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ORIGINAL PAPER

Evaluating the quality of landslide inventory maps: comparison between archive and surveyed inventories for the Daunia region (Apulia, Southern Italy)

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Abstract A landslide inventory map, which shows the location of landslide phenomena and contains information about movement type, activity, etc., is a basic element for landslide susceptibility and risk assessment. For this reason, the evaluation of the quality, in terms of accuracy and completeness, of landslide inventory maps is an important issue. In this paper, two landslide inventory maps are compared, in order to determine the corresponding quality, through a direct comparison, aimed to evaluate the degree of cartographic matching between the maps, and the determination of the statistical properties of landslide areas and the comparison between the frequency-area statistics of landslides contained in the two inventories. The two landslide inventory maps at 1:25,000 scale, used for these analyses, have been produced for Daunia region (Apulia, Southern Italy), by the Apulia River Basin Authority; the first, "archive inventory", by unifying the existing archive inventories; the second, "surveyed inventory", through aerial-photo interpretation and field investigations.

Keywords Landslide · Inventory map · Accuracy · Completenes · Frequency-area statistics

Introduction

The production of landslide inventory maps, which show information that can be exploited to investigate the distribution, types, pattern, recurrence and statistics of slope failures (Soeters and Van Westen 1996; Guzzetti et al. 2012), is connected not only to scientific studies, but also to territory management and planning.

A landslide inventory map should give insight into the location of landslide phenomena, the types, failure mechanisms, causal factors, frequency of occurrence, volumes and the damage that has been caused (Fell et al. 2008; Corominas et al. 2013). Furthermore, it should include information on landslide activity, useful to define the temporal frequency of landslide (Glade 1998; Guzzetti et al. 2006a; Van Westen et al. 2008).

There is no standard for realizing a landslide inventory map. Guzzetti et al. (2012) carried out a wide and detailed critical review of methods, techniques and tools used to prepare landslide inventory maps at different scales.

Depending on the purpose and the available resources, landslide inventory maps are compiled at different scales, from the local to the national, using a variety of techniques, including the analysis of stereoscopic aerial photographs (Rib and Liang 1978; Brardinoni et al. 2003) or of high resolution satellite images (Cheng et al. 2004; Nichol et al. 2006; Alkevli and Erkanoglu 2011), geomorphological field mapping (Brundsen 1985; Reichenbach et al. 2005), engineering-geological slope investigations and the examination of historical archives (Guzzetti et al. 2000). A combination of these techniques is often used.

The differences among the landslide inventory maps are mainly related to the type of represented data, their spatial and temporal distribution and the quantity and quality of information. Moreover, the landslide inventories are subjective products, whose quality depends on the skill and the experience of the investigators, the complexity of the study area and the completeness and reliability of the available information, including the aerial photographs used to identify the landslides (Galli et al. 2008). The above-mentioned differences are due to numerous factors, such as

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the purpose of the inventory map, the map scale, the cartographic map used as basis, the adopted method and the available resources. Relatively to the purposes, landslide inventory maps are used not only for documenting the extent, types and distribution of landslide phenomena (Dikau et al. 1996; Malamud et al. 2004; Duman et al. 2005), but also for assessing and mapping landslide susceptibility, hazard and risk (Wieczorek 1984; Ocakoglu et al. 2002; Gokceoglu et al. 2005; Lee and Lee 2006; Akgün et al. 2008; Gokceoglu and Sezer 2009; Ocakoglu et al. 2009; Pradhan et al. 2010; Van Den Eeckhaut and Hervàs 2011; Pourghasemi et al. 2012; Alemdag et al. 2014; Pellicani et al. 2013a). Accordingly, while detailed maps representing the more critical mass movements are needed for studies related to stability of urban centers or infrastructures, for landslide hazard analyses, through statistical methods, an inventory map which identifies the landslides uniformly in the entire study area is required, in order to correctly individuate the spatial correlation between landslides and environmental predisposing factors. The scale and the topographic maps used as basis for the detection and representation of landslides are very important for the accuracy of a landslide inventory map (Guzzetti et al. 1999; Cascini et al. 2010). The consultation of specific studies or data relating to investigation and monitoring allows one to obtain very detailed information at a large scale. But it is unlikely that these information can be made uniform on a regional scale.

Maps derived from observation repeated over time, through multi-temporal analysis, provide useful information on the evolution of the slope failure (Cheng et al. 2004; Guzzetti et al. 2006b; Witt et al. 1998). In general, the possibility to simultaneously apply different methods allows one to assign to surveyed landslides a greater amount of information and to obtain more complete inventory maps.

When analyzing the extensive literature regarding the assessment of landslide susceptibility and risk, the importance of the landslide inventory map is highlighted, as it contains basic information about the location of past landslide occurrences, as well as the movement typology, frequency of occurrence, activity degree, volumes, etc. However, inventory maps are often incomplete for a variety of causes, such as extension of the study area, lack of adequate financial resources and short time available for the investigation. In these cases, evaluation of the reliability and quality of the available inventory maps is a crucial operation in order to know the level of uncertainty and error, which will be included in the subsequent assessment of susceptibility and risk.

