Digging into the available information on earthquake related disasters in Esmeraldas. What does it tell us about the connexion between knowledge and DPP?

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Digging into the available information on earthquakes related disasters in Esmeraldas. What does it tell us about the connexion between knowledge and DPP?

ANR – REMAKE Programme / working paper (WP6)
(http://remake.osug.fr/?lang=en / https://hal.archives-ouvertes.fr/REMAKE-SHS)

Objectives

This working paper deals with contributions and pitfalls of (earthquake related) **disasters databases** regarding prevention policies. It sheds light on the **links** between (different types of) **knowledge** and risk **management**, by analysing databases (*e.g.* DesInventar, EM DAT) as well as by addressing other sources of information on past events. It stresses on the case of the **city of Esmeraldas** (Ecuador), as an additional input to better catch and tackle longstanding obstacles to the improvement of DPP.

Selection of key points

- **DesInventar** database makes higher frequent and rather lower intensive disasters more visible, whereas **EM DAT** is structured to register less frequent though more intensive disasters.

- Both databases are **complementary** and **limited**. They show symmetric or common pitfalls (more information recorded on recent periods, uneven quality of the information, selective events recorded – particularly in Esmeraldas regarding the 1987 and 2016 earthquake events).

- Both **databases** must be **criss-crossed** with other types of information (local & national medias, institutional archives, geophysics information, scientific literature, interviews) in further works.

- **Underrepresentation** of earthquake-related deaths in Esmeraldas is strong, regarding the relation between # of events and **deaths** at the world scale. Underrepresentation of **damage** is medium.

- **Critical events are expected** in Esmeraldas region: "super cycle theory" as for geophysicists, the release of accumulated energy might follow "super cycles" made of various critical events (from 1906 on). Exposure to hazard is very high.

- As concerns Esmeraldas, we have a limited range of historical information about earthquake related damage. It shows a long period with no major event, and the poor capacity to report… until this day! A **complex link** between knowledge and action does exist (between **past disasters information** and **DPP / risk management**).

Table of contents of the working paper

Earthquake related disaster profile assessments according to EM-DAT and DesInventar databases.
An analysis of disasters concerning the case study of Esmeraldas (Ecuador).

- What is the **use of assessing disaster frequencies** according to previous research on disaster prevention?
- **Main advantages** and **limitations** of the **two mostly used databases** for disasters frequencies and distribution assessment
- Though it focuses on earthquakes, is CERESIS database a means to compensate for disasters databases limitations?
- What can we learn from **DesInventar** concerning disasters related with earthquakes in Ecuador / Esmeraldas?
- What can we learn from **EM-DAT** concerning disasters related with earthquakes in Ecuador / Esmeraldas?
- Contribution from **CERESIS database** and **geophysics**: more major earthquakes disaster prone during the 20th century in the province of Esmeraldas
- **Discussion and conclusions**
- **References**

[1] ANR-15-CE04-0004. Seismic Risk in Ecuador: Mitigation, Anticipation and Knowledge of Earthquakes

Earthquake related disaster profile assessments according to EM-DAT and DesInventar databases

An analysis of disasters concerning the case study of Esmeraldas (Ecuador)

What is the use of assessing disaster frequencies according to previous research on disaster prevention?

The need for having a reliable and usable, if not user friendly database on disasters has already been stressed on during previous decades, and especially by GAR report (UNISDR, 2015). Metrics of disaster frequencies could **help decision-making** as well as could be **used as markers of prevention policies outcomes**. Such a goal explains the recent development of databases as is ONRN in France: it helps giving clues on the results one of the main French disaster prevention policies gains, and on its limitations as well (Nussbaum & Pigeon, 2015).

Mapping disaster distribution also helps assessing **where the most disaster prone areas are found**, orienting research as well as policies devoted to risk prevention towards the most critical places, according to the methods used.

Of course, the quality of the information and the robustness of methods used to capture it for framing databases on disasters are key, as the assessments rely on previous methodological choices.

