SPATIAL QUALITY OF A LANDSLIDE DATABASES OBTAINED WITH DIGITAL PHOTOGRAMMETRY TECHNIQUES

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ABSTRACT:

In this work several techniques for the elaboration of landslides databases are compared. The used techniques are the digitising on ortophotographies, the digitising on aerial photographs and geometrical correction, and, finally, the stereoplotting using digital photogrammetry. The landslide scarps databases derived from the different methodologies have been compared by several indexes such as the displacement between crown lines of scarps, the lengths of scarps, and the adjustment of scarps to a DTM. The analysis shows lower or higher discrepancies between the databases, with displacements between 8 and 45 meters, depending on the compared methodologies and landslides typologies. The best results are obtained with the methodology of digital stereoplotting whose scarps database is well adjusted to the DTM. Among the rest of methodologies, the digitising on orthophotography presents the lower differences with the previous one, while the methodology of the digitising on photogram presents the worst results, with a certain spatial pattern related with the relief displacement. The conclusion is to recommend the use of the digital stereoplotting to elaborate landslides databases and as possible alternatives the digitising on ortophotography (especially if they are derived from the stereoscopic pairs used in the interpretation), being dissuaded the digitising on the photogram, at least in zones with a strong relief.

1. INTRODUCTION

The mapping techniques are the most useful tools for natural risks prevention, as these are consequences of natural processes usually developed on a given territory with a variable frequency. Following internationally accepted methodologies (Varnes, 1984; Chacón et al. 2006) different approaches are available from the application of concepts such as element of the territory, susceptibility, hazard, vulnerability and risks derived from a potentially destructive natural process. Concerning landslides, which are mass wasting processes with very variable typologies, size, velocity, energy or intensity, and destructive potential (Varnes, 1978) associated to different determining and triggering factors (Chacón et al., 2006) there is a need of increasing quality and number of historical or temporal data in order to assess the associated hazard and risk. In many areas were that temporal information is lacking or very difficult to assess, the landslide susceptibility map offers an appropriate alternative for landslide prevention. These maps show a zoning of areas in term of how prone to produce landslide are. The methodologies more frequently applied to mapping landslide susceptibility maps are based on a varied number of probabilistic methods, generally taking as a reference a landslide inventory and a set of factors more or less broadly determining the slope stability conditions.

In opposite to other natural destructive processes, like earthquakes, hurricanes or erosive processes, which most frequently are analyzed at small scales, due to the largest areas affected by its destructive effects, landslides and its effects may be analysed at any scale from small (regional or national land-use planning), middle (provincial or county land-use planning) and large scales (local, urban or city areas) (Rengers et al., 1998). In this last case, higher or more detailed quality are required in the maps for a precise positioning of the data and delimitation of the landslide susceptibility or hazard zones. Because of this, it is increasingly important the use of appropriate data acquisition techniques, as topographical instrumentation, GPS, laser scanner, terrestrial and aerial photogrammetry or remote sensing. In between these techniques, the most adequate for precise large scale landslides inventories and susceptibility mapping of wide regions are aerial photogrammetry and high resolution remote sensing. Further analyses of relationships between inventoried landslides and factors determining slope stability are accomplished in GIS which are essential tools for that purpose (Chacón & Corominas, 2003; Chacón et al., 2006).

In this paper, different landslide databases or inventories are presented which were obtained following several techniques, including digital photogrammetry. The obtained landslide database has been compared to those resulting from more conventional techniques of thematic mapping, in order to attain some conclusions about the level of improvement of the data positioning quality and the implications of it use. In this sense it is interesting to remain that digital photogrammetry techniques were applied to topographic mapping since the eighties, although it use in thematic mapping, and particularly in landslide mapping, has been much more limited as it started just in the last few years (González-Díez et al., 2004; Cardenal et al., 2004).