Absolute criteria to establish the quality of a landslide inventory map have not been established. The quality of a landslide inventory depends on its accuracy, and on the type and certainty of the information shown in the map; accuracy depends on the completeness of the map; completeness refers to the proportion of landslides shown in the inventory compared to the real number of landslides in the study area (Guzzetti et al. 2012). Most commonly, the quality of an inventory is ascertained in relative terms, i.e., by comparison with other inventories (Galli et al. 2008; Trigila et al. 2010).

In this paper, the quality of two landslide maps (at 1:25,000 scale) prepared for the Daunia region is evaluated, by comparing the two maps and determining the statistics of landslide areas. The comparison is aimed at establishing how well the two inventories describe the location and abundance of the landslides (accuracy) and the completeness of the inventories in terms of relationship between area and frequency of landslides.

The study area

The study area covers 1,282 km^2 in the western part of the Apulia region, in Southern Italy, and includes 25 municipalities of the Foggia province (Fig. 1). This area represents the geographical region called Daunia, in which the elevation ranges from about 50 m a.s.l. at Fortore river to 1,152 m a.s.l. at M. Cornacchia.

From the geological point of view, the area is characterized by a wide variety of formations with very different mechanical properties (rocky successions vs. clays), interacting with each other, and often heavily folded and faulted due to the intense tectonic actions occurred during the Apenninic orogenic phases. As a result, the landscape is characterized mainly by clayey slopes with medium steepness (around 12°), which locally increases (until 45°) in the presence of rocky strata.

The lithological, structural, geomorphological and climatic features of the area have a strong influence on landsliding phenomena, which cover about 12 % of the territory. Moreover, in this portion of the Apennines, meteoric events and earthquakes represent the main triggering factors of landslides. Mass movements consist of composite and complex landslides (Cruden and Varnes 1996), which range in type, volume and velocity, from deep slow roto-translational slides to shallow moderately fast earthflows. These landslides are triggered in the lower part of slopes, where the clayey successions outcrop, and then, due to their retrogressive evolution, affect the rocky slabs on which urban centers are located. Most of the urban centers of Daunia have a high level of potential risk (Pellicani et al. 2013b). Indeed, landslides are the main source of damage to properties in the urban centers of the area, especially involving transportation systems and the foundation stability of buildings. Municipalities such as Carlantino, Celenza Valfortore, Motta Montecorvino, Volturino and Bovino are completely surrounded by landslides; generally, the scarps are located at the edge of urban areas and

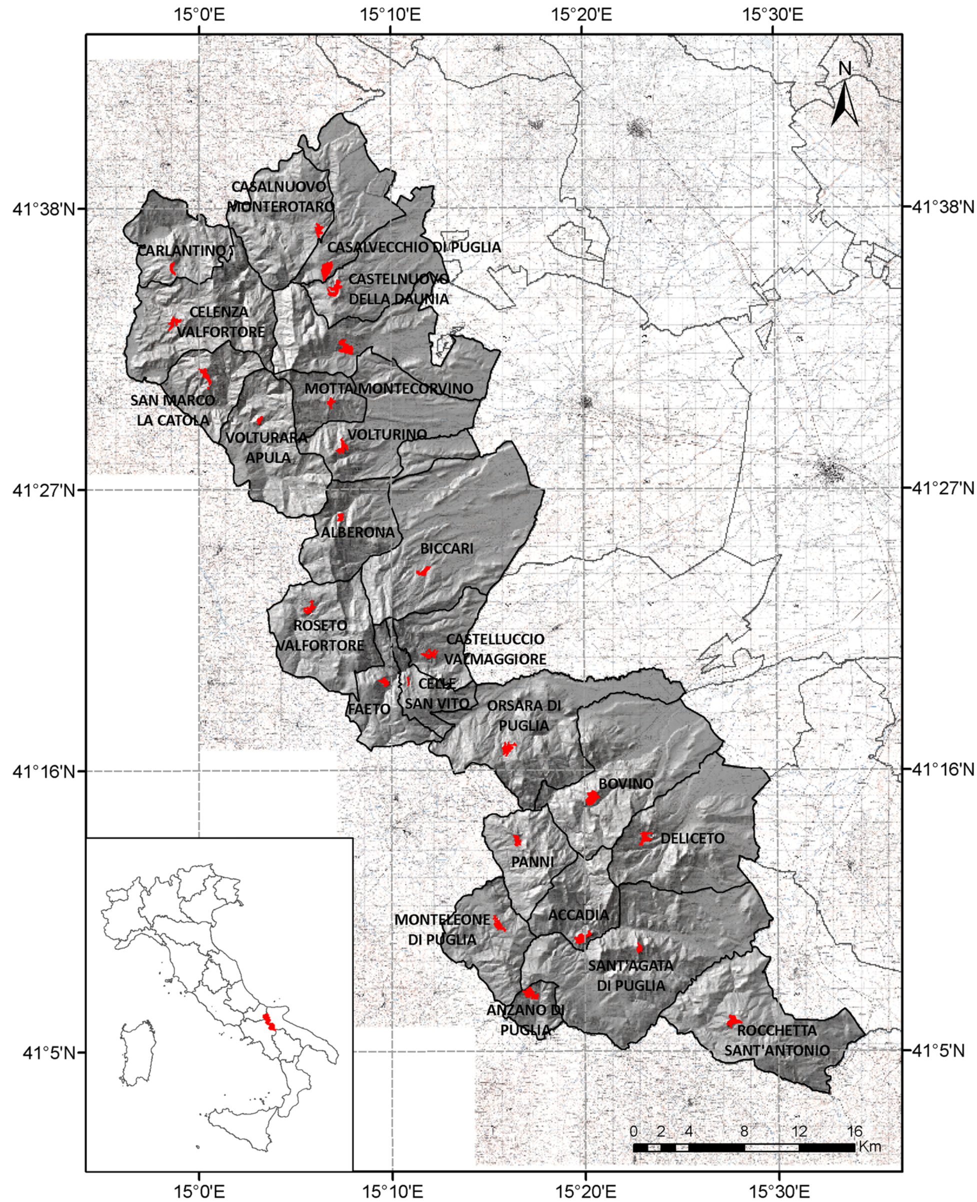

Fig. 1 Study area: Daunia region located in Southern Italy and composed of 25 municipalities