Main advantages and limitations of the two mostly used databases for disasters frequencies and distribution assessment

Advantages and drawbacks of the two main databases available, EM-DAT and DesInventar, have already been scrutinized by in-depth analysis EU funded programmes led, as with SCENARIO (Menoni & Margottini, 2011). Other programmes types such as PACIVUR contributed to the assessments. For the latter, researchers tried to compare both databases at the scale of Latin American countries, including Ecuador. D'Ercole et alii (2009) investigated to what extent DesInventar and EM-DAT can contribute to frame a general assessment on disaster frequencies related with Ecuador:

> « En un primer momento, el artículo de R. D'Ercole, S. Hardy y J. Robert propone un análisis estadístico de los accidentes y desastres ocurridos en las tres capitales [La Paz, Lima y Quito]. Esta presentación general permite conocer mejor las condiciones

> de su vulnerabilidad y al mismo tiempo invita a reflexionar sobre las informaciones disponibles para este tipo de ejercicio y sobre la insuficiencia de las bases de datos existentes ».

Even more, the relevance of taking more into consideration what Lopez (2008) named « small disasters » for meeting the needs of disaster prevention at the scale of urban areas has been discussed in Lopez & Pigeon (2011). This paper stresses on the relevance of using DesInventar in spite of the various limitations this very heterogeneous database meets. This statement is fully in line with the contribution of Latin American researchers on disaster prevention: they drew attention on the limitations previously existing databases meet, with a specific accent on EM-DAT, and on the relevance of compensating them while using DesInventar (2017):

> « However, lack of systematic, homogeneous, and compatible records of disaster typologies, understood as the effect of the occurrence of threatening events on the vulnerability of country, on the one hand, and insistence on considering disasters only as effects of events of huge proportions and high impact, on the other, have hidden the thousands of small and medium scale disasters that occur every year in country ».

Consequently:

> « The development of DesInventar, with its conception that makes visible disasters from a local scale (town or equivalent), facilitates dialogue for risk management between actors, institutions, sectors, provincial and national governments. »

The main conclusions those various and numerous studies on both disaster databases found are as follows:

- EM-DAT captures the most important disasters in accordance with the threshold of damages used for defining them. In that case, the threshold of having more that 10 people dead and/or 100 people affected for defining what a disaster is eliminates less damage-intensive events. EM-DAT addresses disasters seen from the world scale. Indeed, EM-DAT mostly uses information on disasters coming from Reinsurance societies and world scale press. EM-DAT scale is clearly global, which should logically be the case for investigating disasters. Indeed, the concept of disaster supposes that local coping capacities are found limited in the face of major events, this shortcoming therefore calling for national and international aid. This approach is logically consistent with the basic definition of what a disaster should be.
- However, especially for the need of managing and preventing disasters at the local scale, EM-DAT is not found relevant enough. Indeed, and especially for the poorest households, an event with very limited intensity of damage, if considered from the world scale, becomes clearly a major event, and therefore also a disaster, at the local scale. This is why UNISDR stresses on the necessity to integrate « extensive

disasters » in the assessment of disasters frequencies, especially if the analysis is led at the local scale (UNISDR, 2015). In order to capture those events, which are also defined as « small disasters » (Lopez, 2008), DesInventar is found much more relevant, if not key.

- Even more, Lopez and Pigeon (2011) stressed on the relationships between both disaster types. Relying on the case study of Medellin, they found once again an inverse statistical relationship between EM-DAT disasters and DesInventar disaster frequencies. Of course, as expected, the most frequent disasters are found with DesInventar, whereas the intensities of damage related with those events are found much more limited seen from the world scale. Logically, those events are not reported by EM-DAT. The less frequent the disasters are, the more their damage intensities are. This fits what Farmer curve predicts: inverse relationship between disaster frequencies and disaster intensities (Pigeon, 2017).
- But they also found that the distribution of disasters differs depending on their type. In the case of Medellin, the EM-DAT disasters concern firsthand well-off households, while DesInventar disasters concern the poorest of the households living in the informal parts of Medellin urban areas. Such an outcome suggests that prevention policies using structural measures (flood and landslide prevention measures in that case, as are dikes and drainage networks) contribute to reduce disaster frequencies DesInventar records, and also contribute to increase land values. However, such an evolution, even looking so promising at first sight, because it could depict a possibility of increasing land values and preventing disasters at the same time, contributes as well to prepare EM-DAT disaster types.

