APPLIED GEOMORPHOLOGICAL MAPPING IN THE SOUTHEAST OF SPAIN USING REMOTE SENSING AND GIS TECHNIQUES

GARCIA-MELENDEZ, E.*; GOY, J.L.*; ZAZO, C.**; FERRER-JULIA, M.***

* Dpto. de Geología, Facultad de Ciencias, Universidad de Salamanca. 37008-Salamanca, Spain.
** Dpto. de Geología, Museo Nacional de Ciencias Naturales, CSIC, José Gutiérrez Abascal, 2. 28006-Madrid, Spain.
*** U.P.V., Pº Bajo de la Virgen del Puerto, s/n. 28005-Madrid, Spain.

Abstract

Aerospace imagery interpretation with several LANDSAT TM and SPOT satellite images and aerial photographs, combined with field work , were used to produce a terrain classification map at 1:100.000 scale of a part of the Almanzora river basin in the Southeast of Spain. Following a synthetic geomorphological approach in order to differentiate homogeneous terrain units, the main classification criteria were relief, lithology, active geomorphological processes and origin of the landforms. Afterwards a pragmatic geomorphological approach was followed in order to create special purpose maps, using GIS operations. As a result 6 homogeneous terrain units were differentiated for the terrain classification map, and three preliminary hazard maps were generated establishing different conditions in a Geographic Information System: slope instability hazard map, flood hazard map and a general hazard map. The described applied geomorphological mapping method allows a general reconnaissance of the terrain conditions of an area at a semi-detailed scale, and the reclassification of the differentiated mapping units in terms of susceptibility of occurrence of a certain natural hazard. These maps are the base for more detailed surveys related with natural hazard assessment and environmental planning in a specific area.

1 Introduction

Applied geomorphologic maps can be derived from terrain analysis, which results in a terrain classification map. Such a map is based on the study of the landforms and has different units that are homogeneous at a determined scale in terms of some of the following parameters (others are possible): lithology, geomorphologic processes, slope, origin of the landforms, vegetation, drainage. From a terrain classification map, other maps may be derived concerning only those parameters that are relevant for the purpose of a specific study, with a clearly applied component, as for instance natural hazard maps.

The aims of this study are: (1) to evaluate the use of Remote Sensing and GIS techniques in order to make applied geomorphological maps at a semi-detailed scale, (2) to evaluate the terrain classification map as a general purpose map and as a base to generate special-purpose, natural hazard, maps by means of GIS operations, (3) to recognize the main terrain characteristics (landforms) and some of the natural hazards related to them, and (4) to create a base for more detailed hazard studies. This work will serve for further and more detailed studies in this area and its surroundings.

Some examples of the use of Remote Sensing and GIS in applied geomorphological and hazard mapping are related with floods in Bangladesh [2], slope instability zonation in Colombia [1, 2] and land units differentiation with Remote Sensing techniques in Australia

[3]. The general applied geomorphologic mapping and terrain analysis techniques are described by Van Zuidam [4], Cooke & Doornkamp [5] and Verstappen & Van Zuidam [6], among others. A detailed description of the terrain mapping units in the study area is given by García-Meléndez et al.[7].

1.1 Geological and Geographical context

The study area is a part of the Huércal-Overa Basin, located in the eastern Internal Zone of the Betic Cordilleras, in the Almería province, Southeast of Spain. This Neogene and Quaternary basin is influenced by two major tectonic orientations, one E-W and other NE-SW; these orientations have controlled the sedimentary areas, the present morphotectonic elements and the drainage network. The basin is bounded by the Sierra de Las Estancias (1500 m) in the north, and by the eastern part of the Sierra de Los Filabres (1250 m) and the Sierra de Almagro (711 m) in the south. The sedimentary basin ranges from 300 m in the east, steadily rising to 800 m in the west. The region has a dry, semi-arid climate, the average precipitation is 200 mm in the lower parts of the sedimentary basin and more than 400 mm in the surrounding sierras. The distribution of the precipitation is very irregular, sometimes high levels are registered after heavy rainstorms which last a few hours only, but cause considerable damage, triggering as well mass movements.

