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LANDSLIDE FIELD MAPPING: IFFI-RESTART FORMS FOR DATA ACQUISITION AND MANAGEMENT

(Представлено членом редакційної колегії д-ром геол. наук, ст. дослідником О.І. Меньшовим)

Over the last few decades, the approach to geological and geomorphological surveys has changed remarkably. The advent of digital tools has allowed significant advances in the acquisition and management of survey data. In this paper, we demonstrate the development and testing of a new and effective digital survey method that allows for the fast acquisition and collaborative storage and management of data and information. This method was tested in collaboration with five universities for the mapping and classification of landslides in 249 survey areas in Central Italy and, more precisely, in the municipalities affected by the 2016 Central Italy Earthquake. Geological and geomorphological surveys were carried out in the field with tablet PCs, GPS, and cameras. The survey project for collecting field data was based on the structure of the Italian Landslide Inventory (IFFI) and the Territorial Resilience Central Apennines Earthquake Reconstruction (ReSTART) projects. The structure of the database and input forms were implemented for these aims. Moreover, the data and information were retrieved and organised in detailed records useful to the administrative entities.

Keywords: ***digital geological survey, mobile GIS, relational database, geopackage, landslide inventory, post-disaster management.***

Introduction. The reconstruction of the inhabited centres in the municipalities affected by the 2016 earthquake in Central Italy involves a series of studies and acquisition of geological knowledge of the territory, all of which is managed by the government commissioner in a system called ReSTART (ReSTART…, 2020). Within this system, numerous projects are carried out by institutions and universities for technical and planning purposes. Among them, a program agreement was activated between the commissioner for reconstruction and the Central Apennines River Basin District Authority (ABDAC), a public entity (recognised by national law since 2017) with technical-scientific competences and a detailed knowledge base of the geo-hydrological hazards and risks of the involved areas. This agreement also involved five universities of Central Italy (University of Camerino, Chieti, Perugia, Rome 'La Sapienza', Urbino 'Carlo Bo') in a project for the resizing and reclassification of landslides that mainly affect the inhabited centres, according to the schemes of the Hydrogeological Basin Plans (PAI: Piano d'Assetto Idrogeologico) regulated and managed by ABDAC.

PAI represents a fundamental tool for land-use planning through the application of land-use restrictions and regulations and may be changed periodically by the River Basin District Authorities based on new studies and surveys, the occurrence of new landslides and floods, realisation of mitigation measures, or requests by local authorities (Trigila, & Iadanza, 2018).

The landslide hazard zones of the River Basin Plans (PAI) include areas of potential evolution of existing landslides and areas where new landslides may occur, in addition to occurred landslides (Trigila, & Iadanza, 2018). The Italian Landslide Inventory (IFFI Project) realised by the Institute for Environmental Protection and Research (ISPRA)-Geological Survey of Italy and the 21 Regions and self-governing Provinces (Trigila et al., 2007, 2010; Trigila, & Iadanza, 2008) was the preliminary and key tool used in the PAI for defining landslide hazard and risk assessment. The IFFI landslide inventory is the most complete and detailed landslide database in Italy (Trigila, & Iadanza, 2018).

In the framework of ReSTART activities, the ABDAC identified 1948 landslide and 239 survey areas (Fig. 1), i.e., slope sectors delimited by morphological features such as watersheds and drainage lines enclosing places with assets needing rebuilding (Fig. 2).

Geographically, the area includes 138 municipalities (Fig. 1) belonging to the Provinces of Ancona, Macerata, Ascoli Piceno, Fermo, Perugia, Terni, Rieti, L'Aquila, Teramo, and Pescara in the four Regions involved (Abruzzo, Lazio, Marche, and Umbria). In these areas, the PAI regulations and classifications are distinct from each other in the plans of the Marche, the Tronto Basin, Abruzzo, the Tiber, and Umbria. They derive from the territorial analyses of the primary regional hydrographic basins of Central Italy that were conducted individually prior to the formal constitution of the ABDAC, which currently manages them jointly.

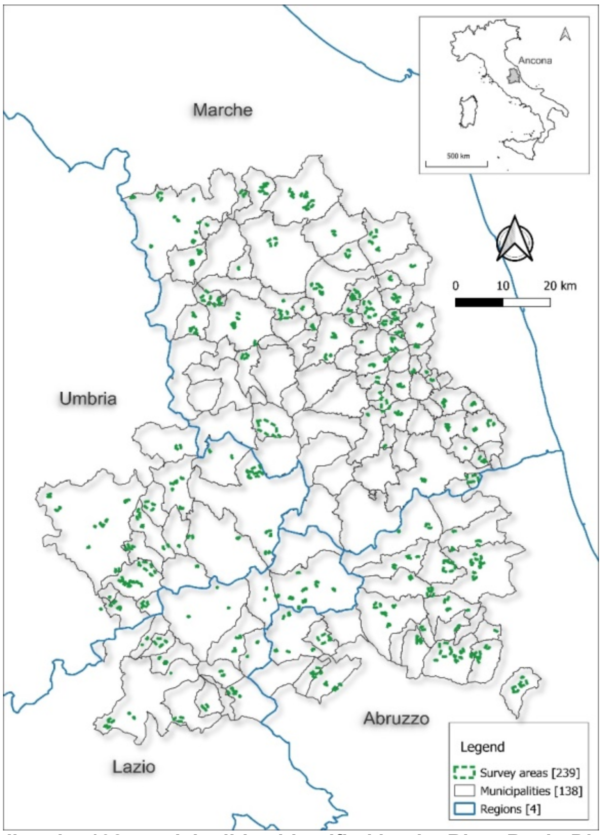

Fig. 1. Geographical area including the 138 municipalities identified by the River Basin District Authority for the recovery and reclassification of landslides occurring near the towns in the Region sectors affected by the 2016 Central Italy earthquake. The green dashed lines represent the 239 survey areas