- Those conclusions should not induce to forget the numerous limitations information on disasters still bear, whatever the type of disaster databases. Even if we can find statistical trend and disaster distribution that look logically consistent, the information the analysis relies on comes from various sources. The information databases capture is still very heterogenous. It mostly embeds a wide range of methods as well as choices reflecting the goals various institutions try to meet. This major drawback has been mentionned at numerous times, without allowing to find a more satisfactory solution. On this basis, Mitchell et alii (2014) come to the conclusion that assessing disaster frequencies should be considered more as an art than a science. Even if it could also be mentionned that, seen from social sciences, confronting various sources is considered as a prerequisite for gaining a more robust information, in case crossing the various sources would give a consistent result. In that case, the result would not be necessarily and only reflecting a specific source and /or the outcomes of a specific method used for reaching them.

Therefore, the following assessments concerning Esmeraldas shouldn't induce the reader to forget those limitations. The results the assessments provide should be considered as nothing but rough trends concerning previous disasters on the basis of very heterogeneous information available. According to D'Ercole et alii (2009), it is necessary to keep in mind:

> « las imperfecciones de las bases de datos y el necesario esfuerzo del investigador para desembocar en interpretaciones que sean lo más exactas posibles ».

Though it focuses on earthquakes, is CERESIS database a means to compensate for disasters databases limitations?

The information EM-DAT and DesInventar deliver could help drawing attention on the most disaster-prone areas of Ecuador as well as on the most disaster prone areas of Esmeraldas itself. It should not lead to indulge into over confidence in the results found. Especially in the case of finding a reduction of disaster frequencies, because the latter could also be seen as a marker of a less frequent/more damage intensive event (i.e. : a disaster) in the making. In that case, the information given could be seen as very close to what is expected from the GAP theory : the reduced frequency of earthquakes could be seen as a marker of a future earthquake of low frequency but high magnitude, and potentially with a high damage intensity level. But this type of anaysis demands to take longer period duration into account, without having the possibility to use instrumental information. We find in Nishenko (1999, p. 169) a definition of what a seismic gap could be : « Time-dependent estimates of seismic potential are based on a physical model of earthquake occurrence which assumes that the probability for an earthquake is low immediately following the occurrence of a characteristic earthquake and increases with time as the stress on the fault segment recovers the stress drop of the event ». « By characteristic earthquake, we mean an event which repeatedly ruptures the same fault segment and whose dimensions define that segment (SCHWARTZ and COPPER- SMITH, 1984) (idem, p. 175). And : « for a segment of a plate boundary to be considered a seismic gap, it must have a history of prior large or great earthquakes and not have ruptured in a large or great event in at least 3 decades (MCCANN et al., 1979), (idem, p. 176). It makes sense to investigate more in depth how the situation in Esemeraldas is in the light of a potential seismic gap.

In that case, the information coming from earth sciences could herald the preparation of a potentially major disaster, especially in case of not having disaster prevention policies enough. Previous investigations on disasters frequencies involving EM-DAT and DesInventar and comparing Quito with Lima and La Paz already stressed on such a possibility concerning Quito (D'Ercole et alii, 2009) :

> « Quito se presenta como una ciudad intermedia, más equilibrada en lo que se refiere a la relación entre los eventos de origen natural y los eventos antrópicos. Se acerca más a La Paz por ser una ciudad de altura en donde los procesos hidromorfológicos son muy activos, pero más cerca de Lima en algunos tipos de

> fenómenos (sismos), por un carácter industrial que tiende a afirmarse **y por la posibilidad de conocer eventos de gran magnitud en el futuro.** »

Even more, and still in line with a possible seismic gap to be discussed below, the need to identify major past earthquakes, be it for geophysical and academic purposes or for prevention, induced earth sciences to collaborate with Historians. « Because the earthquake cycle (if it is cyclic) is a long-term process, study of different earthquakes over a long time interval is essential for a thorough understanding of earthquake phenomena » (Swenson & Beck, 1996, p. 68). Gieseke et alii (2004) add : « despite the fact that «intensity» is not a scale which is based on instrumental measurements, it is nonetheless designed to quantify damage caused by earthquakes, an aspect which no other instrumental parameter can measure as satisfactorily. For the pre-instrumental period and/or poorly monitored areas, intensity values, and focal parameters when possible, were determined by investigating and interpreting historical reports and chronicles ».

