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Data Descriptor

Tracking a Decade of Hydrogeological Emergencies in Italian Municipalities

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Abstract: This dataset collects tabular and geographical information about all hydrogeological disasters (landslides and floods) that occurred in Italy from 2013 to 2022 that caused such severe impacts as to require the declaration of national-level emergencies. The severity and spatiotemporal extension of each emergency are characterized in terms of duration and timing, funds requested by local administrations, funds approved by the national government, and municipalities and provinces hit by the event (further subdivided between those included in the emergency and those not, depending on whether relevant impacts were ascertained). Italian exposure to hydrogeological risk is portrayed strikingly: in the covered period, 123 emergencies affected Italy, all regions were struck at least once, and some provinces were struck more than 10 times. Damage declared by local institutions adds up to EUR 11,000,000,000, while national recovery funds add up to EUR 1,000,000,000. The dataset may foster further research on risk assessment, econometric analysis, public policy support, and decision-making implementation. Moreover, it provides systematic evidence helpful in raising awareness about hydrogeological risks affecting Italy.

Dataset: See annex in Supplementary Materials.

Keywords: flood; landslide; debris flows; hydrogeological; disaster; impact; risk; hazard; civil protection

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1. Summary

Hydro-geomorphological events (namely, floods, debris flows, and landslides) affect urban environments worldwide, causing relevant disasters with increasing frequency and magnitude [1–8]. This is a direct consequence of two processes: climate change driven by the burning of fossil fuels in production systems [9–11] and uncontrolled or poorly planned urbanization in hazardous areas [11–13]. Due to the combined effects of intrinsic natural features, climate change, and urban expansion, Italy is a relevant hotspot for this kind of disaster [14–17]. For this reason, mapping, monitoring, modeling, and forecasting hydrogeological events is a relevant ongoing research topic that demands updated, systematic, reliable, and complete datasets accounting for recent occurrences. However, a nationwide structured collection of information about disasters is far from being achieved, as it is accomplished mainly on a self-reporting basis [18–21] or with experimental tools that do not always grant a high level of completeness and homogeneity and that usually mix minor events and high-impact disasters at the same level [22–27]. Global-scale datasets do not completely solve these problems, since when they are compared to national-level information, inconsistencies and bias clearly stand out, which are mainly related to the quality of reporting [28–30]. A reliable and trustworthy source of information is official documentation from authorities and public administrations, but

this kind of data is not structured, is not interoperable, is rarely provided in geographical format, and the information is sparse and inhomogeneous.

To fill this gap, we set up a comprehensive dataset that collects information about all hydrogeological disasters that occurred in Italy for which a national-level emergency was issued (Hydro-geomorphological Events, HGE henceforth) in the last 10 years (from 2013 to 2022). According to Italian laws, this is the highest possible level of emergency, and it is issued only when (and where) the impacts are so severe and widespread that emergency management cannot be carried out by local or regional governments. Usually, a national-level emergency is issued with a prefixed duration of one year, but in case this time is not sufficient to restore the "normal conditions of life" (this is textually the objective dictated by national rules about civil protection), the emergency could be extended multiple times. A national-level emergency implies that the National Civil Protection Department (*Dipartimento della Protezione Civile*, DPC) coordinates all activities related to emergency management and that the national government provides some funds to help local administrations. In addition, a Delegate Commissioner (DC) is identified to operate in the affected territories and manage the funds.

During the emergency, intense and complex bureaucratic activity involves several national and local administrations, including the DPC, DC, affected regions and municipalities, and the National Council of Ministers. In this work, official administrative documents related to national-level emergencies were tracked and analyzed to gain a comprehensive overview of the disasters affecting Italian territories from 2013 to 2022. The dataset provides information about the severity and the spatiotemporal extension of each emergency, portraying a striking picture of the Italian exposure to hydrogeological risk: in the analyzed period, 123 HGEs occurred in Italy, all regions were struck at least once, and some provinces were struck more than ten times. Globally, local administrations reported a need for more than EUR 11,000,000,000 to overcome the emergency, but the state transferred funds only for more than EUR 1,000,000,000.

