition landform development. The objective of this work is to evaluate a method to combine digital image processing techniques and GIS analysis in order to extract and classify the main terrain attributes that identify Natural Hazard prone areas and to improve the accuracy of the differentiated terrain mapping units. Synergism of multisensor data of different spectral and spatial resolutions (SPOT PAN and Landsat TM images), together with the use of a Digital Elevation Model for rectifying the multisensor data set and for relief quantification contribute to the delineation of terrain mapping units. Additionally, spatial frequency filtering is applied for the enhancement of geomorphological linear features, specially in those images with greater spatial resolution. The resultant integration of Remote Sensing imagery with conventional data (field work and thematic maps) in a GIS is an efficient tool for the assessment and mapping of Natural Hazards.

INTRODUCTION

The active geomorphological-geological processes such as tectonic activity, floods (sedimentation and erosion), mass movements, and others, provoke changes in the Earth's surface creating landforms and modifying, or destroying, existing ones. The study of the actual configuration and characteristics of the landforms, informs about which natural processes are active in the present and have been active in the nearly past. Observation of the Earth's surface from space is essential for mapping the terrain in terms of hazards. For this reason detailed surveys of the terrain using satellite images, aerial photographs and field-work should help in the recognition, inventory and delimitation of mapping units with their different attributes, that will be integrated with thematic data (maps of soils, geology, and others) in the spatial and attribute databases of a GIS. This method of terrain analysis for the identification and mapping of Natural Hazards is very important in a damage preventive approach in order to perform a proper land use planning and disaster prevention, especially in areas with human settlements, and to avoid these settlements in not suitable areas.

Satellite images play an important role in regional-scale analysis, where the initial objective is to divide the terrain in zones with homogeneous conditions of lithology, soil, geomorphological processes, and others (Van Westen, 1993). These zones with homogeneous conditions are also called Terrain Mapping Units, or TMU (Meijerink, 1988). Their importance in the interpretation of Remote Sensing images is due to the fact that the images represent the result of the integration of the reflectance of the terrain attributes (soil, lithology, vegetation, and others) and therefore there is a higher degree of correlation between this integration and the TMUs, than between the image and any single terrain attribute (Robinove, 1979; Franklin *et al.*, 1989). In a previous work (García-Meléndez *et al.*,1995)

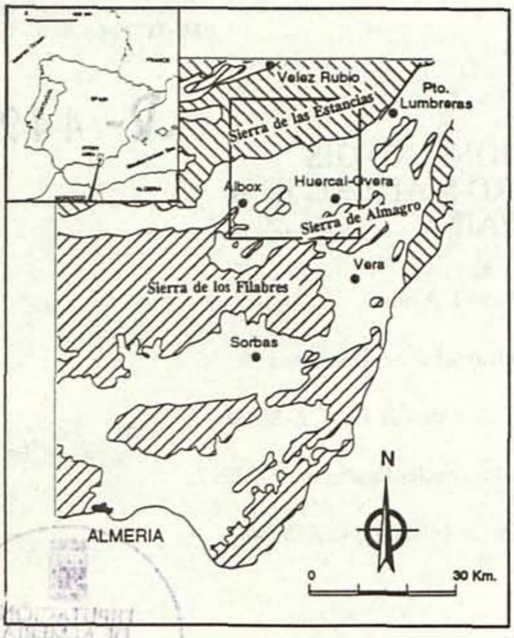

Fig. 1 *Location of the study area*

following an applied geomorphological method severa TMUs were delineated using Remote Sensing techniques with a visual analysis of separated images printed a 1:100.000 scale from different sensors. When the vector fil with the differentiated TMUs is overlaid with georreferenced false colour composition of the study area a a larger scale, the units show a big displacement (eve considering that an error should be present due to the scal change). For the creation of Natural Hazard maps with GI operations, it is necessary to improve the areal accuracy c the mapping units.

One of the main objectives of this work is to improve th accuracy of the delimitation of terrain mapping units, whic are important for the precise location of the natural hazar prone areas present in the study area, and for planification i order to avoid or mitigate the effects of the occurence of certain hazard. The purpose is to evaluate the integration of multisensor data set in order to differentiate mapping unit that show the terrain characteristics. First, a orthorectification is applied by means of a Digital Elevatio Model (DEM), then a synergism is applied to the datas using several methods. To this result Spatial frequenc filtering is performed in order to enhance geomorphologic linear features.