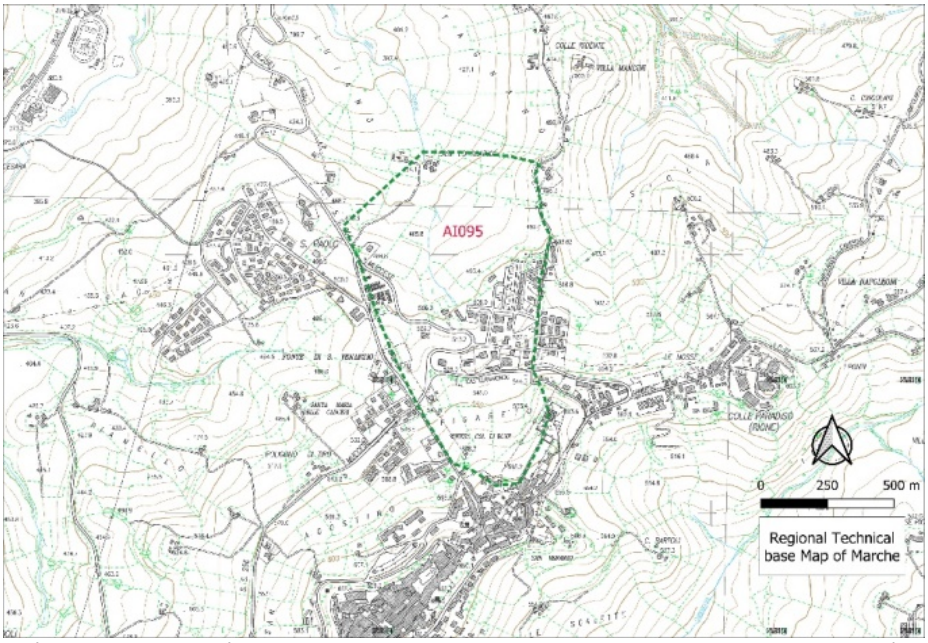

Fig. 2. Example of survey area as defined in Fig. 1. The green dashed line bounds the area. Base map from the Regional Technical Cartography (C.T.R.) at the scale of 1:10.000 (Regione Marche, Carta tecnica numerica 1 : 10000, s.d.)

IFFI-ReSTART form. The need to adopt a common method and a scheme for all operators who work in the field and in the laboratory, while respecting the various regulations but with the aim of standardization, led to the choice of data acquisition according to a well-defined form (Jordan et al., 2005). This form is related to a database management system (DBMS) here designed, implemented, and illustrated (see Appendix A), which was used within the university project for the resizing and reclassification of landslides.

The form, although assuming the definitions and fields of the IFFI Project (Amanti et al., 2001; Trigila et al., 2007, 2010), was redefined and integrated in some parts, both to standardize the different PAI and to adhere to the main purpose – the safe reconstruction of inhabited centers.

In the field, we acquired detectable data from direct observations and measurements or with ground- and/or drone-based photographic acquisitions. The form allowed acquiring relevant observations to facilitate interpretation of the field data.

This new tool allowed the standardization of the field data collection, while guaranteeing a certain work speed and high data quality and providing storage that can be managed within a multi-platform database format and an open-source and free GIS program.

Methods. Before operating in the field, we acquired all the ancillary data and bibliographic documentation for the database and the photographic and satellite images for the identification and multi-temporal analysis of the phenomena under study and the neighboring areas (defined in the project as the area of interest, AI).

The surveys were carried out through conventional geological and geomorphological methods with the aid of digital tools supporting a GIS field project (De Donatis et al., 2019).

Therefore, while compass, hammer, binoculars and all the classic analogue instruments allowed the observation and measurement of geological data, the digital survey method developed during this project enabled acquiring and digitally storing the data directly in the field with the instruments.

1. Hardware. The use of digital tools for field mapping is well-documented (Clegg et al., 2006; De Donatis, & Bruciatelli, 2006; Gallerini et al., 2005). In this project, tablet PCs (Windows Surface Pro 7) equipped with the Windows 10 operating system and an input pen (stylus) were used. Windows tablet PCs had more than adequate capabilities (CPU Intel® Core™ i5-1135G4; RAM 8 GB; 128 Gb Disk; screen size 12.3") to manage maps, images, and data used and/or collected on the ground. An adequate cover made the tablet more rugged and transportable.

The positioning was carried out with Garmin Glo receivers (available for GPS and GLONASS; update rate: 10 Hz; WAAS/EGNOS correction; accuracy: 3 meters; battery life: 13 hours) linked to the tablet via Bluetooth (*Mussumeci et al., 2004*). For photograph acquisition, the tablet cameras and external digital cameras were used.

2. Software. The main GIS software used was QGIS (version 3.16) (Development Team QGIS Geographic Information System, 2020), which has been employed for years in field research. This GIS software was chosen for its ease and widespread use, as well as for the open-source approach that allows the customisation and creation of new tools suited for field work (De Donatis et al., 2016, 2019). Some plug-ins, downloadable from the QGIS plug-in repository) such as BeePen *(Alberti, 2015/2019*), were used to write notes and draw with the stylus directly on the map, similar to the pen-on-paper system (De Donatis et al., 2016). QGIS is a professional, multi-platform Geographic Information System desktop application, the official project of the Open Source Geospatial Foundation (OSGeo, 2022). Another application used in this field work was QField for QGIS (*OPENGIS.Ch, 2022*). It is a free software app released under the GNU Public License (GPL) and available for installation on devices such as tablets and smartphones to collect data on the ground. The QGIS QFieldSync plugin (OPENGIS.Ch, 2022) allowed preparing and packaging the QGIS project and the associated database system into a much lighter "portable" project file that could be opened and used in QField for QGIS. After the field work, the same plugin allowed synchronising the modification and updating of data with the database and the QGIS desktop project file.