This dataset was compiled in the framework of the project RISICOT (RISchi Idrogeomorfologici e COmpetitività Territoriale: interazione tra processi economici e dinamiche naturali, which translates as hydro-geomorphological risks and territorial competitiveness: interaction between economic processes and natural dynamics), funded by the European Union—NextGenerationEU. The main purpose of the dataset is to be used in conjunction with other econometric and environmental data to gain a deeper understanding of the drivers and impacts of severe hydrogeological events. For instance, in the framework of the aforementioned project, the dataset will be coupled with: (i) econometric indicators to assess indirect impacts on local economies; (ii) environmental and administrative indicators to search for correlations between the recurrency of hydro-geomorphological disasters and how much (and where) the Italian territories were urbanized. However, the public release of this dataset may also provide benefits to other fields of research. For instance, [31,32] discussed the lack of standards and comprehensive datasets to validate risk maps; [22,32–35] highlighted the need for updated and homogeneous datasets to calibrate hazard models; [36] stressed the complexity of acquiring detailed information combining sufficient detail with wide temporal and spatial coverage at the same time; and [37,38] identified some spatiotemporal patterns in societal risk that could be compared with the information contained in this dataset. Finally, the dataset and derived research products could be useful to raise awareness and engagement of the general public toward the hydrogeological risks affecting Italy [39].

2. Data Description

The dataset is shared with a CC BY 4.0 license and provided as Supplementary Materials as a .zip folder containing tabular information (.xlsx files) and geographical information (.shp files).

In the period covered by the dataset (2013–2022), each HGE typically strikes more than one province at a time; conversely, the same province/municipality can be hit by many different HGE at different times. This reflects the structure of the data contained in the

dataset, which is organized to highlight both the spatial and temporal dimensions of the phenomenon. The spreadsheets are conceived as inventories of each HGE that occurred in each administration; thus, each line represents an HGE in a province/municipality (in other words, each HGE is repeated multiple times for each province/municipality interested). The shapefiles are conceived as summaries where the information is aggregated over different spatial details (provinces and municipalities).

Concerning the two spreadsheets, they contain the same information, and the main difference is the administrative level at which data are aggregated: in Italian Emergencies 2013_2022.xslx (find in Supplementary Materials), spreadsheet *Provinces* reports data aggregated at the province level, while spreadsheet *Municipalities* accounts for the municipality level. In those spreadsheets, each row accounts for the space-time occurrence of a hydrogeological event as severe as to deserve the declaration of a national-level emergency. The territorial unit may be either a province or a municipality (depending on the file) hit by a specific hydrogeological event, and the following information is reported: [N/A (not available) is used in cases of missing information].

2.1. Italian Emergencies 2013_2022 (Provinces Spreadsheet)

- *Event_code*: Emergency state identification code. It is an alphanumeric code that univocally identifies an HGE, and it is composed of the year of occurrence followed by an underscore and by a progressive ordinal number related to the chronology within the considered year. For instance, 2018_03 represents the third HGE that occurred in 2018.
- *Province:* Name of the province.
- *Prov_code:* Standardized code that univocally identifies the province of occurrence, as defined by ISTAT (Italian Institute for Statistics).
- *Nuts_code:* Identifier of the province of occurrence, standardized at the European level.
- *ES y/n*: Binary code (0;1) expressing inclusion within the emergency state (ES). 0 = The province is hit by the event but not included in the emergency state; 1 = The province is hit by the event and included in the emergency state.
- *Civil Protection Ordinance:* Number and date of each ordinance connected to the emergency state (e.g., an ordinance to issue the emergency state and possible ordinances to postpone its end). These are official codes reported in all administrative and legal acts.