Geological and Geographical context

The area of study is located in the Huércal-Overa Basin, in the Eastern Betic Cordilleras (Almería provinc Southeast Spain). This Neogene and Quaternary basin is affected by a fault pattern coinciding with two region seismic lineations, one E-W and other NE-SW that influence the sedimentary areas, the drainage and the gener morphology. The basin is bounded (Figure 1) in the north by the Sierra de Las Estancias (1500 m), and in the sout by the eastern part of the Sierra de Los Filabres (1250 m) and by the Sierra de Almagro (711 m). The region has dry, semiarid climate with an average precipitation of around 200 mm in the lower parts of the basin, and more th 400 mm in the surrounding sierras. The sedimentary basin is part of the Almanzora river hydrographic basin, whi is characterized by ramblas (local name for water courses without water due to the aridity of the climate). The ramblas are only active depending on the very irregular distribution of the precipitation, normally after hea rainstorms that cause considerable damage. Additionally the lithologies present in the area have a sparse vegetati cover, facilitating the erosion processes when the heavy rainstorms occur.

DIGITAL IMAGE PROCESSING AND GIS ANALYSIS

The satellite data used for this work comprises a SPOT Pan and Landsat TM subscenes. The acquisition data for th images were winter 1988 for the SPOT data and summer 1991 for the Landsat TM data. The incidence angle of th SPOT HRV instrument was 2º3R, whereas for the TM instrument this angle is always considered (vertical) na pointing.

Additional sources of information have also been taken into account, including aerial photographs (1:33.000 scal geological map (1:50.000), field-work information and a topographical map at 1:50.000 scale. The last was al used to derive the DEM of the study area and the control points for the subsequent geocoding and registration of th imagery.

Multisensor data integration

Before the application of the synergism to the multisensor data set, a qualitative consideration of the spectral aspects of the TM imagery has been considered (Figure 2). Since one of the aims of this work is to extract the main mapping units showing an integration of terrain characteristics, an appropiate band combination must be selected. The best visual result was achieved in a pseudo colour composition with the bands 4,5,3 for red, green and blue respectively. Then, this imagery was registered with the high spatial resolution data (SPOT PAN, Figure 3) in order to perform the synergism. The basic concept behind this process is to bring the different sets of images to the same geometry and reference system. The method applied for this purpose has been an orthorectification procedure. Different authors have already reported that the removal of the terrain displacements in this kind of imagery (due to the relief variations) becomes of crucial importance for mapping tasks in thematic studies in order to fit at scale 1:50.000 and larger (Munier, 1990; Bähr, 1991; Strobl *et al.* 1990). The basic algorithm used to correct a pixel location for elevation displacement is the tangent of the angle from the nadir point to the ground control point times the elevation of the ground point, being the pixel shift always along the scan line. The geocoded data set has been generated with a corresponding pixel resolution of 10 m. The next stage was to proceed with the synergistic approach for the integration of the registered data.

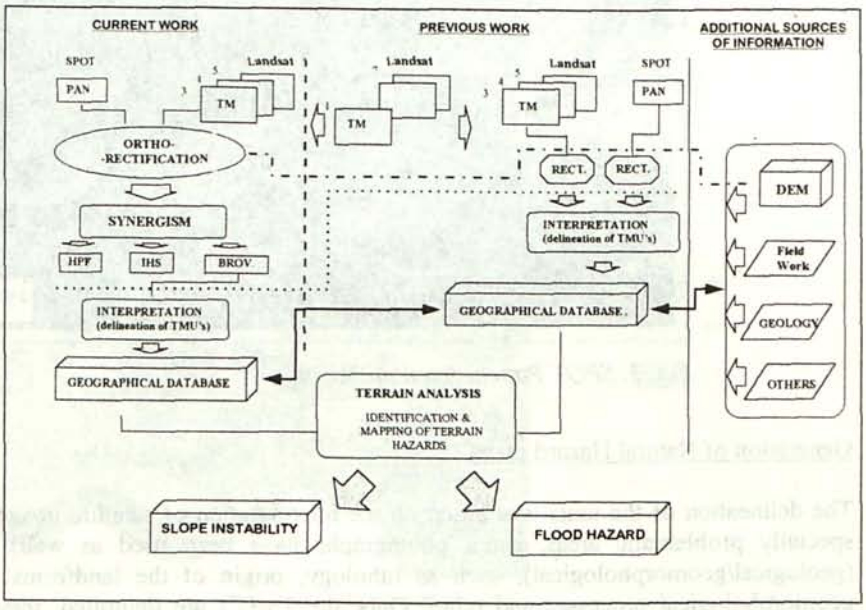

Fig. 2. *Working flow.*

The corregistered data sets were integrated based on digital image processing techniques. The algorithms used for the integration of the multisensor data were the IHS (intensity, hue and saturation), HPF (high pass filtering) and Brovey transformations already described by several authors (Ehlers, 1988; Chavez, 1986), leading to high spatial-multispectral resolution data sets. In each case the spectral information was introduced by the registered and resampled TM data, and the high spatial resolution component introduced with the SPOT panchromatic band. Finally the selected integrated result was edge enhanced by a non directional high pass filter (Laplacian) in order to boost lines with geomorphological significance determined by visual interpretation.