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2. STUDY AREA AND LANDSLIDE SAMPLING

A small area of the Contraviesa and Lújar Sierras (Figure 1) in a mountain region (Alpujarra) of the South of Granada province (Spain) was selected because of the high density of landslides previously mapped by Fernández et al. (1996; 2003). From this landslide inventory or database, two small samples of landslide scarps are selected, each located in two grey color aerial photograms at a scale 1:20.000, obtained from the mapping services of the Andalusia Government. In this preliminary research landslide, scarps have been selected as the most visible and easily identifiable geomorphology feature (Figure 2).

Each sample has a total of 20 landslide scarps resulting from four basic landslide types: rockfall (5), debris flow (5), shallow slide (5) and deep slide (5) spread in the photogram. The sampling method was conditioned random (1 scarp by each typology and km^2). In order to analyze correlations between landslide and the DTM, the main landslide scarps were identified and digitized as polygonal entities; from these, the upper boundary scarp lines (crown) were considered to make easier the analyze of its geometry and the displacements between the scarps obtained from the different methodologies.

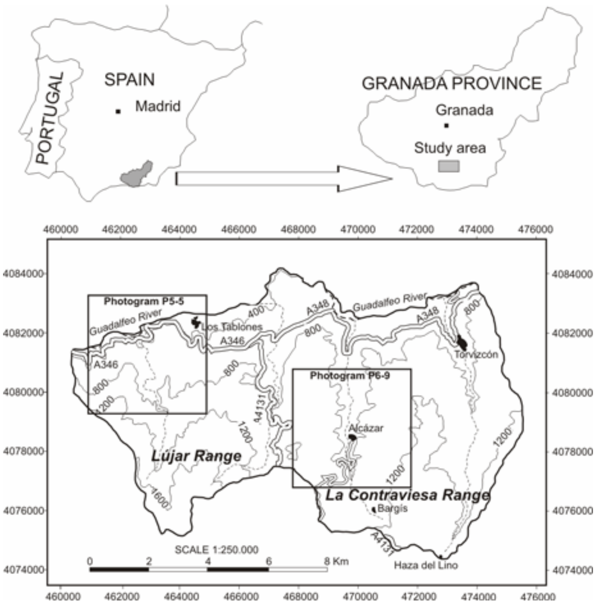

Figure 1. Location of study zone.

3. APPLIED METHODOLOGIES

The methodologies applied to this comparative research were:

- Digital photogrammetry, this is stereoplotting from the stereoscopic models and direct derivation of a landslide scarps database.
- Photo interpretation and digitising of landslide scarps on the aerial orthophotography (mono plotting).
- Photo interpretation on stereoscopic pairs using a mirror stereoscope, digitising of the identified scarps and geometrical correction by control points.

In a previous work (Fernández et al., 2006), we use other technique, photo interpretation on stereoscopic pairs, translation into a topographical map and digitizing of the scarps on the map. This technique is also explained in the following sections.

3.1 Digital photogrammetrical stereoplotting

This is the methodology subjected to a calibration and the more recently used in this thematic. The process was followed for the correct application of these techniques may be summarised in the following points (Fernández et al., 2006):

- The first step is the scanning of grey level photograms at scale 1:20.000 (1992, Junta de Andalucia), using a precision photogrammetrical scanner Vexcel Ultrascan 5000, with a pixel size on the terrain, GSD, of 30 cm.
- From the digitized photograms the images are oriented by means of a digital photogrammetric station and the software Socet Set 5.2. The orientation is made from 20 control points extracted from the inventory of control points available in the Junta de Andalusia, using spatial techniques of aero-triangulation and block adjustment.
- Once the images are oriented and adjusted to a terrestrial coordinates system, with the stereoscopic viewing which allows the photogrammetrical workstation and the Socet Set software, its editing tools (stereoplotting) are used to restore the landslide boundary lines (by delimiting polygons or zones) which are registered in a 3D vector file.
- These polygons are introduced directly to ArcGIS 9.2, were the crown lines are obtained using the edition and topological tools of that software.

The advantages of the methodology are its high accuracy derived from the stereoscopic viewing – with the possibility of making zooms and displacements-, permitting a correct identification of the topographical details, a direct digitising of polygons and a correct geo-referencing of the resulting lines; an additional advantages is the three-dimensional character of the resulting information, which allows more detailed analysis of the landslide elements. As disadvantages regarding to traditional methodologies of landslide mapping, some restrictions in the previous processing (block orientation) and the restoring itself, both processes requiring an adequate and expensive hardware and software as also a really trained professional.