the main bodies evolve along the slope down to the valley. These are usually complex phenomena, of slide-flow type, whose retrogressive evolution often causes severe worsening of the stability conditions of the urban areas.

In most cases, the most recent areas of urban expansion, rather than the old historical center, are more directly threatened by instability processes. This highlights the importance of carrying out a landslide risk analysis for territorial planning purposes.

Landslide inventory maps

Several landslide inventory maps have been made for the Daunia region. In this paper, two inventory maps have been analyzed, both produced by the River Basin Authority (AdB) of Apulia for the project POR PUGLIA 2000–2006 (2009). The first map is an archive inventory map, realized by merging four existing archive inventories. The second map is a surveyed map, produced through aerial-photo-interpretation and field investigations.

Archive inventory

In the study area, the landslide phenomena are mapped in different archive inventories. For this study, the following four existing archive inventories were considered: PAI (Plan for the Hydrogeological Asset) of Apulia, PAI of Fortore-Saccione, PAI of Liri-Garigliano-Volturno and IFFI project (Table 1).

Table 1 Archive inventories existing in the study area

Existing archive inventories	No. of landslides
PAI of Apulia	271
PAI of Fortore-Saccione	456
PAI of Liri-Garigliano-Volturno	36
IFFI Project	157

The Italian Landslide Inventory (IFFI Project) is a national project, financed by Italian Government and aimed at identifying and mapping landslides over the whole Italian territory, based on standardized criteria (http://www.isprambiente.gov.it/en/projects/iffi-project).

The applied methodology is based on collection of historical and archive data, validated with aerial-photo interpretation and field surveys. In order to homogenize and integrate the landslide data over the whole national territory, the landslide database has been prepared on the basis of International standards of classification: Recommendations of International Association of Engineering Geology (IAEG 1990), International Geotechnical Societies UNESCO Working Party on Word Landslide Inventory (WP/WLI 1990), International Union of Geological Science Working Group on Landslides (IUGS/WGL 1995), and Cruden and Varnes (1996).

The IFFI landslide database is composed of three information levels with increasing detail:

- The first level contains the basic data on landslide location, type of movement and state of activity;
- the second level provides data on morphometry, geological setting, lithology, land use, causes of activation, date of activation;
- and the third level gives detailed information on damages, investigation process and remedial measures for risk reduction.

The IFFI geo-database contains vector layers of landslides and an alphanumeric archive of attributes. The mapping scale varies between 1:10,000 and 1:25,000, but is 1:25,000 in the study area. With regard to the Apulia region, the IFFI project has been conducted by Department of Geology and Geophysics of University of Bari (Pennetta 2006). The work started in 2001 and lasted beyond the deadline for the closure of the project, i.e., December 2005, in order to also consider landslide events subsequent to this date in the mapping, i.e., those related to winter 2005–2006, which was particularly rainy and characterized by widespread instability phenomena. Currently, part of the IFFI inventory has been acquired by the PAI project. Indeed, other three existing archive inventories were realized by local River Basin Authorities: those of the Apulia, Fortore-Saccione River and Liri-Garigliano-Volturno River, respectively. In order to manage and control the hydrogeological instability in the Italian territory, the PAI (Plan for the Hydrogeological Asset), required by the law 267/98 (Law 1998), was adopted by Local River Basin Authorities (AdB) in 2004.

In particular, the PAI project is related to the major regional river basins, within which areas at hazard and risk are present. In the context of the PAI, the landslide hazard is considered as the combination of geological and geomorphological instabilities that affect the basin of interest for planning. The methodological procedure for delimiting the unstable areas consists of the two following phases:

1. Editing of landslide inventory maps, through the: (a) acquisition of the available data from public (national, regional, provincial and municipal) offices and research centers; (b) recognition of landslide processes by means of aerial photo-interpretation and field surveys, in order to obtain an acceptable level of homogeneity of information at the scale of entire basin; (c) identification and classification of the typology, intensity and state of activity of landslides; (d) definition of morphological features and locations of landslides, and representation on an appropriate cartograph.
2. Definition of the landslide hazard, through the analysis of landslide susceptibility for the entire basin or for its portions.