3. Database. A geographic relational database was developed to support the acquisition of landslide data in the field and their storage using tablet PCs, GPS, and open-source software. The database was designed and implemented in the Geopackage format (Open Geospatial Consortium). Geopackage is an open, standards-based, platform-independent, compact native storage format using an SQLite database as container and the Geopackage encoding standards defining the scheme. Database tables and fields correspond to entities and attributes derived from the IFFI Project Italian landslide inventory (Trigila et al., 2010; Trigila, & Iadanza, 2008) and updated following the criteria adopted by the abovementioned ReSTART project. The entity–relationship scheme of this database was fully developed from scratch.

The database is named restart.gpkg and was implemented in accordance with the scheme shown in Fig. 3, in which the tables named lslide, photo, extent, risk area, anthropic and mitigation (green in the figure) are spatial tables. Their geometry type is "polygon" except for the photo table, the geometry type of which is the "point". The other tables (blue in the figure) are non-spatial tables: 12 are association tables and 27 are lookup (Connolly, & Begg, 2005) or dictionary tables (Fig. 3).

The lookup tables store fixed categorical and ordinal data values representing classification standards of landslide-related information and are associated with the other tables mainly by means of "one-to-zero, one or many" relationships (Fig. 3).

The lslide table stores only the information regarding the landslide bodies, already censused or newly identified, and the polygon geometry representing both the landslide detachment zone and the zone of accumulation.

The extent table is a spatial table storing a polygonal geometry representing the potential enlargement of the landslide, which may coincide with the current one or be mapped by the surveyor as larger than the landslide assuming its maximum expansion area. This table is associated with the lslide table by means of a "one-to-one" relationship and is an intermediate table between the lslide table and hazard table, because the latter contains the four hazard levels to be assigned to the landslide extent polygon as required by the ReSTART project standards. The extent table is also associated with the risk area_extent table by means of "one-to-zero, one or many" relationship (Fig. 4). The riskarea_extent table is an intermediate table between the extent table and the risk area table. The latter stores the polygons of the risk areas possibly enclosed by the landslide extension area. Each polygon of the extent table can enclose any, one or more risk areas. A risk area table polygon encloses the asset features already mapped in the official cartography. The lookup risk table provides the classes of risk to assign to each risk area. The greater risk class between those assigned to the risk areas will be associated with each polygon of the extent table.

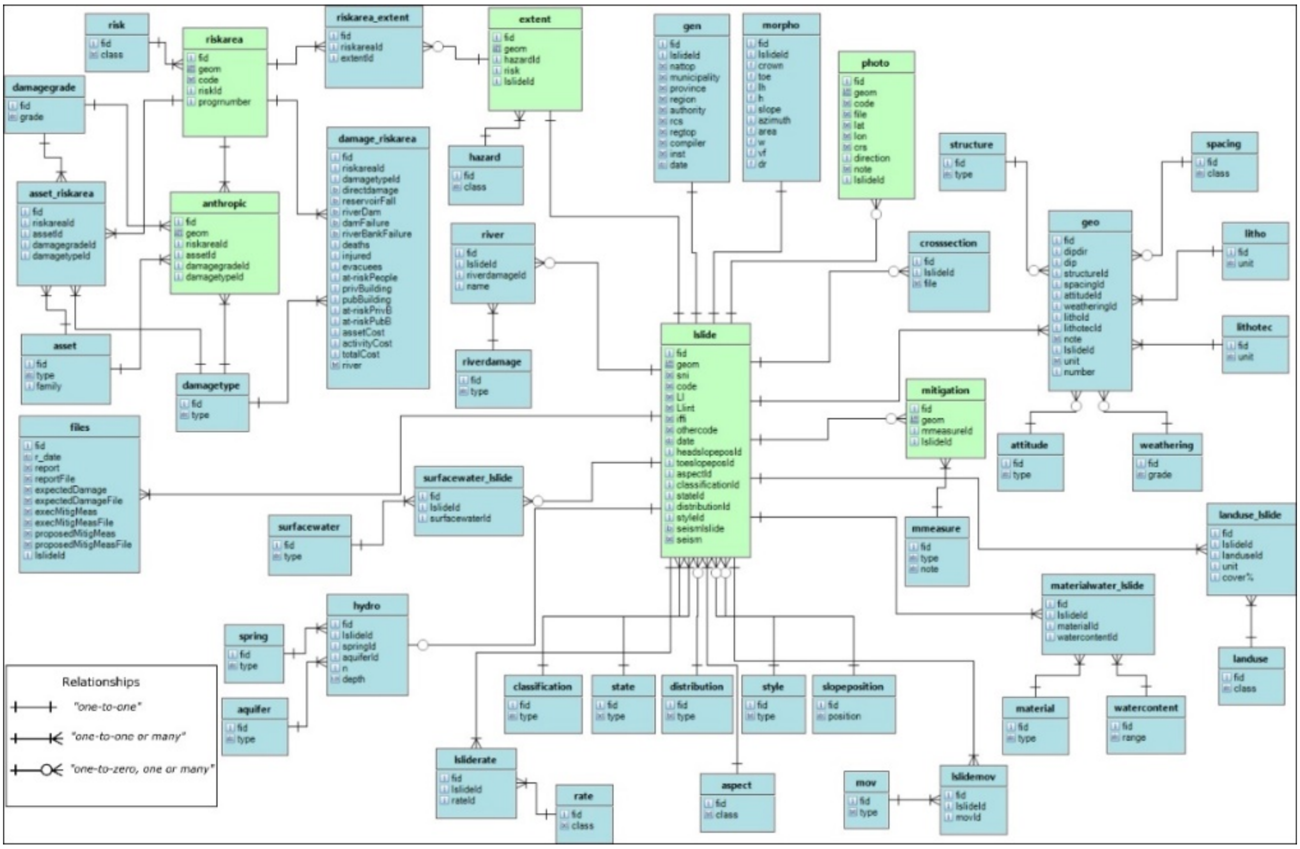

Fig. 3. The restart database entity-relationship (E-R) diagram representing core spatial tables in green, non-spatial association and lookup tables in blue, with listed fields and relationships between tables. The fields and the reasons for choosing the types of relationships between tables are illustrated below. The symbols of the types of relationships are described in the legend

The asset_riskarea table is another intermediate table between the riskarea on the one hand and the damagetype, damagegrade, and asset tables on the other, allowing the association of the types of assets involved in the landslide and the type and grade of damage with the risk area enclosing the assets (Fig. 3). In addition, the anthropic table is an intermediate spatial table with the same role as the asset_riskarea (Fig. 4). The latter table stores data relative to assets already mapped in the risk areas; the anthropic table instead allows the surveyor to map new polygons or linestrings representing asset features not yet mapped, as well as to record the relative types of assets and the type and grade of damage (Fig. 4). In the damage_riskarea table, instead, it is possible to store information on the different types of damage induced by landslides in each risk area and the related costs (Fig. 3). The spatial riskarea table is associated with this table by means of a "one-to-one or many" relationship.