Digital Elevation Model (DEM) and derived maps

A DEM is an ordered array of numbers that represents the spatial distribution of elevations above some arbitrary datum in the landscape (Moore *et al.*, 1993). In the present study, its generation was done based on digitized countour lines at a scale of 1:50.000 with a contour interval of 20 m. A linear interpolation method was applied to transform the countour data into a DEM.

From a DEM, a slope map was generated in order to determine together with other geomorphological parameters, Natural Hazards present in each of the mapping terrain units. The slope is the first derivative of altitude and its map was generated from gradients in x and y directions, transforming the scalar DEM into a vector field (Meijerink *et al.*, 1994). Differences in x and y direction pixel values are used to approximate the partial derivatives, taking into account the pixel size and a linear filter. The resulting map presents the values in percentages. Afterwards, it was reclassified into different class intervals, according to their influence in the several types of Natural Hazards analyzed.

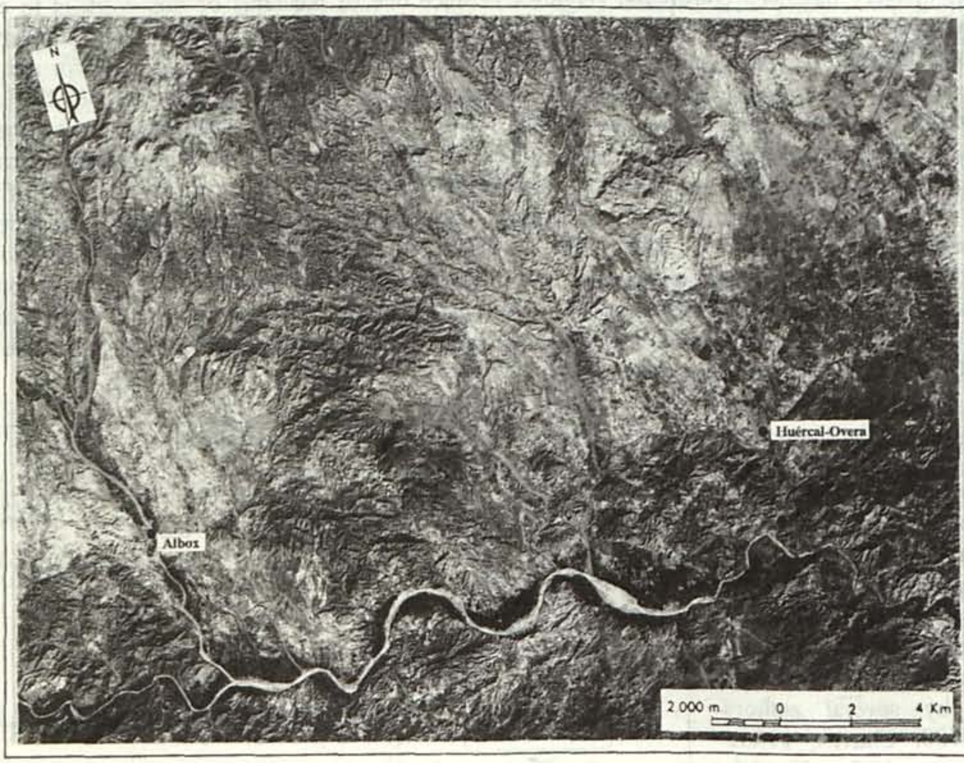

Fig. 3. *SPOT Panchromatic subscene.*

Generation of Natural Hazard maps

The delineation of the units was based on the interpretation of satellite images and field-work (in some of the specially problematic areas, aerial photographs have been used as well), according to physical paramet (geological/geomorphological), such as lithology, origin of the landforms (structural, denudational,...), acti geomorphological processes and relief. Once the TMU's are delimited, they were integrated in a geographi database. In order to obtain hazard values for each pixel, a qualitative hazard analysis (Van Westen, 1993) was us by means of a qualitative attribute combination, in which the field knowledge is important to decide the paramet for each type of hazard. For this reason, all TMU's were reclassified by GIS operations with attributes such lithology, internal relief, vegetation and slope. Weighting values were assigned qualitatively to each of th attributes or parameters, as well as to the slope map. This was followed by a weighting calculation for each pixe order to classify in few hazard classes the TMU map (high, medium and low hazard). The main goal of th integration was to determine main Natural Hazard prone areas. Three are the main Natural Hazards present in th studied area: mass movements, flooding and seismic activity.