As shown in Fig. 2, the above cited landslide inventories cover different areas within the study area. For this reason, the existing inventories were merged into a unique landslide "archive inventory map" at 1:25,000 scale. This operation was made by AdB of Apulia during a project (POR PUGLIA 2009) aimed to update the state of knowledge on the instability phenomena in Apulia region. The four existing inventories are homogeneous for the mapping date and the representation scale. Indeed, in the PAI, the mapping of landslide phenomena is periodically updated; so, the landslide polygons contained in these inventories, at the moment of the creation of the archive inventory, are relative to 2006, as are those in the IFFI inventory. With regard to the representation scale, it is the same, i.e. 1:25,000; while the maps used as a cartographic base for digitizing the landslides are slightly different. The IFFI project used the IGM map at a 1:25,000 scale, and where available, the Regional Technical Map at 1:5,000 scale. The PAI used the IGM map at 1:25,000 scale, and where available, the Regional Technical Map at 1:5,000 scale and different orthophotos at 1:10,000 scale.

Not all the existing archives of landslides were integrated into the archive inventory map. For example, the AVI project (http://avi.gndci.cnr.it/welcome_en.htm) (Guzzetti et al. 1994), despite being one of the most

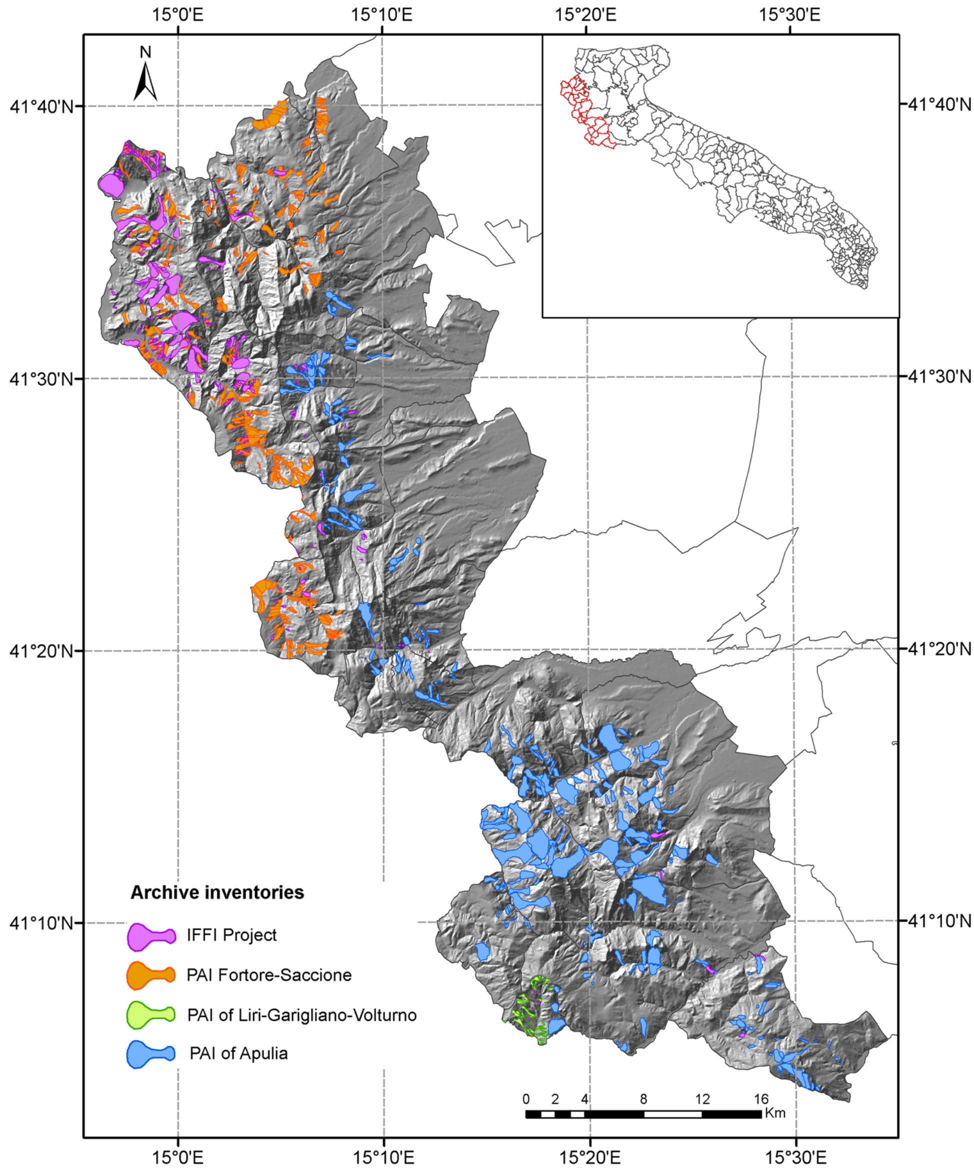

Fig. 2 Archive inventory: landslide inventory map obtained merging the landslides from the existing inventories (IFFI and PAI) in the study area

consistent, with about 350 landslides, lacks of information on the exact location, the spatial extension and the type of landslides. Moreover, the representation scale is different from the other inventories, i.e., it is at 1:100,000.

In the landslide archive inventory, about 920 landslides were detected, mapped and classified according to movement typology. In particular, ten different landslide typologies were recognized (Fig. 3a): falls/topples (1 %), translational slides (1 %), widespread shallow landslides (1 %), rotational/translational landslides (1 %), rapid flows (2 %), solifluction (8 %), complex movements (9 %), rotational slides (11 %), slow flows (11 %), earth flows (37 %). For 39 % of the landslides, the movement typology was not determined.