The database can also store the information relative to the type of damage eventually induced by landslides to a river course by means of the "one to zero, one or many" relationship between the lslide table and the river intermediate table (Fig. 4), because a landslide can affect or potentially affect one or more river courses. The riverdamage lookup table provides the list of damage types to assign to the river table (Fig. 4).

The photographic documentation is stored in the photo table associated with lslide by means of "one-to-zero, one or many" relationship (Fig. 3). Each individual landslide can be documented by one or more photographic images. In this table, geometry type data and the point coordinates are also stored.

The lslide table is the spatial table storing the polygonal geometry of the landslide and containing a set of foreign keys pointing to lookup table attributes characterising landslides regarding the classification of the kinematics, state, distribution, style, and position on the slope (Fig. 3).

The lslide table is associated with the gen and morpho tables by means of a "one-to-one" relationship, and with the geo table by means of a "one-to-one or many" relationship. In the gen table general information about the geographical and administrative location of each landslide is stored. In the morpho table, instead, the values of the main morphometric parameters of each landslide can be registered (Fig. 3).

One or more lithological and lithotechnical types (retrievable from the litho and lithotec tables, respectively) and one or more lithostratigraphic units can be affected by the same landslide; thus, one or more records of the geo child table can be associated with one record of the lslide parent table. The attributes of the geo table are mainly foreign keys pointing to the primary keys of six lookup tables, allowing the association of values of the compositional, physical, and mechanical characteristics with each geological unit affected by the landslide (the lookup tables are litho, lithotec, structure, spacing, attitude, weathering; see Fig. 3).

The materialWater_lslide table has three foreign keys referring to the primary keys of the lslide table, the material table and the watercontent table. This table allows the association of the material and the water content with a landslide by means of a "one-to-one or many" relationship (Fig. 4).

The lslideId foreign key of the lslidemov intermediate table points to the primary key of the lslide table establishing the "one-to-one or many" relationship from the lslide parent table to the lslidemov child table, thus allowing the association of the types of movement with a landslide. This is because one or more types of movement, retrievable from the lookup table mov, can characterise a landslide, particularly if it is a complex one. The lslidemov child table is associated with the mov parent table by means of a "one-to-one or many" relationship (Fig. 4). Identical relationships are established between the lsliderate intermediate child table and the lslide parent table, and between the lsliderate table and rate parent table. One or more classes of the rate of movement of a landslide, retrievable from the lookup table rate, can characterise the different types of movement of a complex landslide (Fig. 3).

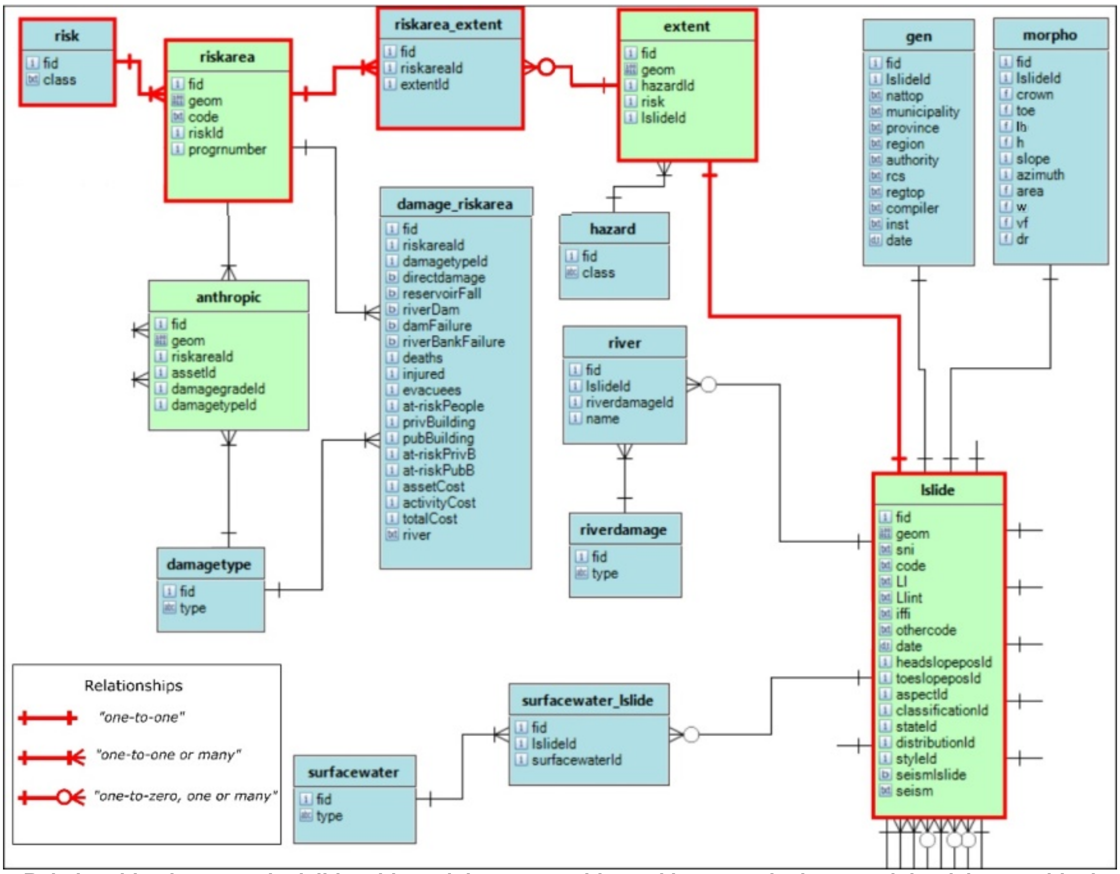

Fig. 4. Relationships between the lslide table and the extent table, and between the latter and the riskarea table through the riskarea_extent intermediate table. The red line symbols represent the type of relationship as described in the legend