Indeed, archives allowed to find back major earthquakes on the basis of damage intensities at a time when instrumental information, of course, was not available. This resulted in another database : « the creation of the Regional Centre for Seismology for South America (CERESIS) was a major factor for homogenous regional progress, in that CERESIS promoted the implementation of the first unified earthquake catalogue and database for the whole Andean Region » (Gieseke et alii, 2004). Of course, CERESIS database concerns Ecuador and integrates various historical sources :

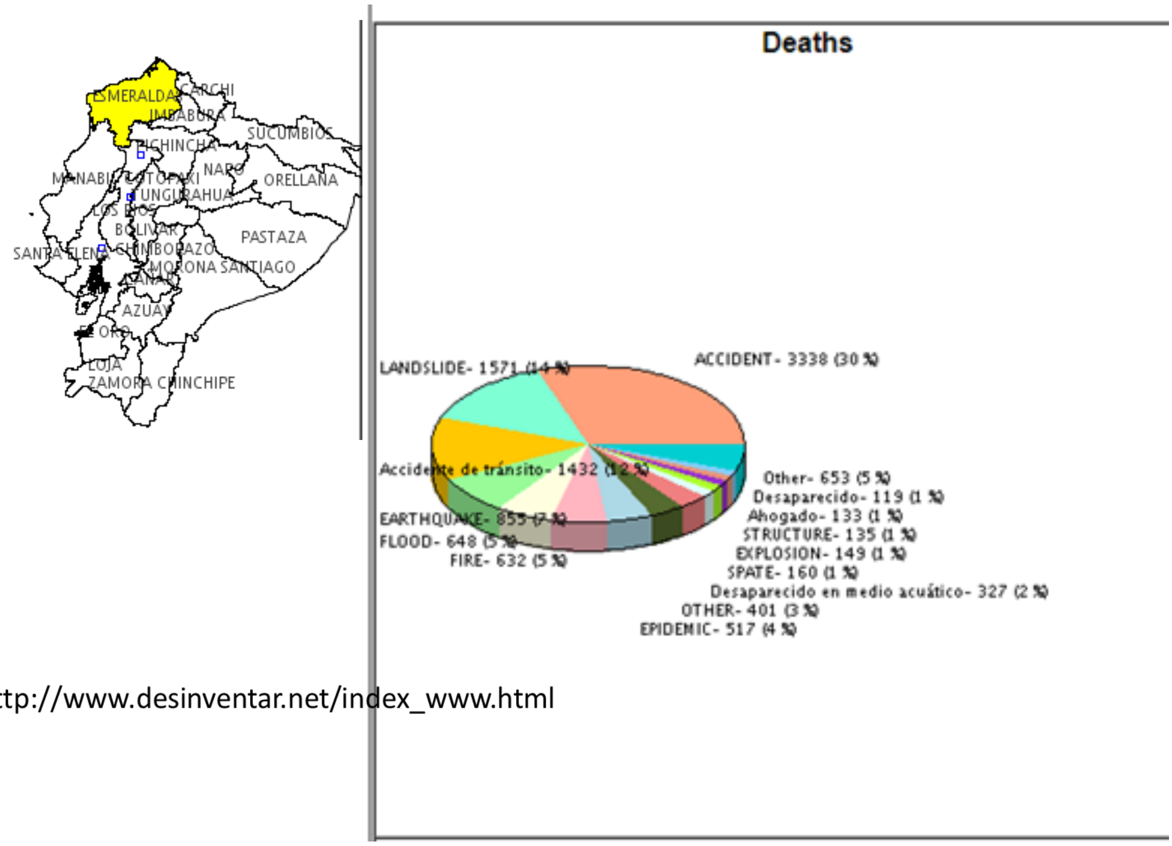
> « The catalogue and intensity database compiled in the framework of the SISRA Project and published in vol. 6 of CERESIS (1985), are based on information from Observatorio Astronómico de Quito (1959), Egred (1968) and data from international seismological agencies. Historical archives were consulted as the Archivo Municipal de Quito, the Archivo Nacional de Historia, the National Library and the Aurelio Espinosa Polit Library in Quito. » (Gieseke et alii, 2004).

What can we learn from DesInventar concerning disasters related with earthquakes in Ecuador / Esmeraldas?

The internet site of DesInventar allows to gain access to a wide range of informations concerning disasters evolution and distribution in Ecuador and in the province of Esmeraldas. It has been developed with the institutional support of UNISDR.

The site records 33 509 damages related with earthquakes for the period 1970-2017. Each time, those events gave rise to data cards.