3.2 Photointerpretation and digitising on orthophotography

The methodology comprises a digitising of landslide scarps on the orthophotography, and therefore this technique really is a 2D interpretation or monoplotting. The orthophotography has been automatically generated by means Socet Set software from the stereoscopic pairs, with 1 m resolution. In a previous work we used the Orthophotography of Andalusia (1999), in colour at scale 1:10.000, and 1 m resolution (100 micras).

The vectorial digitising of the landslide scarps was performed in the computer screen using ArcGIS, firstly as polygonal entities; from these, crown landslides lines are obtained as before.

Between the advantages of the methodology it may be pointed out its simplicity and the obtaining of a geo-referenced mapping product geometrically corrected. The main disadvantage is the fact of doing the photo interpretation by a two-dimensional observations, what increases the likelihood of errors and incorrect interpretation when stereoscopic or 3D observation is available.

3.3 Photo interpretation and digitising on photograms

This methodology starts by analogical photo interpretation using mirror stereoscopes and tracing of the landslide scarps on an acetate sheet placed on the photograms corresponding to the previously mentioned flight. After this, the scarps polygons are digitised as vectors in ArcGIS taking as reference the lines traced on the acetate and converted into an image (.tiff), which is geometrically corrected to UTM30 coordinates, using a second degree polynomial transform, by means ERDAS 9.0 software. Finally, the scarps are newly digitised in the GIS on the corrected image.

The main advantage in this method is the quality produced by a 3D photo interpretation. The disadvantages are problems arising with the geometrical correction made with 2D defined points – in a very mountainous terrain- and the complexity of the technique with some transforms which increase the likelihood of added errors.

3.4 Transference on a topographical map and digitising

The digitising on maps is the methodology used in previous researches (Fernández et al., 1996; 2003; Irigaray et al, 1999, 2005; El Hamdouni, 2003). After the photo interpretation described in the precedent section, the landslide scarps are transferred to the topographical maps and subsequently digitised. In this case the Topographical Map of Andalusia at scale 1:10.000 was used in a raster mosaic version (obtained by scanning and geo-referencing the analogical map, what permits to obtain a continuous map for the entire region). Nevertheless, in the GIS, the digitising of the landslide scarp on this map took, as reference, the tracing of polygons on the acetate.

The advantages of this method are the simplicity of the process itself and the digitising on a geo-referenced image. The main problem is the subjective perception of the process of scarps transference from the photogram to the map based on its more or less correct identification and other morphological features form the configuration of the elevation lines. In this sense, the change of shape and size of these features, depending of its position in the photogram, the slope angles and attitude make more difficult the use of this methodology.

4. COMPARATIVE ANALYSIS

The analysis is intended for the determination of the differences between the landslide scarps databases obtained from the different methodologies, with the objective of accepting or rejecting it, and finally to make clear if the technique of digital photogrammetrical stereoplotting supposes a significant improvement with regard to the other methodologies.

The analysis is made from the described sample of 40 landslide scarps and 40 crown lines of scarps distributed in two photograms. The landslide scarps as polygons permit to study the adjustment of the landslide to the DTM (particularly the slope angle), while the crown lines permit to analyze changes in the scarp length and to determine displacements in between the landslide databases obtained from different methodologies.
Thus, a series of indexes necessary to make this comparative analysis of different database were defined. The indexes are the following:

- Displacements (D) between landslides crown lines obtained from the different methodologies. Average and maximum displacements are calculated by different computer algorithms (Mozas et al., 2008) based in Hausdorff distances (Abbas et al., 1995) and epsilon bands (Skidmore and Turner, 1992). In this work, we use mainly the mean displacement between lines based in Hausdorff distance, calculated from the line points of the first methodology to be compared to the points of the second methodology.
- Displacement trends with regard the North (Dd) between crown lines computed with the same algorithms as before. The values express also the displacement from first methodology to the second.
- Length of the landslide crown lines (Le).
- Average slope angle of the scarps (Sl), computed by cross correlation between scarps polygons and a DTM obtained from stereographic model with 5 m resolution. In a previous work the comparison was made with the DTM of Andalusia of 10 m resolution.