Surveyed inventory

This landslide inventory map was produced in 2007 by the River Basin Authority (AdB) of Apulia (POR PUGLIA 2009), mainly through the aerial-photo-interpretation technique. The stereoscopic analysis was carried out using black and white aerial photographs at scale 1:33,000, flown in 2003 by the Italian Military Geographical Institute.

The landslide polygons were digitized in GIS on georeferred orthophotos (relative to 2006) at a scale of 1:5,000 (Fig. 4). About 1,320 landslides were detected, mapped and classified according to movement typology. Five landslide typologies were recognized (Fig. 3b): rotational slides (1 %), translational slides (4 %), earthflows (21 %), complex movements (23 %) and widespread areas

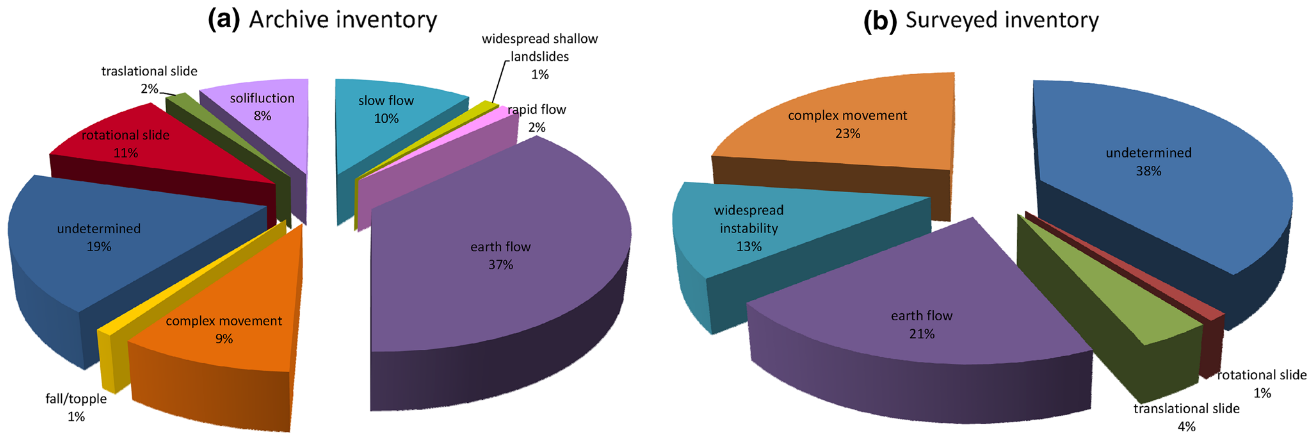

Fig. 3 Percentages of landslide typologies contained in the **a** archive inventory and **b** surveyed inventory