The information found draws attention to the limited contribution of earthquakes related disasters to mortality **(Fig. 1, especially when compared with the assessment of mortality at world scale, Fig. 2**).



http://www.desinventar.net/index_www.html

Fig. 1 : Location of the province of Esmeraldas and mortality related with earthquakes at the national level. DesInventar, 2017,

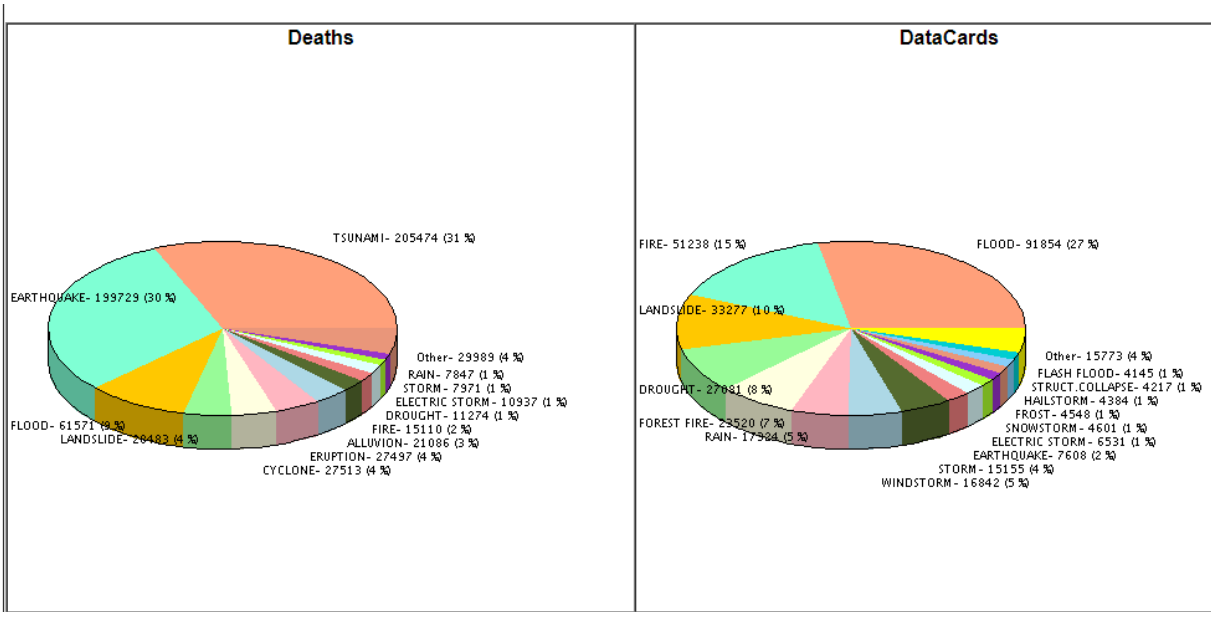


Fig. 2 : International assessment of disaster frequencies (data cards here) and mortality. According to GAR 2015 consolidated database.
http://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=g15&continue=y

Mortality related with earthquake is (hopefully) not even mentioned in the global assessment, reported below. On the contrary, earthquake damages related with buildings rank second after building damages related with floods.

Ecuador: global asessment according to DesInventar, 2017:

« **<u>Highest Mortality:</u>**

ACCIDENT: 3338 Deaths; 630 DataCards

LANDSLIDE: 1571 Deaths; 5895 DataCards

Accidente de tránsito: 1432 Deaths; 1772 DataCards

<u>Highest Housing Damages</u>:

FLOOD: 84966 Houses; 4141 DataCards

EARTHQUAKE: 27674 Houses; 445 DataCards

RAIN: 10640 Houses; 691 DataCards »

The **evolution of disasters** reported displays only 29 years over 46 years (period 1970-2016), with a clear increase of reporting for the most recent period (**Fig. 3**). Of course, it does not mean that there should be more earthquakes during the most recent period, a point Singaucho Armas (2009) considers not relevant in the light of a steady speed of Nazca plate. However, changing time scale delivers another statement, as will be developed further below. But, as for the last decades, the increase of disaster reports would firsthand result from having more assets and population exposed. It should induce to think that damages are more reported as time goes along. We find here one of the most important biases related with databases: the propensity not to declare local damages (considered as not relevant seen from the world scale) for the more ancient periods, and also the reverse. This is precisely why UNISDR and also researchers belonging to La Red, who promoted the so-called « radical » thinking on disasters, complained about the under reporting of so-called « small disasters ». The latter could be more significant at the local scale than the EM-DAT disasters although being less « visible » seen from the world scale. DesInventar strives to give more visibility to the « small disasters », and this also contributes to explain the increase of disaster reporting for the most recent periods.