5. OBTAINED RESULTS

In table 1, 2, 3 and 4, as in Figure 2, the obtained results are shown from which the following remarks (Fernández et al., 2006 a) may be outlined:

5.1 Displacement between crown lines

The methodologies showing a closer position of the landslide scarps in the databases are the digital stereoplotting and the digitising on the orthophotography with an averaged displacement below 8 m between points in both databases. For the same comparison in previous studies, in which orthophotography was not derived from the stereoscopic model, the displacements were of about 18 m. On the contrary side, the comparisons of digital stereoplotting and digitising on orthophotography with digitising on photogram show higher average displacements, over 20 m, although lower than those obtained in previous studies (about 40 m).

By typologies, the lower displacements are related to rock falls when digital stereoplotting and digitising on orthophotography, are compared, followed by shallow slides, while debris flows and deep slides show higher displacements. However, when digitising on photogram intervenes, there is higher variability in the displacements by typologies. Analysing single landslide scarps, the higher displacements take place, in general terms, in those landslide with higher vertical distance with regard to the average plane and more distant from the principal point in the photogram, particularly in comparisons between the digitising on the photogram and the other methods. Finally, by zones, the results of stereoplotting-orthophography comparison are very similar in both zones, but displacements of digitising on photogram regarding to other methods are lower in P6-9 zone.

5.2 Displacement trend between crown lines

In general terms, an average displacement between crown lines in North-South trend is observed. In this sense, the landslides databases obtained with the methodology of digitising on photogram appear displaced to the South regarding databases corresponding to other methodologies. Nevertheless, there is a great local variability.

Indexes	S-O	S-M	S-P	O-M	M-P	O-P
Displacem. (m)	18	25	33	24	35	40
Directions (º)	8	330	191	338	187	174

Table 1. Summary of displacements and displacements trends between crown lines in previous studies (photogram P5-5): S: Stereoplotting; O: Digitalization on orthophotography; M: Digitalization on map; P: Digitalization on photograms.

Indexes	S-O		S-P		O-P	
	D	Dd	D		D	Dd
Scarp 5	2,4	162	43,7	99	43,0	41
Scarp 7	2,8	153	38,0	30	40,4	88
Scarp 10	2,2	218	16,3	117	21,5	123
Scarp 12	6,8	161	10,0	211	9,9	251
Scarp 19	3,9	197	28,0	128	30,7	123
Rock falls	**3,8**	**173**	**28,5**	**113**	**30,9**	**93**
Scarp 6	5,1	229	58,6	237	55,7	219
Scarp 9	4,8	177	21,7	122	17,8	139
Scarp 13	8,0	256	69,5	230	56,3	177
Scarp 15	10,9	198	16,8	259	19,2	230
Scarp 17	12,8	158	22,6	214	21,8	176
Debris flows	**9,4**	**200**	**32,4**	**233**	**30,4**	**201**
Scarp 1	5,5	190	13,2	256	16,8	285
Scarp 4	4,1	158	30,3	90	28,6	90
Scarp 11	3,1	116	46,1	94	48,4	128
Scarp 16	3,6	170	56,9	341	64,8	342
Scarp 18	7,7	233	39,8	233	38,9	192
Shallow slides	**5,1**	**181**	**39,5**	**266**	**44,0**	**243**
Scarp 2	8,8	193	17,2	245	18,3	265
Scarp 3	6,8	179	21,3	136	19,7	144
Scarp 8	8,9	132	36,6	118	33,6	119
Scarp 14	3,7	159	22,9	157	25,3	170
Scarp 20	8,0	187	17,7	211	19,2	199
Deep slides	**7,7**	**177**	**21,4**	**187**	**21,6**	**190**
Total Phot. P5-5	**7,3**	**182**	**25,9**	**201**	**32,2**	**191**
Scarp 1	6,1	178	34,7	156	37,9	373
Scarp 2	8,6	123	23,2	329	43,8	151
Scarp 3	2,1	175	15,1	130	33,1	324
Scarp 18	6,2	171	20,9	315	11,6	275
Scarp 20	7,6	183	12,5	226	21,5	147
Rock falls	**5,8**	**166**	**21,3**	**263**	**26,0**	**240**
Scarp 5	6,2	216	20,4	128	15,5	48
Scarp 10	11,1	268	36,7	99	26,6	176
Scarp 15	4,8	118	9,6	273	7,0	82
Scarp 17	4,1	162	9,7	132	16,0	202
Scarp 19	6,5	225	8,1	177	15,7	217
Debris flows	**6,4**	**191**	**16,0**	**154**	**16,2**	**156**
Scarp 6	5,9	174	17,1	318	18,6	144
Scarp 9	4,6	133	59,5	265	35,1	90
Scarp 12	7,0	227	21,4	193	19,9	300
Scarp 13	4,2	280	12,3	180	10,5	242
Scarp 16	6,8	146	12,7	271	15,0	176
Shallow slides	**5,8**	**199**	**20,2**	**237**	**17,8**	**211**
Scarp 4	16,3	250	65,0	157	45,5	165
Scarp 7	8,0	221	33,6	320	25,6	350
Scarp 8	9,4	219	25,5	181	21,0	185
Scarp 11	15,5	139	11,3	183	19,7	151
Scarp 14	7,6	216	28,9	148	9,5	183
Deep slides	**11,7**	**199**	**27,4**	**175**	**22,1**	**169**
Total Phot. P6-9	**7,9**	**195**	**21,2**	**192**	**25,5**	**178**