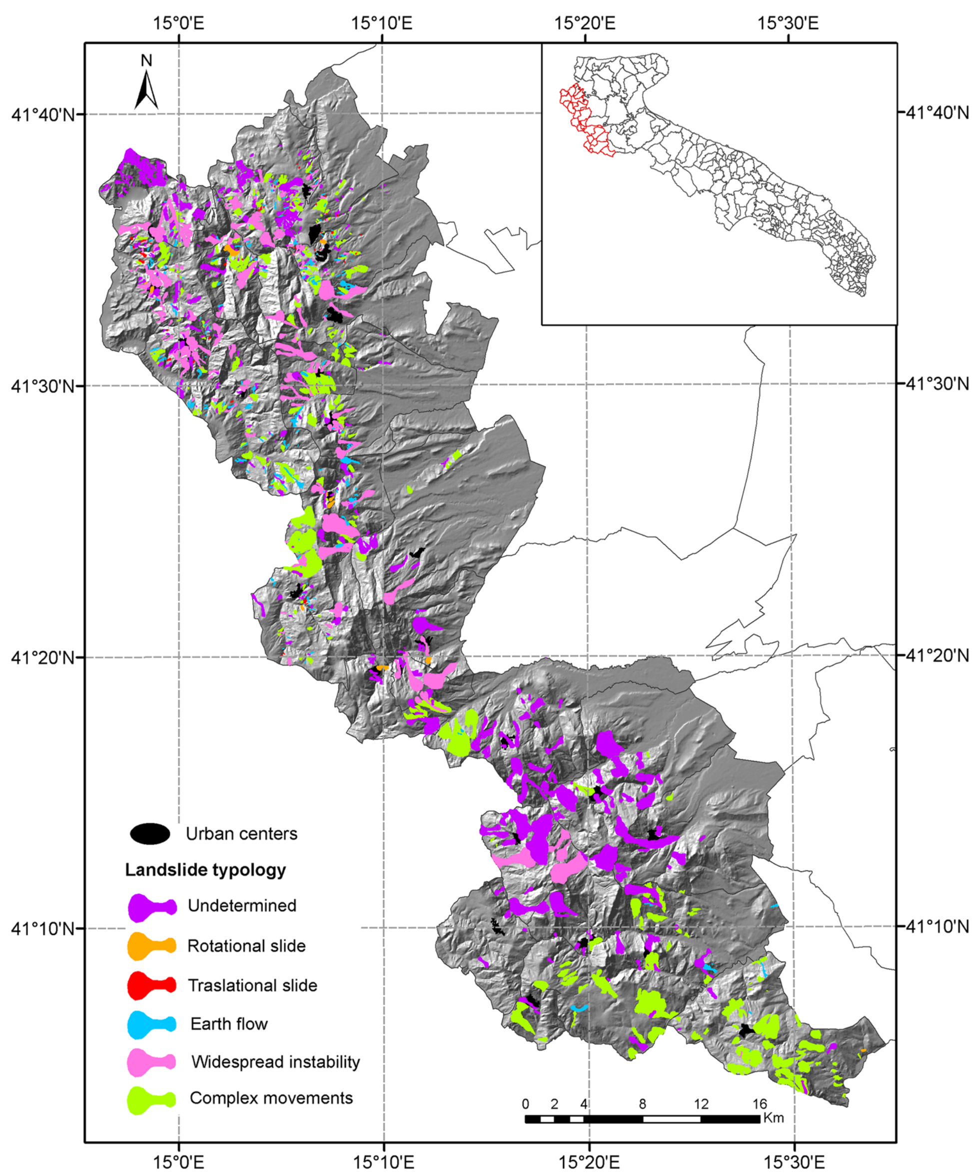

Fig. 4 Surveyed inventory: the location of landslides is identified and mapped through aerial-photo-interpretation by Apulia AdB

(13 %). The first four types are in accordance with the classification defined by Varnes (1984), while the last category was introduced to indicate areas characterized by the coalescence of different landslides not individually classifiable or by shallow landslides with poorly defined boundaries.

In the study area, lateral spreads, topples and falls are not present, as these typologies are connected to geological features not present in the study area. The typology of movement has been attributed to each landslide by recognizing in the aerial photos particular morphological features of the landslide body. For 38 % of landslides, the movement typology was not determined, due to the absence or alteration by external factors of the morphological features. In some cases, the aerial photo interpretation was supported and validated by field surveys, especially in those areas affected by widespread instability phenomena, typologically difficult to define.

The scale for the cartographic representation of this inventory map is 1:25,000, which corresponds with those of the IGM map used as a topographic base. The choice of this scale, which is a good compromise between coherence and precision in data visualization, was also conditioned by the fact that it represents the scale of the main available archive of landslide (PAI, IFFI, etc.). So it was convenient to use inventory maps at the same scale to compare them and to establish the relative quality.

The loss of accuracy resulting from the cartographic representation at 1:25,000 scale is still at acceptable levels, while the main limitation of the landslide inventory map is the absence of information about the degree of landslide activity, since the landslides were not detected in different years for the lack of a multi-temporal landslide analysis.

Methods for comparing landslide inventories

As the landslide inventory map represents a thematic layer of fundamental importance for elaborating the landslide susceptibility predictive model, determining the quality of the landslide inventories is a necessary task. Indeed, the quality and completeness of the landslide maps affects the reliability of the subsequent analyses derived from the inventory, such as a landslide susceptibility map.

Absolute criteria to define the quality of a landslide inventory map have not been established (Galli et al. 2008). In this case, the quality of the two inventory maps has been evaluated through a direct map comparison, aimed to assess the degree of cartographic matching between the maps, the determination of the statistical properties of landslide areas, and the comparison between the frequency-area statistics of landslides obtained from the two inventories.

In the first analysis, aimed to evaluate the degree of cartographic matching between the maps, the landslide inventories were overlapped in GIS and the following areas were computed: (a) the area with landslides in both the maps; (b) the area with landslides only in the surveyed inventory; (c) the area with landslide only in the archive inventory; (d) the area free of landslides in both the maps.

To quantify the geographical discrepancy between the two inventories, a procedure proposed by Carrara et al. (1992) was implemented. The overall error index, E, was computed as following:

$$E = \frac{(A_1 \cup A_2) - (A_1 \cap A_2)}{(A_1 \cup A_2)}, \quad 0 \leq E \leq 1$$

where A_1 and A_2 are the total landslide area in the surveyed and archive inventory, respectively, and $\cup$ and $\cap$ are the geographical union and intersection of the two inventories.

From E value, the degree of matching, M, between the two maps was deduced as following:

$$M = 1 - E, \quad 0 \leq M \leq 1$$

In the second analysis, the frequency–area statistics of landslides obtained from the two inventories has been compared. The landslide frequency–area distribution allows us to evaluate the completeness of a landslide inventory map, as a substantially complete inventory should include a substantial fraction of the smallest landslides (Stark and Hovius 2001; Guzzetti et al. 2002; Malamud et al. 2004; Galli et al. 2008). In particular, to obtain the dependence of landslide frequency on landslide area, probability density function (pdf) is calculated (Malamud et al. 2004):

$$p(A_L) = \frac{1}{N_{LT}} \frac{\delta N_L}{\delta A_L}$$

where δN_L is the number of landslides with areas between A_L and $A_L + \delta A_L$, and N_{LT} is the total number of landslides in the inventory. This landslide probability distribution is essentially characterized by an exponential rollover for small landslides and inverse power-law decay for medium and large landslides.

Results and discussion

In order to evaluate the quality of the two inventory maps and define the inventory map as more reliable for analyses of the landslide susceptibility and risk, the two inventory maps were compared and the above cited analyses were performed.