The lslide table is also associated with the lslidelanduse intermediate table by means of a "one-to-one or many" relationship, because one or more land-use units can be affected by the same landslide; thus, one or more records of the lslidelanduse table can correspond to one record of the lslide parent table (Fig. 3). Another foreign key in the lslidelanduse table (landuseId) points to the primary key of the landuse lookup table and stores the unique 'id' of the land-use class involved in the landslide (Fig. 3).

The lslide table is also associated with the mitigation table by means of a "one-to-zero, one or many" relationship (Fig. 3). The mitigation table is an intermediate spatial table between the lslide table and the measure. This table allows the surveyor to use the mapping polygons or linestrings representing mitigation features not mapped. The measure parent table is a lookup table storing a list of mitigation methods that can be associated with the landslides through the mitigation child table (Fig. 3).

The crosssection table stores any cross-section crossing the landslide body. The lslide table is associated with this table by means of a "one-to-zero, one or many" relationship because one or more representative cross-sections can be drawn for the investigated landslide, or no cross-section may be available (Fig. 3).

The surfacewater_lslide intermediate table shows the same relationship types as the mitigation table, with the lslide table on the one hand and the surface water table on the other (Fig. 3). The table allows the surveyor to associate the surface water content with the landslide.

4. Input forms. The restart database is behind a GIS implemented with the QGIS software. The attributes of the restart database tables are linked to the fields in a series of forms designed for use within the QGIS graphic interface; they, in turn, constitute the graphic interface with the restart.gpkg geographic database. The forms allow the surveyor to quickly record and store the data directly in the restart database, ensuring proper entry and integrity.

The form setting was based on the QGIS project file layer relations, based, in turn, on the database table relationships.

One main form was configured for the purpose of expediting the acquisition of data in the field and storing it directly in the restart database. The form is a multi-pages form accessible through 11 tabs (Fig. 5).

The first form page named "POSITION and ACTIVITY" is used to record the landslide identification data and the main landslide attributes surveyed and recorded (Fig. 5).

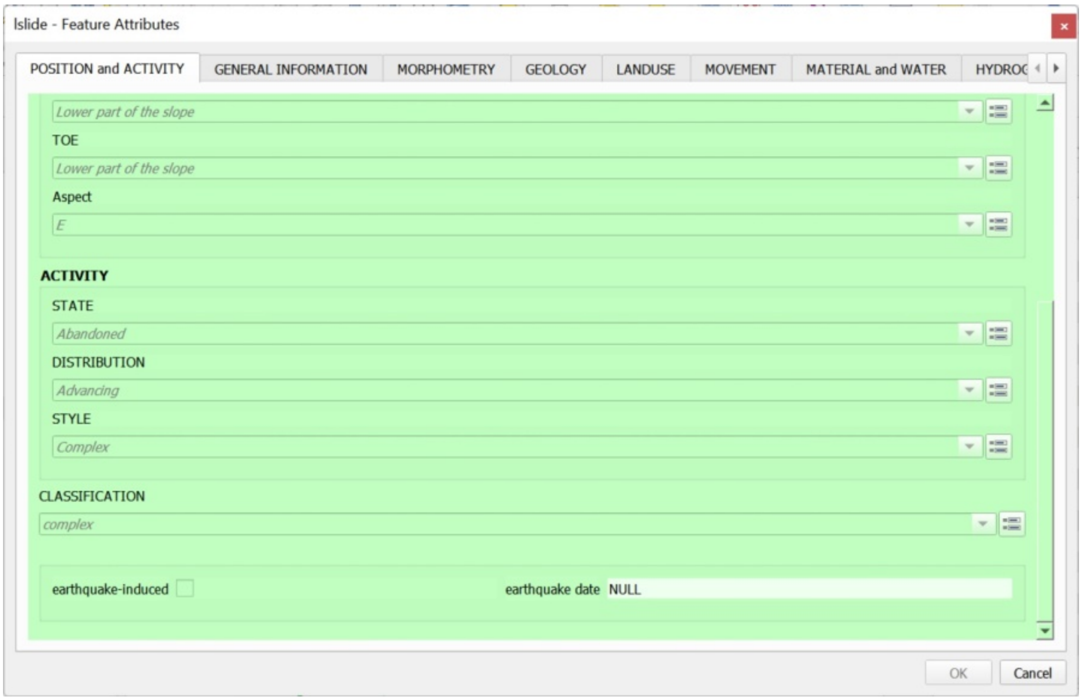

Fig. 5. The remaining quarter of the first form page named "POSITION and ACTIVITY" from Figure B1 with the other field boxes described in the text

After digitising each landslide polygon, the form window opens and field boxes are autocompleted. The "LABEL" field is automatically filled based on the autocompletion rules coded in the database triggers. The autocompletion of the label value depends on the eventual intersection of the digitised polygon with one or more landslides already present in the PAI inventory and pre-loaded as layers into the QGIS project file. In this case, the surveyor chooses the pre-existing landslide label to change and deletes all others. Then, the autocompletion rules store in the LABEL field the value composed of the label chosen and the surveyor's initials. In the event of digitising a new landslide polygon not intersecting with any pre-existing one, the autocompletion rules store the label value composed of the local administrative unit code, the surveyor's initials, and the progressive number. Thus, the landslide label displays a new unique landslide identifier code.