2 Method

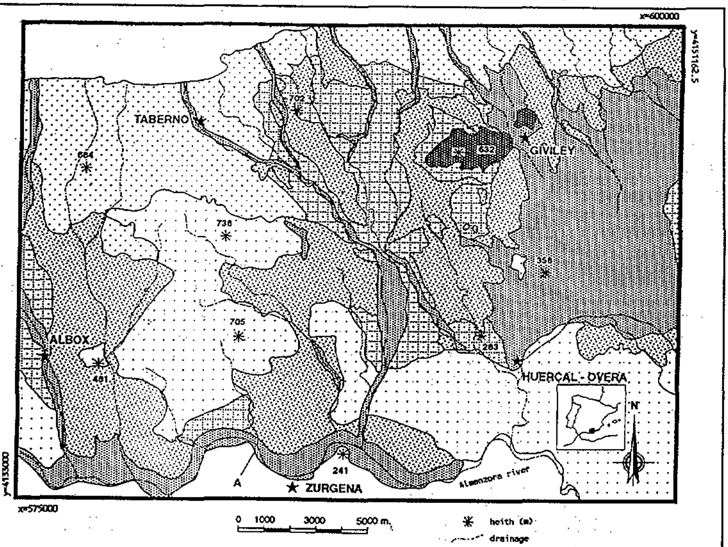
In the first part of the study a *synthetic geomorphologic approach* is followed, which deals with a synthesis of the land. The maps generated through it are used in multidisciplinary surveys of the land, and it is designed to achieve a synthesis between the landforms and other environmental parameters (relief, lithology, hydrology, soils, and others). Through this approach, a terrain classification map was created. Its units were differentiated according to basic physical parameters such as the origin of the landforms, relief, active geomorphologic processes, and lithology (vegetation and drainage were also considered in the descriptions, but not as defining factors). These units were differentiated with satellite images: a false colour composition with the electromagnetic spectrum bands 4, 5 and 3 (RGB) of the LANDSAT TM sensor, a false colour composition of SPOT XS with bands 1,2 and 3 (RGB), and a SPOT panchromatic image. All of them have been digitaly processed with a nondirectional filter (Laplace-plus) in order to enhance linear features with almost any orientation in the images, highlighting in this way the drainage lines, and hence the relief. The visual interpretation of the images was carried out with paper prints at 1:100.000 scale. After the interpretation the images were georreferenced in order to display over them the terrain units. In some key areas aerial photographs at 1:18.000 and 1:33.000 scale were used.

Once the terrain classification map was obtained, a *pragmatic geomorphologic approach* was followed in order to derive applied geomorphologic maps, or special purpose maps, related with hazards. For these applied maps the full range of synthetic data is not required, selecting only the features directly relevant for the purpose of the survey [6]. Three preliminary maps based on a qualitative hazard analysis were generated, in which the main parameters are geomorphologicaly defined [1]. These parameters considered were: (1) for the slope instability hazard map, lithology, slope, presence of mass movements, internal relief and vegetation density; (2) for the flood hazard map: slope, origin of the landforms, presence of active sedimentation and internal relief; (3) the general hazard map was generated from the previous two. Besides, as flood events cause slope instability at the sides of the main ramblas, it has been defined an estimative average distance of 120 m around some parts of the fluvial unit (four pixels each side), to map these areas as both related with the effects of floods and slope instability. A spatial and attribute data base was built in a Geographic Information System (ILWIS, version 4) with all the above physical parameters and with the terrain classification and topographic maps digitized. Once the parameters values were introduced in the GIS data base for each unit of the terrain classification map, they were used to generate by means of conditional operations, two new parameters values (slope instability and flood hazard). The two new parameters were used to reclassify (recode) each mapping unit of the terrain classification map in terms of hazards (high, medium and low). The pixel size chosen for the maps was 30 m, which is the same as the spatial resolution of the LANDSAT TM images.

3 Results

From the analysis and interpretation of satellite images, aerial photographs and field work observations, six homogeneous terrain mapping units were differentiated. These mapping units appear on the terrain classification map of figure 1, and their characteristics in the table of the same figure. In the study area, where neogene materials are predominant, three units have been differentiated. Unit (ED5) is formed by red conglomerates, sandstones and silts; it is lithologically well depicted in the false colour composites and morphologically in the SPOT panchromatic image. Unit (ED6) is formed by several lithologies alternating (marls, sandstones, conglomerates and pelites); it does not have a well defined and homogenous reflectance due to the variability in lithologies and due to the fact that is covered in large areas by quaternary deposits, outcropping in the slopes generated by rambla (local name for drainage line with sporadic flow of water) incision. Unit (ED7) is well depicted in all images due to its high relief and to its spectral homogeneity. Concerning the quaternary deposits, two main units have been differentiated. Unit (FD) is formed by several levels of alluvial fan deposits (Pleistocene in age), covering great parts of the basin; they present a low relief and different colours in the false colour composite images due to different lithologic compositions in the source areas, to the presence of calcareous crusts on the surfaces, and to the presence and type of vegetation; in the SPOT panchromatic image they appear with light grey tones and with a characteristic drainage pattern that at present is actively incising this unit in some areas. Unit (F) is characterized by rambla bottoms, floodplains, terraces of the Almanzora river and by alluvial fans (Holocene and actual in age); these fans present dark grey tones in the SPOT PAN image and an active agricultural land-use. Unit ED4 was differentiated only from aerospace imagery interpretation with limited field work observations, it present a great variety of lithologies but appears as a homogeneous unit according to its relief.