Afterwards, the spreadsheet reports the time of occurrence (starting day and ending day) of the critical meteorological event that caused the emergency state. However, in cases where subsequent storms have severely hit the same territory in distinct but quite near periods of time, they may be included in the same emergency state because, from a bureaucratic point of view, the extension of an existing emergency state may be considered easier than the proclamation of a new one. To account for that, the spreadsheet may contain a separate start/end date for each of these critical events.

- *Ev1end:* End date of the first period of occurrence of the critical event.
- *Ev2start:* Start date of the second critical event (if present).
- *Ev2end:* End date of the second critical event (if present).
- *Ev3start:* Start date of the third critical event (if present).
- *Ev3end:* End date of the third critical event (if present).
- *Ev4start:* Start date of the fourth critical event (if present).
- *Ev4end:* End date of the fourth critical event (if present).

Information about the start/end times of each event was reported in the official documents with different levels of detail. To account for that, a numerical code was used as follows.

- *Detail:* 1 = High detail (daily precision): the exact start/end days of the event are reported. 2 = Medium detail: the exact start/end days are reported, the event has a long duration (more than one week and less than one month), and the exact days may slightly vary from one place to another. 3 = Low detail: the months of occurrence are reported, and the exact days are unknown.
- The last block of information concerns bureaucratic details.

- *ES_start:* Start date of the emergency state.
- *ES_end:* End date of the emergency state. The end of the emergency is declared once the socioeconomic condition of the territory is deemed to have returned to the same level as before the event. Typically, for severe events, it takes some years.
- *Funds_received:* Amount of statal funds transferred to the Delegated Commissioner (DC), who is in charge of managing the emergency [€].
- *Funds_req_prod*: Funds requested by the DC to restore production activities, based on a preliminary recognition of needs [€].
- *Funds_req_tot:* Funds requested by the Delegated Commissioner, in total, based on a preliminary recognition of needs [€].

2.2. Italian Emergencies 2013_2022 (Municipalities Spreadsheet)

Most of the fields in this spreadsheet are the same as noted above, but they refer to the municipalities, which are identified by two additional fields:

- *Municipality:* Name of the municipality
- *Mun_code:* ISTAT code for each municipality.
- *LAU_code*: Identifier of the municipality, standardized at the European level.

Finally, two shapefiles summarize how many times each Italian province and municipality has been included in an ES and for how long, cumulatively. The file is provided in the ETRS 1989 LAEA projected coordinates system, which is widely used by Italian administrations, thus ensuring quick matching with other official geographic data. The fields composing the attribute table of the shapefiles are described hereafter.

2.2.1. Provinces Shapefile

- *Region:* Name of the region
- *Province:* Name of the province
- *Prov_code:* Standardized code that univocally identifies the province of occurrence, as defined by ISTAT.
- *Nuts_code:* Identifier of the province of occurrence, standardized at the European level.
- *N_ES:* Number of times the province was included in an emergency state (ES)
- *M_ES:* Cumulative number of months of duration of the Ess.

2.2.2. Municipalities Shapefile

- *Municipality:* Name of the Municipality
- *Mun_code:* Standardized code that univocally identifies the municipality of occurrence, as defined by ISTAT
- *LAU_code:* Identifier of the municipality, standardized at the European level.
- *N_ES:* Number of times the municipality was included in an emergency state.
- *M_ES:* Cumulative number of months of duration of the ESs.

The fields *Mun_code* and *Prov_code* can also be used to join the attribute table of the shapefiles to the spreadsheets for further analysis.

3. Methods

All the information contained in the dataset was extracted from official acts and documents. The primary sources used to compile the dataset are webpages of the institutions involved in the management of emergencies: the Italian National Civil Protection Department (DPC) and the local territorial governments involved (regions and provinces).

The first source of information analyzed was the DPC website (https://www.protezionecivile.gov.it/it/dipartimento/amministrazione-trasparente/interventi-straordinari-e-di-emergenza/emergenze-il-rischio-meteo-idro, accessed on 29 June 2023. Source: Civil Protection Department—Presidency of the Council of Ministers) [40]. Here, a complete list of each national-level emergency issued from 2013 onward is made publicly available (under a CCBY 4.0 license) to increase the transparency of emergency management and to disseminate the efforts undertaken by the DPC.