In Daunia, the surveyed inventory shows 1,322 landslide deposits, corresponding to an average density of 1.03 landslides per square kilometer. The mapped slope failures

Table 2 Characteristics of the two inventory maps for Daunia region

	Surveyed inventory	Archive inventory
Date of inventory (years)	2005–2006	2004
Scale of aerial photographs	1:33,000	–
Scale of topographic base map	1:5,000	–
Scale of final map	1:25,000	1:25,000
Study area extent (km^2)	1,282	1,282
Total number of mapped landslides (#)	1,322	920
Total area affected by landslides (km^2)	150	114
Percent of area affected by landslides (%)	11.8	9.5
Landslide density (#/km^2)	1.03	0.72
Smallest mapped landslide (m^2)	298	616
Largest mapped landslide (m^2)	3,062,000	2,857,000
Average size of mapped landslide (m^2)	115,700	132,800
Size of most abundant landslide (m^2)	~33,000	~52,000

cover a total landslide area of 151 km^2, 11.8 % of the Daunia region. Landslides range in size from 298 m^2 to 3.06 km^2, and the most frequent landslides have an area of about 33,000 m^2 (Table 2).

The archive inventory shows 920 landslides, corresponding to an average density of 0.72 landslides per square kilometer. The mapped slope failures cover a total landslide area of 122 km^2, 9.5 % of the study area. Landslides range in size from 616 m^2 to 2.86 km^2, and the most frequent landslides have an area of about 52,000 m^2 (Table 2).

The comparison between the descriptive statistics relative to the two inventory maps, summarized in Table 2, reveals a greater number of landslides mapped in the surveyed inventory (1,322) than that of landslide contained in the archive inventory (920). Generally, the number of landslides increases with enhanced accuracy of the mapping.

Furthermore, the area of the most abundant landslide is ~33,000 m^2 for the surveyed inventory and ~52,000 m^2 for the archive inventory. This means that the first inventory is more complete than the second inventory, because the area of the most abundant landslides decreases with the increase in completeness of the inventories (Malamud et al. 2004), while the average size of mapped landslides may be considered as a unreliable statistic to compare populations of landslides (Stark and Hovius 2001; Galli et al. 2008).

In the first analysis, aimed to evaluate the degree of cartographic matching between the maps, the inventories were overlapped in GIS (Fig. 5). The results, synthesized in Table 3, highlight a spatial disagreement between the two landslide inventory maps; namely, the area with landslides in both inventories is only 55 km^2, which corresponds to 36 % of the landslide area in the archive inventory and to 45 % of the landslide area in the surveyed inventory.

Table 3 Spatial comparison between the two inventory maps (A_X area with landslides, $A_{\overline{X}}$ area free of landslides)

Surveyed inventory	Archive inventory (km^2)	
	A_2	$A_{\overline{2}}$
A_1	55	95
$A_{\overline{1}}$	59	1,073

From the geographical union and intersection of the two inventories, a value of 0.74 was found for the overall error index *E*. This error is probably a geometric error associated with mistakes in transferring and digitizing the landslide polygons on the base map. According with the error value, a value of 0.26 was obtained for the degree of matching *M*. This result is indicative of the significant discrepancy between the two inventories; therefore, because they are not comparable, it was necessary to identify the most accurate and complete inventory to be used for subsequent susceptibility, hazard and risk analyses.

The landslide frequency–area distribution obtained for the two inventories is shown in Fig. 6. Landslide abundance increases with landslide area up to a maximum value, where landslides are most frequent, and then it decays rapidly with exponential law for landslides with medium and large size. The rollover at small areas indicates the completeness of inventory, because in nature large numbers of small landslides do not exist.

The probability density function (pdf) obtained from the surveyed inventory differs significantly from the pdf obtained from the other landslide map for small areas. Indeed, the rollover of the surveyed inventory is for landslide area $A \approx 1{,}000\ m^2$, while the rollover of the archive inventory is for higher value, $A \approx 16{,}000\ m^2$. Based on these results, the surveyed landslide inventory map predicts reasonably well the frequency distribution of landslides and could be used for landslide susceptibility and risk analyses.

Conclusions

The landslide inventory represents the basic map in a framework for assessing landslide susceptibility, hazard and risk. It contains information on the location of past landslide events, the extension of phenomena, the movement typology, etc. For this reason, the realization of a reliable landslide inventory map is an important task, but it is often difficult.

This work does not represent a review of several available methods for preparing landslide maps, but provides a valid procedure for evaluating the quality of existing inventory maps. Indeed, it is more difficult to