The other identification data are represented by the field boxes:

- "Name of the surveyor", the field containing the surveyor's name;
- "Progressive number", to be filled only in the event of digitising a new landslide polygon not intersecting with any pre-existing one. Otherwise, it is left empty;
- "IFFI", the field automatically filled with the univocal landslide identifiers from the national inventory (Inventory of Landslide Phenomena in Italy, IFFI) only when digitising a new landslide polygon intersecting with one or more pre-existing IFFI inventory landslide polygons pre-loaded into the QGIS project file as a layer;
- "Other", the field provided to store a label or identifying code of the landslide reported in a scientific publication.

Scrolling down, fields describing the landslide slope position (relative to landslide head, toe, and aspect), the activity (including landslide state, distribution, style) and the main type of movement are completed, along with whether the landslide is earthquake-induced or not:

- "HEAD", "TOE", "Aspect", "STATE", "DISTRIBUTION", "STYLE" and "CLASSIFICATION" are attributes whose values are selected from the respective drop-down lists present in the form (Fig. 5). The fields are linked to the attributes of the database's lookup tables (slopeposition, aspect, state, distribution, style, classification) containing the codes of the geological/technical data representing the descriptors of landslide position, movement, and activity following (Cruden, & Varnes, 1996; WP/WLI, 1990, 1993);
- "earthquake-induced", the field storing a Boolean data type: the true value means that the landslide is earthquake-induced, the false value that it is not. The default value is set on false;
- "earthquake date", the field storing the value of the earthquake date time.

The second form page, named "GENERAL INFORMATION", contains the attributes relative to the location of the landslide, the date of the inspection, and the surveyor's name (Fig. 5).

The "MORPHOMETRY" form page is used to record the values of the landslide morphometric parameters (Fig. 5):

In the "GEOLOGY" form page the fields to be compiled hold the attributes of the geo association table and of six lookup tables providing the list of compositional, physical, and mechanical parameters associated with the geological units affected by the landslide (Fig. 5).

Two last fields contribute to the complete description of the unit: "LITHOLOGY" and "LITHOTECHNIC UNIT", whose values are selected from their respective drop-down lists. In this case, the fields are linked to the attributes in the database's lookup tables containing the descriptors of lithological and geological/technical units (*Trigila et al., 2007*).

The fields of the "LANDUSE" form page (Fig. 5) are linked to the lslidelanduse table's fields unit, landuseId, cover%, and lslideId.

The "MOVEMENT" form page is composed of two internal sections: Movement and Rate (Fig. 5).

Also in the "MATERIAL and WATER" form page are two internal fields displayed as "MATERIAL" and "WATER

CONTENT", which are drop-down menus listing descriptor values derived from (Varnes, 1978; Cruden, & Varnes, 1996) (Fig. 5).

• "MATERIAL", the field describing the type of material before involvement in the landslide;

• "WATER CONTENT", the field describing the moisture conditions of the material before the occurrence of the landslide movement.

The form page "HYDROGEOLOGY" allows storing information, if available, related to the surface water and groundwater of the landslide area by means of two separate internal sections: Surface water and Springs and aquifer (Fig. 5). Descriptor values are selected from drop-down lists, then stored in the surfacewater_lslide and hydro association tables, respectively.

The ninth form page ("PHOTOGRAPHIC DOCUMENTATION") is used to enter the information regarding the images depicting the landslide features, the structures that have suffered landslide-induced damages, and the adopted mitigation measures (Fig. 5). The data related to the images are stored in the "restart" database's photo table. This table is associated with the lslide table using a foreign key in accordance with "one-to-many" relationships for which each landslide is associated with one or more images (see section 5. Photo acquisition).

The photo table is a spatial table, and an Add point button on the form page allows digitising a new geometry point representing the photographic shot point (the button with the three points in Fig. 6). Once the point is drawn, the attributes dialogue box opens showing the LAT, LON, and REFERENCE SYSTEM fields, which will be filled by the action of triggers executed when data are saved. The triggers are defined on the photo table and stored in the database as photo_coords_ins and photo_crs_ins.

Before saving, is necessary to:

• Load an image file with the Browse button aligned with "FILE NAME" from the folder where the file was previously saved. This action stores the file name and path in the photo table's file corresponding field and displays the file name on the page. A QGIS "Photo" widget is used, which allows the image to be previewed on the same form page (Fig.6). The file field represented by the alias "FILE NAME" is constrained to unique, so duplicate entries are avoided;

• Store in the "PHOTOGRAPHIC SHOT DIRECTION" field the azimuth of the photography direction. The field corresponds to the photo table's direction field;

• Compile the field "CAPTION" with a brief description of the image subject;

• The "Landslide code" field is automatically filled by means of the relationship between the lslide table and the photo table.

"REPRESENTATIVE CROSS-SECTION" is the form page allowing the loading and storing of the images of one or more cross-sections relative to the selected landslide (Fig. 6).

• By means of the Browse button in the "FILE NAME" field, an image file may be loaded from the folder where it was previously saved. The action stores the file name and path in the crosssection table's file field and displays the file name under FILE NAME on the page. A QGIS "Attachment" widget is used, which allows the image to be previewed on the same form page (Fig. 6). The file field, alias "FILE NAME", is constrained to unique, so duplicate entries are avoided;

• The "Landslide code" field is automatically filled by means of the relationship between the lslide table and the crosssection table.