For each emergency, the list summarizes information about the regions and provinces affected, the type of event, the beginning and end dates, the reference code of the issued ordinances (the acts used to declare a new emergency or postpone the end of an ongoing one), and the total funds allocated for recovery.

First, this list was filtered and reorganized by removing events and information not directly related to the purpose of this research, such as water supply crises or swells. This allowed for compiling a spreadsheet where information is aggregated at the province level.

Afterward, to increase the information detail and to downscale it at the municipality level, other official documents were retrieved from the involved local authorities. The reference number of every civil protection ordinance (listed in the DPC summary) was used as a keyword in the web pages of the regions to retrieve regional-level acts and in the Italian Official Gazette website (https://www.gazzettaufficiale.it/home, accessed on 29 June 2023) to retrieve national-level acts. Overall, more than 400 official documents were analyzed, including regional decrees, governmental decree-laws, national and regional-level ordinances, administrative reports, and technical annexes. These acts were a relevant source of additional information, as they usually included accurate details on the triggering meteorological events (including the day and hour of occurrence and the spatial extension), a list of affected municipalities, inventories of damages, requests for funds, the amount of funds received, and references to other official acts (including civil protection ordinances) connected with the same emergency. Every emergency in each territory was therefore tracked from the beginning (declaration of an emergency state) to the end (declaration of the end of the emergency state). This tracking was fundamental because a state of emergency cannot stay "open" for an undefined time: when emergencies are opened, an ending date is also defined, and subsequently, an extension act can postpone the end up to 12 months. This can happen an undefined number of times, and every extension act can modify some details (e.g., the list of the impacted municipalities).

After this process, which also allowed for a refinement of the national-level data, new details were added to the "province spreadsheet" (e.g., all information concerning the timing of occurrence, the start/end dates, and the inclusion within the emergency state); moreover, the "municipality spreadsheet" was created to provide information with a finer spatial resolution. In particular, the main objective of this step of the procedure is to distinguish, within each province, between the municipalities that were included in the emergency (because relevant impacts were ascertained by national authorities) and those that were not (because the impacts suffered were not considered severe enough).

Another refinement was necessary to obtain full interoperability of the dataset. Over the last decade, Italy underwent an administrative rationalization process that led to a reduction in the number of municipalities. Typically, pairs of small neighboring municipalities were merged into a new (larger) municipality, gradually reducing the total number of municipalities from 8092 to 7901. To maximize the possibility of interoperability with other updated datasets, the name of the municipalities was standardized using the most recent name, and the official LAU and ISTAT (*Istituto nazionale di STATistica*—national institute of statistics) codes were also added. Finally, for each administrative level (provinces and municipalities), the number of times it was included in a national-level emergency was counted (Figure 1c), as well as the cumulative duration (in months) of the emergencies. These summarizing statistics were reported in the shapefiles to account for the recurrence of HGEs and the persistence of their effects across the Italian territory (Figure 1a,b). It should be highlighted that emergency states are usually very long (more than 50% of HGE durations are more than 12 months), and it may happen that a territory is hit again when a previous emergency state has not yet been closed. Therefore, different emergencies may coexist in the same territory at the same time, sometimes resulting in a cumulative length of emergencies higher than the duration of the timespan of this work (Figure 1a,b). We consider this information to be a feature that could be used to account for the persistence of the cumulative impacts of repeated HGEs. To add a temporal dimension to the basic

summarizing statistics describing the dataset, Figure 1c shows, on a year-by-year basis, how many HGEs occurred and how many provinces were hit.