Table 2. Displacements and trends obtained in present analysis

In the analysis by typologies or given landslides, any pattern different from the general behaviour described in the previous paragraph, is observed. Following this, in most landslide typologies, displacements toward the South of points obtained from the methodology of digitising on the photogram, with regard to those obtained from other techniques are observed. The same occurs to most landslides, no matter its location.

Mean slopes	S	O	M	P
Rock falls	36,3	26,3	28,0	28,0
Debris flows	24,9	32,7	30,0	30,7
Shallow slides	28,0	36,0	35,9	35,7
Deep sldes	28,3	31,3	35,4	34,2

Table 3. Summary of length and averaged slope angles of scarps in previous studies.

Indexes	S		O		P	
	L	Sl	L	Sl	L	Sl
Scarp 5	191	44,2	213	32,5	240	22,6
Scarp 7	178	58,8	179	54,9	228	17,9
Scarp 10	97	38,9	84	35,8	76	33,1
Scarp 12	180	54,3	164	50,9	179	49,9
Scarp 19	151	45,1	161	40,5	146	33,0
Rock falls	**160**	**50,2**	**160**	**44,9**	**174**	**35,3**
Scarp 6	255	40,0	253	40,1	461	35,8
Scarp 9	185	36,7	182	37,0	154	38,1
Scarp 13	258	37,7	285	37,9	347	36,0
Scarp 15	684	36,5	741	36,8	636	36,3
Scarp 17	376	37,6	372	37,4	318	38,33
Debris flows	**352**	**37,2**	**367**	**37,4**	**383**	**36,2**
Scarp 1	295	29,3	303	29,0	293	26,8
Scarp 4	153	39,8	158	38,4	160	30,6
Scarp 11	196	49,0	204	49,3	246	37,9
Scarp 16	268	33,4	288	31,3	294	40,1
Scarp 18	305	40,3	295	37,6	187	36,35
Shallow slides	**243**	**37,9**	**250**	**36,5**	**236**	**35,9**
Scarp 2	860	36,6	923	37,3	963	34,2
Scarp 3	742	43,0	715	43,1	754	44,4
Scarp 8	534	39,8	533	38,7	527	36,3
Scarp 14	314	45,4	318	47,5	279	34,1
Scarp 20	1282	39,5	1366	39,9	1402	41,39
Deep slides	**746**	**39,4**	**771**	**39,9**	**785**	**39,5**
Total Phot. P5-5	**375**	**40,1**	**387**	**38,6**	**394**	**35,7**
Scarp 1	124	45,7	99	40,7	102	22,1
Scarp 2	149	46,5	147	43,6	89	36,5
Scarp 3	133	48,6	128	49,0	133	38,9
Scarp 18	191	30,1	201	25,0	201	28,2
Scarp 20	120	49,9	167	49,5	169	33,5
Rock falls	**143**	**41,7**	**149**	**36,7**	**139**	**32,6**
Scarp 5	126	21,0	162	20,9	168	21,5
Scarp 10	147	17,9	188	17,6	178	16,4
Scarp 15	206	25,7	187	24,1	214	22,5
Scarp 17	172	29,7	205	30,3	197	27,0
Scarp 19	150	32,8	143	34,4	202	31,6
Debris flows	**160**	**25,9**	**177**	**25,2**	**192**	**24,24**
Scarp 6	569	28,1	588	28,1	536	26,7