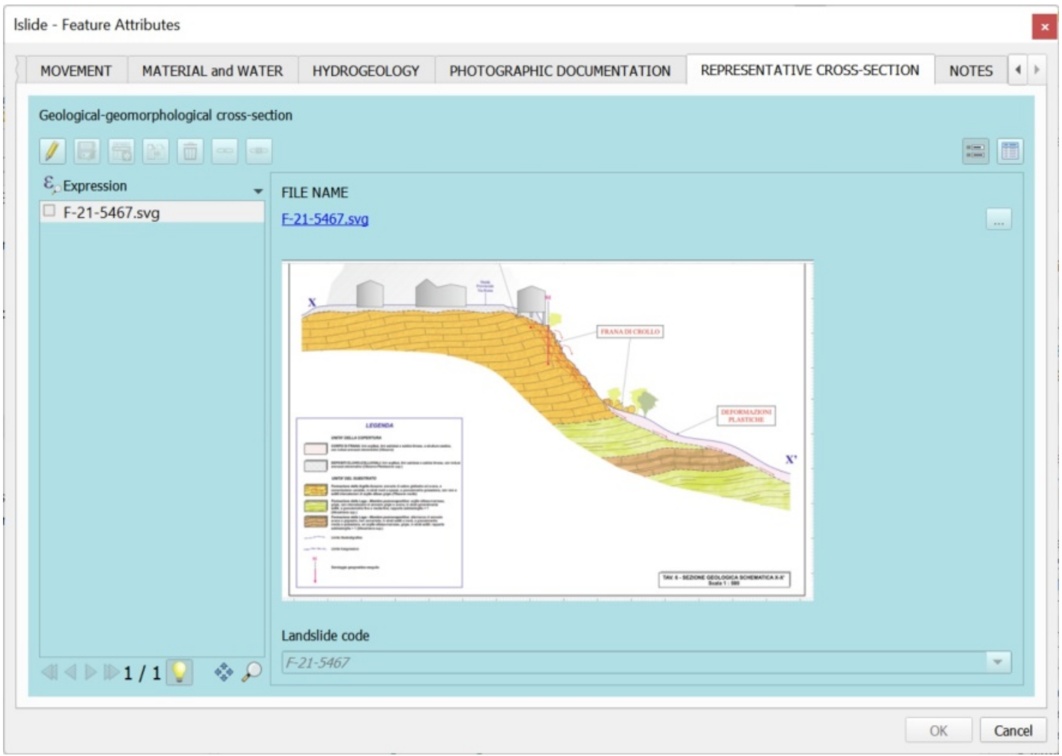

Fig. 6. The tenth form page named "REPRESENTATIVE CROSS-SECTION" for loading one or more images of geological–geomorphological cross-sections by means of the top right Browse button. Landslide code is automatically recorded

The last form page is "NOTES". It is composed of four tags allowing for storing different types of reports: reports on expected damages, reports on executed and proposed mitigation measures, and landslide analysis reports (Fig. 6).

Each tag is composed of:

• "Registration date of the report", a field for recording the report date in the database;

• "SUMMARY REPORT", a multiline field for recording a synthetic report of the analyzed landslide. In each tag, the summary report covers the topic in the header;

• "REPORT FILE", a field for saving the report file name and path in the database and creating a link to open it directly from the form.

5. Photo acquisition. The "Photographic Documentation" form page was set up to facilitate the rapid storage of the points representing the photographic shots taken in the field and of the other form attributes simultaneously with the point digitization (Fig. 6).

By clicking on the top left Add point button, visible in Fig. 6, the form disappears, giving way to the map view. After digitizing the new photographic shot point, the form reappears to allow loading the previously saved photo's files and filling in the other requested parameters, such as the PHOTOGRAPHIC SHOT DIRECTION and the CAPTION. The LAT, LON, and REFERENCE SYSTEM field boxes, instead, will be automatically compiled by the action of database triggers executed when data are saved.

6. QField for the field work. The restart database contains 91 tables. Many of these can store data obtained from bibliographic sources or from the subsequent processing and analysis of data previously acquired on the ground. By using the QFieldSync plugin installed in the QGIS Desktop main project, it was possible to prepare and package the main QGIS project into a much lighter "portable" project file for QField to ease the acquisition of data in the field. The QField package created includes the project file and only the tables and features useful for field surveying that may be copied and used on a land-data collection device (Fig. 7). The new QField project shows only the forms needed to collect the data observable in the field.

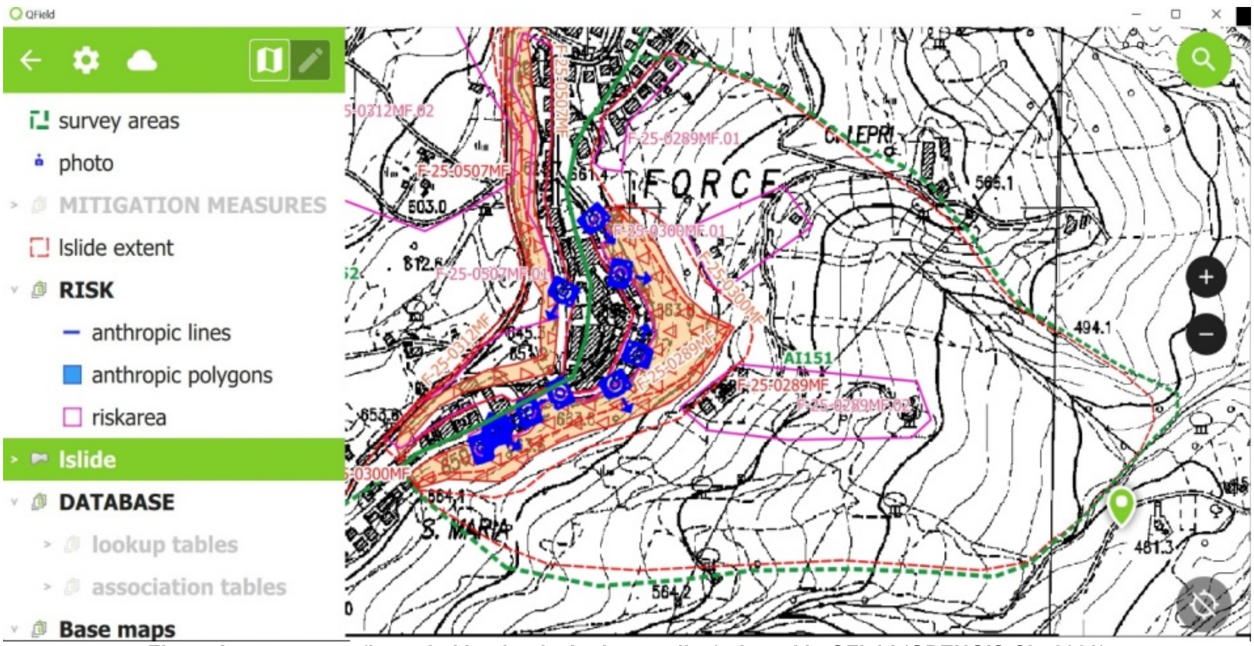

Fig. 7. A survey area (bounded by the dashed green line) viewed in QField (OPENGIS.Ch, 2022) with some features mapped and saved into the restart database with their attributes: two landslides (of light orange with red triangles), ten photographic shot points (marked by blue cameras), and other features explained in the QField left panel displaying the legend of the map with the main layers of the project