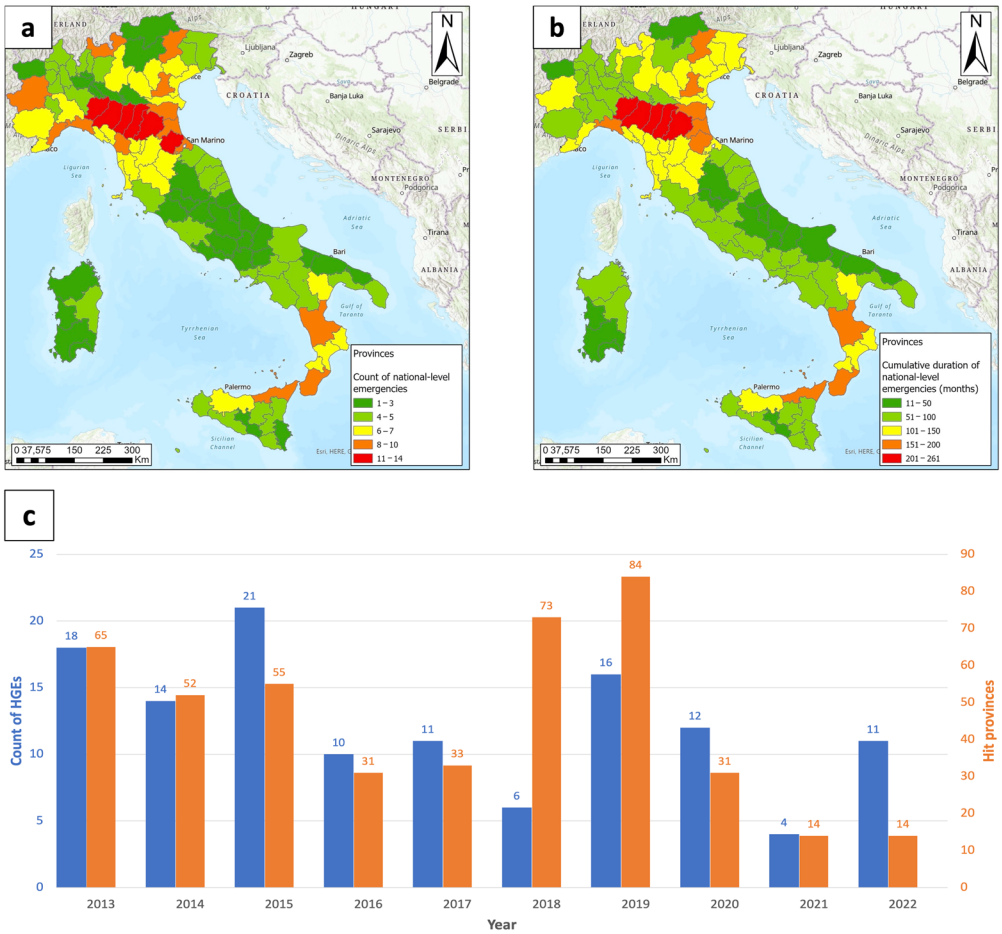

Figure 1. Summary of national emergency states at the provincial scale. (**a**) count of national-level emergencies; (**b**) cumulative duration of national-level emergencies; (**c**) annual distribution of HGEs and impacted provinces.

4. User Notes

Before using this dataset as input for other analyses, the significance of the inventoried events and territories should be noted. The presence of a municipality/province in an emergency state implies that the national department of Civil Protection takes the lead in management (mobilizing all national operational structures as well as regional ones coming from non-hit regions) and, notably, that the State provides national funds to face the emergency and restoration phases. The regulation about the management of these funds has changed several times during the period covered by this research, but we can generalize that the funds are delivered to a Delegate Commissioner (DC). Inspecting the dataset, it could be noted that funds requested by the DC and funds provided by the State differ very much (approximately EUR 10,000,000,000 and approximately EUR 1,000,000,000, respectively). Despite this 1:10 disproportion, both funds are reported in the dataset, leaving the user with the choice of which one is more appropriate for the purpose of subsequent research. The DC request in theory should be a complete recognition of all damages suffered and all the resources needed to return to normality; however, it is expected that this estimation is in excess, as it collects many requests from local authorities and privates that tend to overestimate the damage. Thus, the DC request could be used as an upper bound for the direct impacts on tangible assets. Conversely, the amount of funds received is acknowledged to be a lower bound, as the State does not have an