In order to delimit slope instability, or mass movements, areas, the following parameters were taken into accou from the attribute database: lithology, soil type, slope, presence of mass movements, internal relief and vegetati For the flood hazard maps, the variables used were slope, origin of the landforms (fluvial), presence of act sedimentation and internal relief (García-Meléndez *et al*., 1995). For the seismic hazard, the investigations are s in progress, following as a first step two methods for lineaments detection: visual interpretation of satellite imag and GIS analysis for gently slopping terrains using a DEM (García-Meléndez *et al*., 1996).

ESULTS

e application of an orthorectification method to the multisensor data set has improved the image, eliminating the ief distortion. From the three techniques used, the HPF transformation was disregarded due the large amount of gh frequencies contained in the panchromatic band resulting in a very high quantity of added noise, while the two ier transformations lead to qualitatively visible acceptable results. In this way, the interpreted TMU on the horectified HSI image show a greater accuracy than the TMU's delineated on an unrectified false colour mposition. Nevertheless, the variability of spectral information, the visual appearance, etc., are more interpretable the original TM false colour composition, since the resampling algorithms of the geometric correction involve a ange in the radiometric integrity of the data (Lunetta *et al*., 1991), not yet quantified in our case. The overlay of th resulting vector files shows an average error of 15 pixels (150 m.). However the geocoded image is not mogeneously improved due to the lack of control points in some areas where it is difficult to identify points. This oblem could be solved using a GPS in the field, instead of registering the image to a topographic map, or through

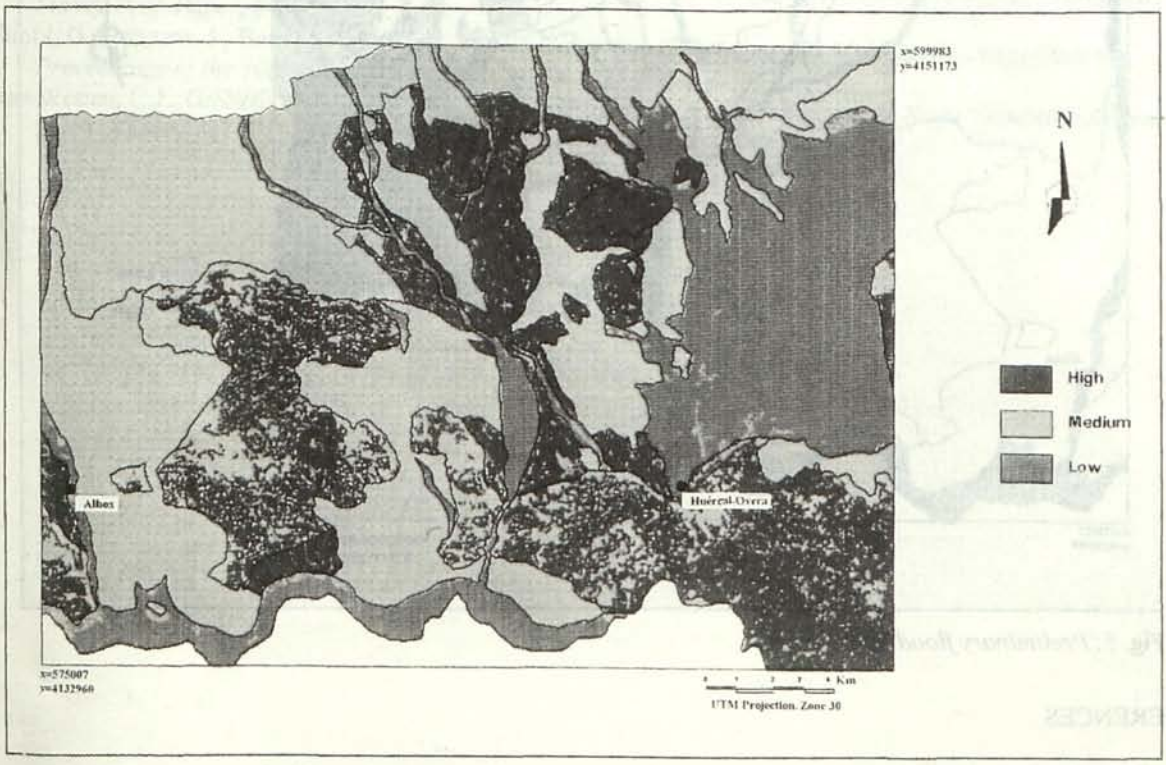

Fig. 4. *Preliminary slope instability hazard map.*

combination of GPS and topographic maps.

nally, two preliminary maps of Natural Hazards were obtained by reclassifying the TMU map: a slope instability zard map (Figure 4) and a flood hazard map (Figure 5). The first one shows a high degree of hazard in the units in iich compositions are, among others, marls or alternanting marls with sandstones, together with a high internal ief. The second map shows high values in areas of low relief which are related with "ramblas" or plains with ive alluvial fan sedimentation.