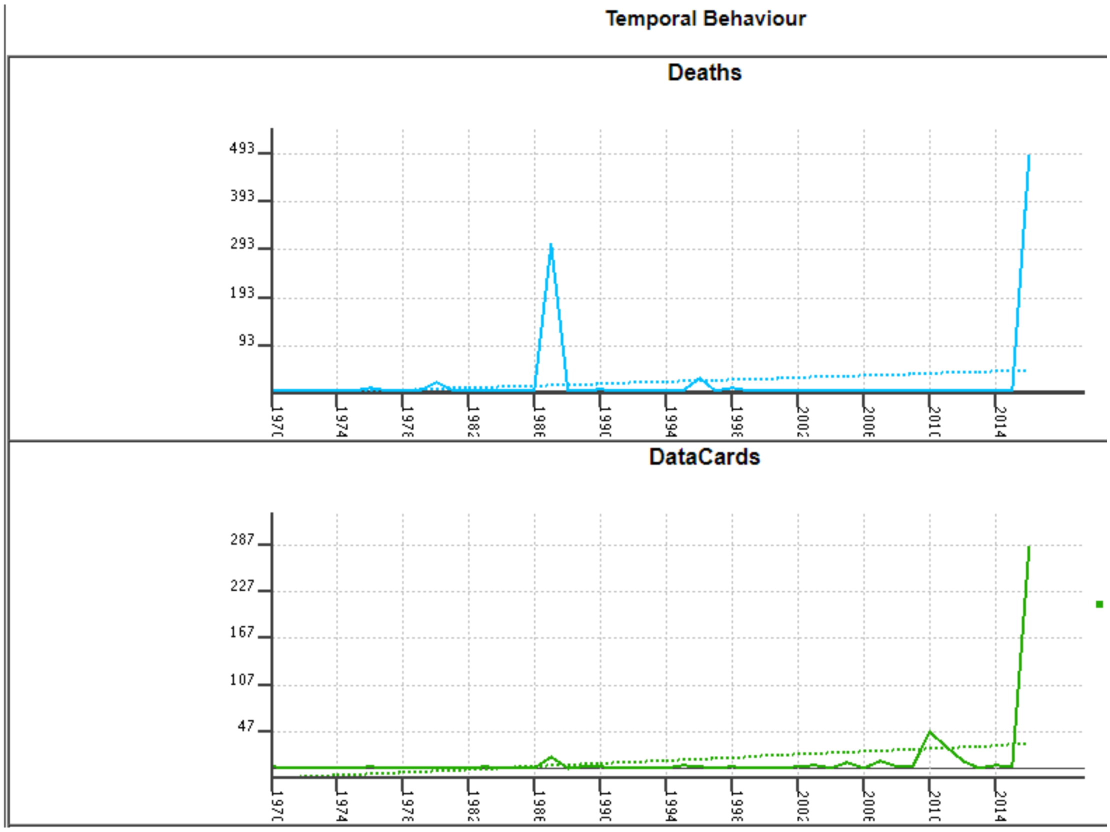


Fig. 3: Evolution of mortality and disasters frequencies (data cards), Ecuador, national.

However, and unfortunately, the trend for reporting more damages does not mean that the information could be necessarily more reliable. Comparing data available for the 1987 and the 2016 earthquakes is instructive (**Fig. 4**): 400 people reported « missing » in 1987 whereas we have only one reported in 2016. On the contrary, we have almost 400 000 people reported as affected in 1987 but only 45 360 in 2016. This data looks poorly consistent with the amount of buildings « destroyed »: 0 en 1987 (!) and 8397 in 2016.