unlimited budget to face disasters; the amount provided depends on the financial contingency of the moment, including the number of emergencies that are open at the same time. Moreover, the funds transferred also depend on the outcomes of a recognition coordinated by the personnel of the DPC, which evaluates if the damages declared by the DC deserve to be included in the list to be funded by the State. This led to the opportunity to introduce in the dataset an additional detail with the binary code (*ES y/n*): all provinces/municipalities hit by a severe event that triggered a HGE are included in the dataset, but only a part of them may be included in the emergency state (those for which enough evidence of the severity of the impact suffered was collected and for which *ES y/n* = 1). We leave it to the users, according to their needs and the purpose of their analysis, to decide if the minor impacts have to be kept or filtered out using the *ES y/n* field. Last, it should be noted that full interoperability of the dataset is granted by the presence, for each element in the spreadsheets and shapefiles, of the LAU, NUTS, and ISTAT codes, which can be used to link the dataset with any other official dataset or indicator released in Italy or Europe.

Lastly, a series of checks and additional analyses were carried out to evaluate the completeness, interoperability, temporal detail, and spatial accuracy of the information contained.

The method used to compile the dataset ensures a high level of homogeneity and completeness: the use of official data from national and local institutions involved in emergency management guarantees the inclusion of all occurrences during the considered period (2013–2022). The completeness of the dataset was ascertained with a cross-check against the Italian Official Gazette, which collects all national acts. Since every HGE is issued with a decree-law of the government, it was possible to assess that all HGE present in the Gazette are reported in our dataset and vice versa. Delays in the process of transferring information from the regional governments to the DPC are possible; however, the dataset is not affected by similar issues, as it was verified that the information about the last HGEs of the considered timespan (occurred in November and December 2022) was made available online during March 2023. Nevertheless, for all events in 2022, information about funds is not complete because the post-emergency management phase is still ongoing and a definitive figure of damages, funds requested, and funds allocated cannot yet exist.

Since the main objective of this research is to combine the ES dataset with other econometric and environmental data to gain a deeper understanding of the drivers and impacts of severe hydrogeological events, the interoperability of the dataset is a fundamental feature to validate. To this end, Table 1 lists a series of relevant nationwide datasets, describes how they can be linked to the dataset presented in this work (key linkage column), and reports the finest possible spatial unit (spatial aggregation column) and temporal time step (updating frequency column) at which joint analyses can be performed. Table 1 is not intended as an exhaustive list of existing datasets; it contains some examples coming from institutional providers of environmental, statistical, and economic data, e.g., ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale—*Italian Institute for Protection and Environmental Research*), SOSE (SOluzioni per il Sistema Economico—*Solutions for the Economic System*), and Eurostat (European Statistical Office).

Concerning the temporal detail of triggering events, 82% of ES have been reported with high detail (triggering rainfall events identified with daily precision), 9% with medium detail (triggering events identified with a timespan longer than a week and shorter than a month), and 9% with low detail (timespan longer than a month). Scaling down from events to the hit municipalities, 74% of them come with excellent temporal precision, 10% with medium precision, and 16% with coarse precision. Regarding provinces, the results are almost the same: 72% have high, 9% have medium, and 19% have coarse detail. For the medium and coarse events, the start and end dates were compared with the technical meteorological reports annexed to the regional acts (if present). This validation procedure was also targeted to identify with higher precision the temporal occurrence of the triggering rainfall. Interestingly, this validation showed that coarse and medium detail is not usually due to oversights or a lack of precision in the official reports. Rather, we verified that larger time spans are typically used to aggregate complex meteorological events in which periods

of intense rainfall alternate with periods of mild rainfall or no rain at all. In these cases, it is not possible to identify a specific triggering moment, as the meteorological event that led to the emergency is usually a long period of intermittent and/or prolonged rainfall, which could have slightly different start and end days in different portions of the struck territory. However, it should be stressed that the dataset is conceived to be used as input data for correlation with other nation-wide datasets of different types, which are mostly updated on a yearly basis; consequently, even the HGEs with coarse temporal detail could be considered adequate for dynamic comparisons with yearly or semesterly timesteps, as reported in Table 1.