ONCLUSIONS

e synergism of SPOT PAN and Landsat TM images results in a better geometric resolution for visual erpretation. This improvement, together with the removal of terrain displacements allows one to fit more urately the delimitation of homogeneous terrain units at a given scale, although the radiometry of the images has been modified by the resampling procedure. The characterisation of these units is used in order to prevent damage from future Natural Hazards events, such as mass movements, seismic activity and flooding. It is very useful to perform risk analysis, adding new information such as infrastructures, human settlements, population density, etc. to the GIS database. One of the big advantages of using the TMU approach instead of the overlay operations with different thematic maps, is that the time required for data collection has been reduced. The interpretation of the satellite images in a semiarid zone like the study area of this work is helped by: (1) the good response of the landforms (alluvial fans, areas where the incision of the drainage predominates, etc.); (2) the scarce vegetation cover, which allows one to observe the full range of the lithology's reflectance in an area where some landforms are exactly related to certain lithological compositions.

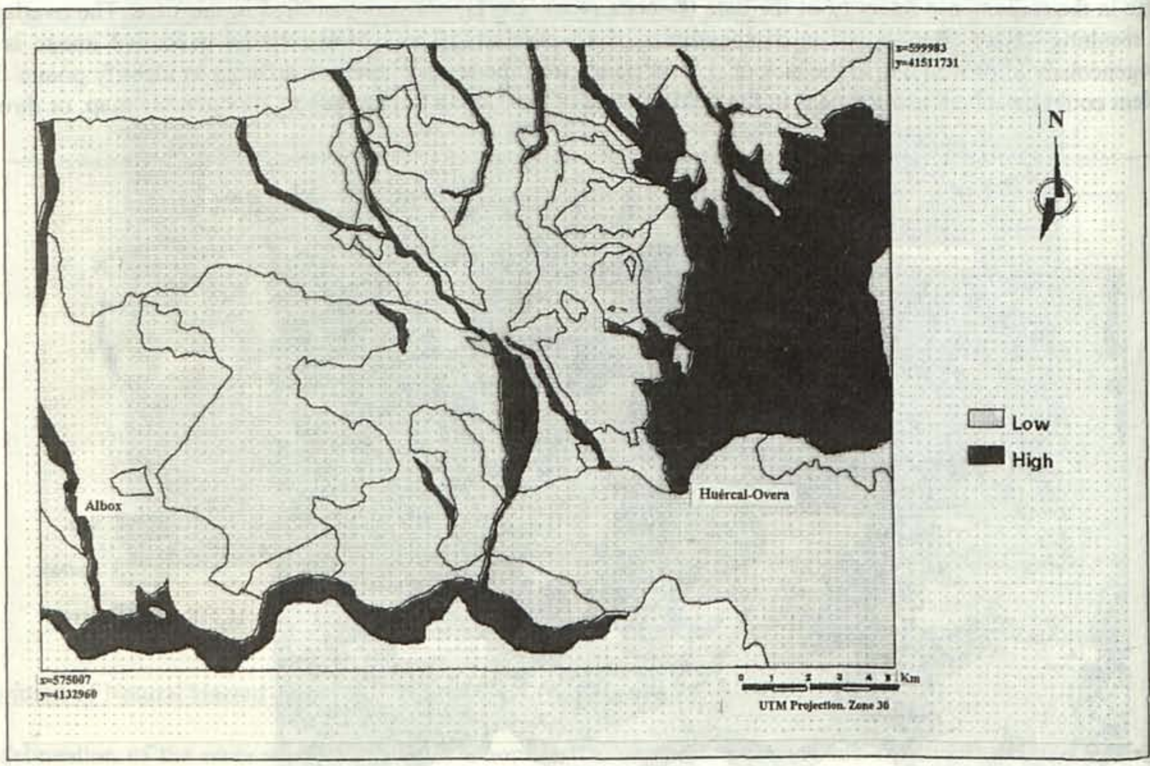

Fig. 5. *Preliminary flood hazard map.*

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