After the digital survey in the field, the QField project package is copied from the device to the desktop computer where the QFieldSync plugin allows for synchronization of the changes from the portable database tables to those in the main database.

The Chieti University survey group chose to work with the QField for QGIS version 1.X for Android on the Samsung Galaxy Tab Active Pro tablet as they assumed it was the fastest way of collecting field data (Miccadei, 2022).

To use the QField project, they organised the export according to the guided procedure from QGIS to QField, inserting the main layers/tables useful for data collection in the field.

The only information layers used were lslide and photo, and all other information useful for the population of the database was collected in the "digital field notebook".

The total compilation of the whole project, including the related database, was conducted in a second phase on the PC using QGIS Desktop.

7. Other Data and Information. In addition to acquiring "structured" data in tabular form through the survey sheet system illustrated above, customised with some plug-ins and other accessory programs, this mobile system makes it possible to acquire and manage usage information for final processing.

The BeePen plug-in allows drawing notes directly on the map on the screen. Some quick corrections were made to the landslide and outcrop limits available from previous landslide cartography (IFFI, PAI, and regional geologic and geothematic cartography (CARG) (CARG Project – Geologic and Geothematic Cartography, 1988) projects) or new acquisitions with indication/comment. These simple lines were digitized to a proper level.

Another useful application is the Windows Journal, which can be freely downloaded and installed (Microsoft Corporation, 2021). This app is used for field notes where text and sketches can be kept. Moreover, pictures and drawings in the app can be imported. The handwriting text can also be converted into digital text.

Discussion. The need to create a survey that could be used by different geologists and managed in a simple and reliable way in the field and to organise data and information for easy import and synthesis into the ABDAC database led to the creation of a dedicated GIS project.

The database structure complicated the challenge of including data and information, as well as maps, images and photos, sketches, and sections, that were manageable both on the ground and indoors and in the end would lead to a synthesis providing a means to analyze and produce the required reports. The Geopackage format best responded to these needs because it was simple to use and allowed unifying data collected by different users in one database.

To improve the ease of management of the GIS project in the field, several data and information entry forms were created. Each of these windows had different characteristics and often benefited from lists of terms and standardized classifications.

Collecting the data of each survey group in an overall project was a key point of this project, and it was possible thanks to the QGIS project implemented and packaged in a portable version for QField and to the platform-independent, portable, and compact format of the Geopackage database that connected with the overall ABDAC database structure.

Conclusion. Thus, with the data and information structured in the database, it was possible to use the tablet as a normal analogue campaign notebook in which to insert the observations that were useful for interpretations and processing but did not fit into the rigid structure of the IFFI-ReSTART card. Using the stylus both directly on the cartography ("Pen-on-map" surveying system) and on the pages of an annotation sheet (Windows Journal) maintained the traditional and proven surveying practices consolidated by decades of field practice.

The integration of field data with those already available or obtainable in the enabled creating a definitive database for PAI data that could be managed (and potentially increased or adapted to other functions) or consulted at various administrative levels (ABDAC, Regions, Provinces, Municipalities, professionals, and so on).

The accuracy of the GPS positioning was adequate. In fact, even if a cartographic antenna was used with an accuracy of the metric order, the reference base maps equalled those of the topographic map (Regione Marche, Carta tecnica numerica 1 : 10000, s.d.) at a scale of 1 : 10,000. At this scale (1 mm on the sheet equalled 10 m on the ground) the accuracy and precision of these instruments were largely sufficient. The possibility of entering data into a GIS database directly in the field also reduced the possibility of errors in the subsequent phases of indoor so-called "digitization", perhaps by a different operator (Campbell et al., 2005). For this purpose, GIS skills are no longer the prerogative of lab operators but also of field geologists.

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ПОЛЬОВЕ КАРТУВАННЯ ЗСУВІВ: IFFI-RESTART-ФОРМИ ДЛЯ ЗБОРУ ТА УПРАВЛІННЯ ДАНИМИ

За останні кілька десятиліть підхід до геолого-геоморфологічних досліджень помітно змінився. Поява цифрових інструментів дала змогу досягти значного прогресу в отриманні та управлінні даними опитувань. У цій статті продемонстровано розробку й тестування нового та ефективного методу цифрового опитування, який дозволяє швидко отримувати та спільно зберігати й керувати даними й інформацією. Цей метод був випробуваний у співпраці з п'ятьма університетами для картографування та класифікації зсувів у 249 районах обстеження в Центральній Італії, а точніше, в муніципалітетах, які постраждали від землетрусу в Центральній Італії 2016 року. Геолого-геоморфологічні дослідження проводились на місцевості за допомогою планшетів, GPS та камер. Проєкт обстеження для збору польових даних базувався на структурі проєктів Італійської інвентаризації зсувів (IFFI) і проєктів Територіальної стійкості Центральних Апеннін після землетрусів (ReSTART). Для цього реалізовано структуру бази даних та форми введення. Крім того, дані та інформація були отримані та організовані в детальні записи, корисні для адміністративних установ.

Ключові слова: ***цифрова геологічна служба, мобільна ГІС, реляційна база даних, геопакет, інвентаризація зсувів, управління після катастроф.***

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