From the GIS analysis three preliminary hazard maps were obtained: (1) the slope instability hazard map with high value for units ED4, ED6 and ED7, medium value for units ED5 and FD, and low value for unit F; (2) the flood hazard map with high value for unit F, and low value for the rest; and (3) the general hazard map with high value for units ED4, ED6 and ED7, medium value for units ED5 and FD, and high value for unit F. It is important to remark that the medium value in unit FD in the slope instability and in the general hazard maps is related with the fact that this unit is affected by mass movements only in the areas close to the main ramblas. Slope instability occurrence is related with the presence of water, but due to the characteristic semi-arid climate, water is scarce and slope instability is closely related to flooding events. When heavy rainfall occurs, the more active areas for the ocurrence of slope instability are those related with the incision of the



Legend	Name	Origin	Lithology	Internal relief	Active geomorphological processes	Drainage density	Vegetation
ED4	Structural - denudational slopes on metamorphic rocks, breccia and conglomerates	Structural-denudational	Metamorphic rocks, breccia and conglomerates	Very high	Toppling, rill, gully and sheet erosion, rotational slides	Intermediate	Scrub, pine tree reforestation
ED5	Structural - denudational terrains on conglomerates, sands and silts	Structural-denudational	Conglomerates, sands and silts	Moderate	Rill, sheet and gully erosion	High	Scrub
ED6	Structural - denudational terrains on marls, pelites and sandstones	Structural-denudational	Marls, pelites and sandstones	Moderate	Rill, sheet, gully and pipe erosion, rock and debris and mud slides	Very high	Scrub
ED7	Structural-denudational hills and slopes on limestones, conglomerates, sandstones, marls and pelites	Structural-denudational	Limestones, conglomerates, sandstones, marls and pelites	Very high	Northern slopes: gully erosion, debris and mud slides Southern slopes: rock- fall and rock slides	High	Scrub
FD	Fluvial - denudational surfaces	Fluvial-denudational	Gravels, sands and conglomerates	Low	Sheet, rill and gully erosion, and block-fall	High	Scrub, almond trees and pine tree reforestation
F	Forms of fluvial origin	Fluvial	Gravels, sands, silts and clay	Very low	Sedimentation (channel bars, river terraces, alluvial fans) and *pipe erosion*	Low	Irrigated crops

Figure 1. Terrain classification map and legend.

ramblas, which forms very steep, not vegetated slopes at their sides.

4 Discussion and conclusions

The terrain classification map created from aerospace imagery interpretation and field work has proved to be a good tool to derive special-purpose applied maps based on a geomorphologic analysis of the terrain. GIS techniques facilitate the analysis of the different mapping units and its attributes in order to interpret the terrain in terms of specific conditions, and allow a flexible and rapid analysis of data. The use of Remote Sensing techniques provide a general view of the study area, and allow the enhancement of the landforms through digital processing techniques. The use of aerial photographs and field work increases the accuracy of the satellite images interpretation in the more complicated areas. At the mapping scale of this study, it is only possible to obtain preliminary hazard areas and values. These areas are indicatives for deeper studies at larger scales in which other factors and more detailed data from field work and laboratory observations should be added to the data base.

References

[1] Van Westen, C.J., 1993. GISSIZ: Training Package for Geographic Information Systems in Slope Instability Zonation. Part 1: Theory, ITC Publication 15, 245 pp., Enschede.

[2] Van Westen, C.J., 1993. Remote Sensing and Geographic Information Systems for Geologic Hazard Mitigation. ITC Journal 1993-4: pp. 393-399, Enschede.

[3] Robinove, C.J., 1979. Integrated Terrain Mapping with digital Landsat images in Queensland, Australia. Geol. Survey Prof. Paper 1102, 39 pp., Whasington.

[4] Van Zuidam, R.A., 1986. Aerial photo-interpretation in Terrain Analysis and Geomorphologic Mapping. Smits Publishers, 442 pp., The Hague.

[5] Cooke, R.U.; Doornkamp, J.C., 1990. Geomorphology in Environmental Management. Clarendon Press, 410 pp., Oxford.

[6] Verstappen, H.T.; Van Zuidam, R.A., 1991. The ITC System of Geomorphologic Survey. ITC Publication 10, 89 pp., Enschede.

[7] García-Meléndez, E.; Goy, J.L.; Zazo, C.; Soeters, R.; Ferrer Julià, M. (in press). Clasificación del Terreno de la Cuenca de Huércal-Overa y la Sierra de Las Estancias mediante un método de Geomorfología Aplicada (Almería, SE de España).