Scarp 9	267	36,6	271	35,9	276	26,2
Scarp 12	670	33,4	759	30,6	724	22,5
Scarp 13	656	29,0	701	30,3	741	29,7
Scarp 16	580	24,5	622	24,1	576	25,3
Shallow slides	**548**	**28,7**	**588**	**28,7**	**571**	**26,6**
Scarp 4	574	25,2	691	21,5	862	30,8
Scarp 7	498	30,4	543	28,6	539	27,2
Scarp 8	1074	26,1	1106	25,4	1310	25,3
Scarp 11	1495	25,9	1551	25,0	1653	23,5
Scarp 14	957	23,9	1020	23,8	1034	23,8
Deep slides	**920**	**25,8**	**982**	**24,9**	1080	**25,2**
Total Phot. P6-9	**443**	**29,5**	**474**	**27,7**	**495**	**27,1**

Table 4. Length and averaged slope angles in present analysis.

5.3 Scarps length

The scarps obtained from digitising on the photogram are generally longer than those obtained from other methodologies, while the scarps obtained from stereoplotting are the shortest. In the analysis by landslide typologies and single landslide, some differences with regard to the general trend are observed, although it is not possible to establish clear patterns concerning to the typology or the position in the photogram.

5.4 Averaged slope angle of the scarps

Firstly, it is observed that the average slope angles are broadly quite similar no matter the landslides database considered in the calculations. Much more interesting is the result of the analysis by typologies where the average slope angles of the scarps are significantly higher in rock falls than in the resting typologies, especially when the methodology of stereoplotting is considered, while the lowest averaged values are obtained mainly in debris flow. In the other methodologies the same trend is observed but not so clearly. By zones, the averaged slope angles of scarps are lower in P6-9 zone than in P5-5.

In this index we can observe some differences regarding previous studies, where a DTM not derived from stereoscopic pairs and a lower resolution (10 m) is used. In general, slope angles of scarps are lower these analysis, especially in rock falls.

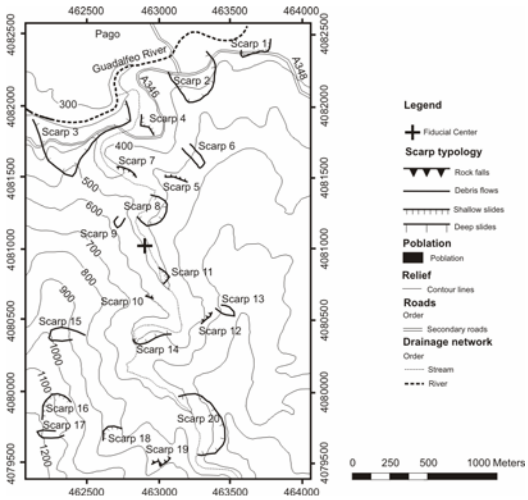

Figure 2. Landslide crowns of zone (photogram) P5-5.

6. DISCUSSION

From the described results, several remarks may be pointed out concerning either all the landslide scarps, as also the different typologies or single landslides (particularly in connection to the location of the scarps inside the zone or analysed photogram).