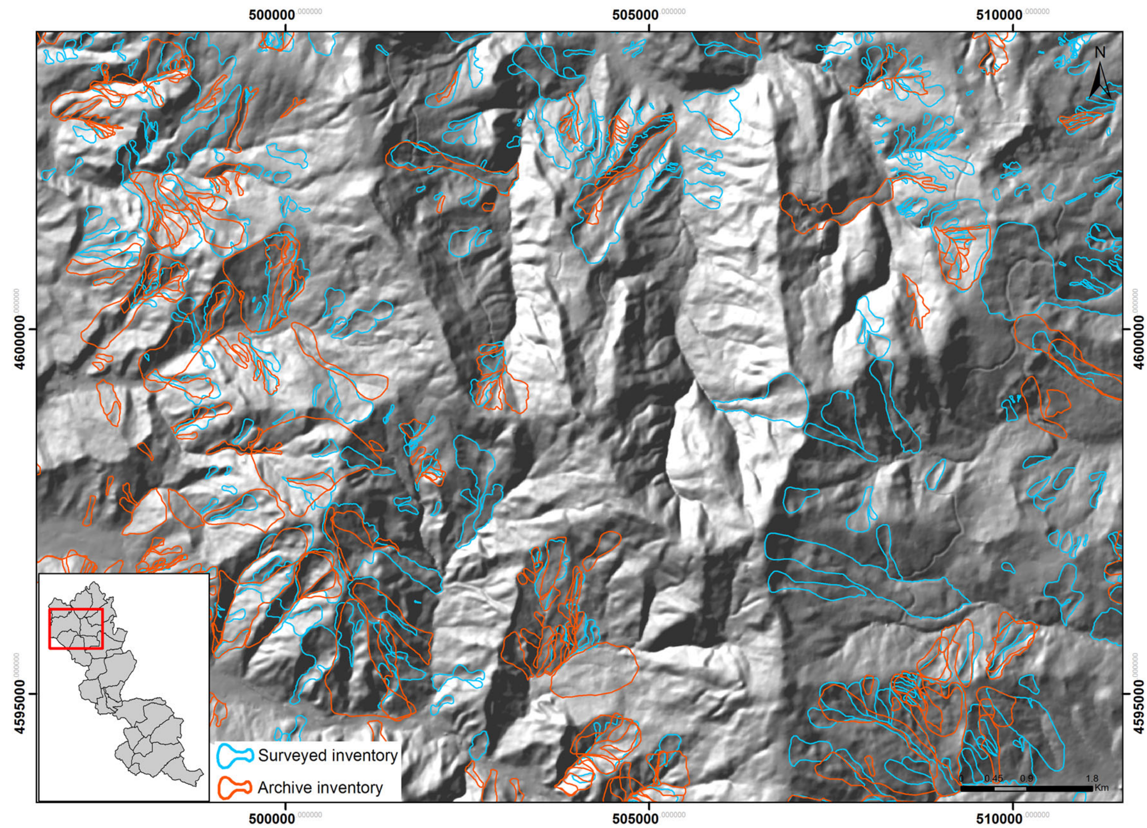

Fig. 5 Comparison between the surveyed inventory and the archive inventory through the cartographic matching

determine the quality of existing landslide maps than to prepare a new inventory map through the best existing methodologies. This is due to: (a) the quality depends on the accuracy, type and certainty of information mapped in the inventory, (b) the new and semi-automatic procedures that are already available for preparing landslide maps (e.g., through analysis of multispectral images or SAR data), with the advantage of reducing the subjectivity in landslide detecting, and thus, the interpretation and mapping errors. The landslide inventory maps used in this study were prepared through conventional methods, mainly based on the visual interpretation of stereoscopic aerial photos validated and supported by field surveys. These techniques are widely used, but are also time consuming and characterized by subjectivity in landslide mapping. Other authors, such as Guzzetti et al. (2012), suggest a combination of different methods (e.g., satellite, aerial and terrestrial remote sensing data) as an optimal solution for landslide detection and mapping.

In this paper, two different landslide inventory maps at 1:25,000 scale were compared in order to assess the quality, in terms of accuracy and completeness of the contained information. Both the maps were produced by the River Basin Authority of Apulia Region for the Daunia area, during a project aimed to update the regional landslide

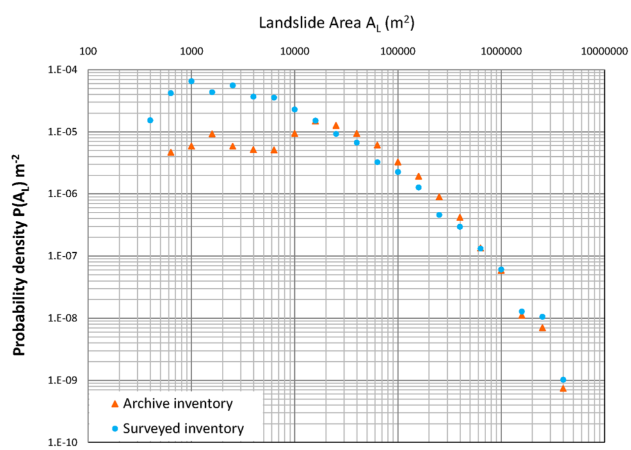

Fig. 6 Landslide frequency-size distribution, representing the dependence of landslide probability density p on landslide area

database. The "archive inventory" map was derived by merging four existing archive inventories, each of them prepared by means of the acquisition of the available historical and archive data, the aerial-photo interpretation and field surveys; similarly the "surveyed inventory" map was produced through aerial-photo interpretation and limited field surveys. The comparison between the two maps was carried out by assessing the cartographic matching between the maps, the abundance of the mapped landslides and the frequency-area distribution of landslides. Through the direct map comparison and the frequency-area statistics, it was evaluated that the archive inventory map is less accurate and complete than the surveyed inventory map, which, for this reason, could be used for modeling the landslide susceptibility and risk. The main problems deriving from the unification of the existing archives are related to the inhomogeneity of information associated with geographical data and the spatial overlap between the data related to different archives. Moreover, the indication of the type of mass movement was provided in different ways according to the various sources; for example, the IFFI is the only database that distinguishes rapid flows from slow flows, but considers the rotational and translational slides in the same category, without distinguishing them.

Definitively, in this paper, we highlight the importance of assessing the quality and reliability of landslide inventory maps, in order to evaluate the level of uncertainty that will be included in subsequent susceptibility and risk modeling based on these maps.

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