Table 1. List of a series of relevant nationwide datasets, describing the issuer, the topic, and how they can be linked to the dataset presented in this work (key linkage column), possible spatial unit (spatial aggregation column), and temporal time step (updating frequency column).

Dataset	Issuer	Topic	Reference	Updating Frequency	Spatial Aggregation	Key for Linkage
OMI	Italian Tax Agency	Real estate market	[40]	6 months	LAU	ISTAT code
StatBase	ISTAT	Demography, census, society, social expenditure, economy, territory	[41]	Yearly	LAU	ISTAT code
Idrogeo	ISPRA	Hazard and risk indicators	[42,43]	semistatic	LAU	ISTAT code
Soil sealing monitoring program	ISPRA	Soil sealing, land cover, urban areas	[44,45]	yearly	LAU	ISTAT code/GIS spatial join
Global Human Settlement Layer	Copernicus	Built up soil (residential and other uses); population; degree of urbanization	[46]	5 years	LAU	GIS spatial join
Corine Land Cover	European Environmental Agency/Copernicus	land use/land cover classification	[47]	6 years	LAU	GIS spatial join/LAU code
Open Civitas project	SOSE	Quality and cost of public services	[48]	yearly	LAU	ISTAT code
Bank of Italy statistical database	Bank of Italy	Loans, public finance, bank fundings	[49]	yearly	LAU	ISTAT code
MEF Open Data	Ministry of Economy and Finance	Taxable income, taxpayer	[50]	yearly	LAU	ISTAT code
Data Browser	Eurostat	Employees, business demography	[51]	yearly	NUTS	NUTS code
MEF Open Data	Ministry of Economy and Finance	Taxable income, taxpayer	[50]	yearly	LAU	ISTAT code
Data Browser	Eurostat	Employees, business demography	[51]	yearly	NUTS	NUTS code

Concerning spatial accuracy, the maximum possible degree of reliability is ensured by the documents themselves that were analyzed to compile the "*ES y/n*" column of the spreadsheets. The official acts found on the websites of the interested regions include the results of independent technical surveys, usually carried out in conjunction with the personnel of the DPC, aimed at ascertaining in which administrations the impacts demand an intervention of the State and in which ones they could be managed by local or regional authorities. It follows that there is not always a correspondence between provinces/municipalities hit by an event and those included in the emergency state; this distinction and this detail should be considered one of the main novelties and points of strength of the dataset.

The dataset is also affected by some defects. For a small number of entries, some information is missing. The list of hit municipalities is not available for the events 2013_15, 2015_01, 2015_13, 2016_04, and 2016_07 (no detailed information about affected territories

is reported, and the official acts refer to "the whole province"). Moreover, in some cases, in a region (Liguria) included in the same list of hit municipalities, different events occurred in a relatively short period of time for three separate emergencies. Consequently, the official documents report a cumulative list of damaged municipalities for the events 2019_09, 2019_12, and 2019_14, and it is not possible to assess if a municipality was hit during all the events or only twice or once (and in which event). The emergency states affected by these limitations are only a small fraction of the total and were included in the dataset for the sake of completeness. The objective of having the highest possible degree of homogeneity is the reason why an extension of the dataset before 2013 was not feasible. In 2012, the Italian Civil Protection was radically reformed and reorganized, and the DPC started publishing data and accounting for the provided/requested funds only starting from the year after. Before that time, the definition of emergency itself was different, information was sparse, and a reliable track of the funds was not always envisaged.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data8100151/s1, Italian Emergencies 2013_2022.

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Data Availability Statement: The data presented in this study are available at [link to be added by the Editorial Office]; scholars interested in reusing the dataset are encouraged to contact the corresponding authors to check the availability of updated versions.

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