First, it is necessary to take in account that the observed average displacements among the obtained scarps are sufficiently high to be considered, especially when the methodology of digitising on a photogram is used due to the relief effect. In this sense, the less abrupt relief of P6-9 zone produces lower (relief) displacements than in the other zone when this methodology intervenes in the analysis. On the other hand, the higher adjustment of databases from stereoplotting and digitalization on orthophotography regarding to previous works, lead to think that the employment of a orthophotography derived from the stereoscopic pair allows the clear improvement of this database.

The typology with lowest displacements or errors between landslide databases are rock falls because its location is more unequivocal, followed by debris flows and slides where scarps are more irregular and ambiguous. This results are similar than in the previous studies, where the methodology of digitalization on map (not used in the present analysis), show a higher errors in those landslides scarps more difficult to identify in maps.
The displacement trend is mainly North-South, what is due to the major extension of the landslide databases in that direction, besides the general setting of the study region (included the zones in the two considered photograms) as a basin inclined mainly toward the North. From the analysis of single landslide scarps, it obvious to find out certain patterns in the displacements when point obtained from digitising on the photogram are compared to those obtained from the other methodologies. These patterns are related, in certain extent, to the effect of the displacement due to the relief of the photogram points. Thus, as consequence of this, the displacement of crown lines is usually higher in those points corresponding to the more remotely located scarps and with a higher vertical level difference with regard to the principal point or reference centre of the photogram. Besides, in this zone very inclined generally toward the North, this effect makes the South as the averaged displacement direction. Nevertheless, there are many exceptions due firstly to displacement to East-West (in slopes inclined toward East or West); secondly, and most important, due to the application of geometrical correction by control points, more precise than in previous works; and, in third place, due to the own errors in the scarp delimitation and digitising.

In the other hand, when the displacements resulting from the application of other methodologies are considered, these patterns are not observed and the irregular displacements may be related mainly to errors in identification and digitising. These errors are higher in digitising on map, where identification of geomorphological features is more difficult.

The analysis of the length of scarps does not lead to any clear result, with the exception of the larger scarp lines obtained from digitising on photogram, probably because of the higher deformation associated to the application of this methodology.

Finally, but very important, the averaged slope angles of the landslide scarps show higher adjustment by the digital stereopleotting, where rockfalls have higher slope angle than the other typologies, followed by slide and debris flow; this is a logical analysis, as in agreement with field data, the scarps in rock falls are almost vertical until scarps in debris flow are always less inclined. The increase of averaged slope angles of scarps obtained from digitising on orthophotography is also related with the commented improvement of this database.

7. CONCLUSIONS

The observed displacements in between crown lines of the landslide scarps obtained from different methodologies, and therefore the associated errors, are high enough to conclude that the applied methodology largely influence the quality of the landslide scarps database and of those map, as the derived landslide susceptibility or hazard maps.

The methodology offering the best adjustment to the DTM is the digital photogrammetrical stereoplotting, and because of this it is strongly recommended its application in all the studies where the necessary hardware and software, as also the appropriated technical professionals are available.

A good alternative is the digitising on the ortophotography, although it may be based on a previous photo interpretation with stereoscopic source. However, the use of a standard ortophotography without enough precision and resolution can be the origin of important errors. The methodology of digitising on a topographical map may be also a good option it is carefully applied. It may be reminded that both methodologies introduce errors without a clear pattern in the study zone. Besides, the errors are higher in those typologies with a more ambiguous interpretation (slide and particularly debris flows).

Nevertheless, it is not recommended using the methodology of digitising on photogram because of the great discrepancies between the landslide scarps databases computed with that method compared to the obtained from stereoplotting, mainly in mountain areas with high slope angles and difference in elevations. In this case, the errors are related to the displacement due to the relief, although the process of geometrical correction may hide these patterns which are not easily observed.

These preliminary results open a way for further more detailed and deeper researches, for which it will be necessary the use of more and better indexes of comparison between methodologies, as also to compare with other regions with smoothed relief and with calibration of scarps from other landslide typologies and its associated geomorphic features

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