Temporal Behaviour get it as Excel

Year	DataCards	Deaths	Injured	Missing	Houses Destroyed	Houses Damaged	Affected	Relocated	Evacuated	Losses $USD	Losses $Local	Education centers	Hospitals	Damages in crops Ha.	Lost Cattle	Damages in roads Mts
1970	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	2	6	4	0	6	0	0	0	0	0	0	0	0	0	0	0
1980	1	17	160	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	15	305	35	400	0	1000	398977	0	0	0	0	0	0	0	0	0
1988	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	2	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	2	3	0	0	2	902	5	0	0	0	770	0	0	0	0	0
1992	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	5	0	0	0	0	6	0	0	0	0	5000	0	0	0	0	0
1996	2	27	66	0	1590	0	0	0	0	0	16000	0	0	0	0	0
1997	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	2	6	106	0	264	484	5000	0	0	0	0	0	0	0	0	0
2000	1	1	0	0	100	0	0	0	0	0	0	0	0	0	0	0
2002	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	1	0	0	0	0	20	100	0	0	0	0	0	0	0	0	0
2005	8	0	0	0	1	60	0	0	0	10000	10000	2	0	0	0	0
2007	9	0	0	0	3	32	248	0	0	0	0	1	0	0	0	0
2008	3	0	0	0	3	3	24	0	0	0	0	0	0	0	0	0
2009	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	47	0	0	0	0	0	130	0	30	0	0	0	0	0	0	0
2011	27	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2012	9	0	0	0	0	37	178	0	43	0	0	1	0	0	0	0
2013	1	0	0	0	0	16	80	0	0	0	0	0	0	0	0	0
2014	4	1	12	0	0	190	150	0	80	0	0	8	0	0	0	0
2015	3	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0
2016	283	488	1879	1	8397	14555	45360	0	1477	0	0	421	0	0	0	1362

Fig. 4 : The evolution of disasters related with earthquake and in Ecuador according to DesInventar (1970-2016)

Consequently, the data available should not induce us to think that there would be an increase of damages for the recent period. The 2016 earthquake has been more investigated and data for the 1987 earthquake were most likely under ranked, and poorly reported. A similar situation has been stressed on for the 1979 earthquake, according to Espinoza (1992, p. 26) who mentions a discrepancy between Ecuador and Columbia:

> **« revisando la información de los principales diarios de esas fechas, se encontró que en Ecuador los daños materiales fueron leves y que no se produjeron victimas », « algunos edificios sufrieron daños en su estructura, en especial en la ciudad de Esmeraldas ». However: « Las poblaciones costeras no reportaron daños por efectos del tsunami o del terremoto », whereas, « en el suelo colombiano los daños fueron graves. En Charco, con una población aproximada de 4000 persones, todas las casas fueron seriamente dañadas o totalmente destruidas. »**

The **distribution of disasters** by province on the period 1970-2016 (**Fig. 5**) draws attention on the specific place the province of Esmeraldas has. The frequencies of disasters, all types included, as identified by the number of data cards here, ranks the province of Esmeraldas as second at the national scale: 82 for Manabí province versus 69 for the province of Esmeraldas. Once again, this may also display the distortion of information related with the trend towards declaring more damages at the local level. However, this trend should be the same whatever the province considered. On this basis, Desinventar information identifies most likely two provinces most disaster prone.

Spatial Distribution get it as Excel

Geography	Code	DataCards	Deaths	Injured	Missing	Houses Destroyed	Houses Damaged	Affected	Relocated	Evacuated	Losses $USD	Losses $Local	Education centers	Hospitals	Damages in crops Ha.
AZUAY	01	5	0	0	0	1	23	215	0	0	0	0	1	0	0
BOLIVAR	02	34	0	0	0	41	321	1264	0	24	0	0	20	0	0
CAÑAR	03	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CARCHI	04	5	0	0	0	0	113	17922	0	39	0	0	8	0	0
CHIMBORAZO	06	7	1	0	0	0	4	22	0	5	0	0	0	0	0
COTOPAXI	05	14	33	70	0	1635	49	430	0	0	0	16000	12	0	0
EL ORO	07	8	0	0	0	0	4	3	0	0	0	0	0	0	0
ESMERALDAS	08	69	2	52	1	1116	1260	10607	0	840	0	0	47	0	0
GUAYAS	09	49	20	174	0	52	160	707	0	231	0	0	0	0	0
IMBABURA	10	34	2	0	0	100	40	221417	0	0	0	0	24	0	0
LOJA	11	7	0	0	0	1	0	0	0	0	0	0	1	0	0
LOS RIOS	12	30	0	27	0	230	634	1740	0	387	0	0	32	0	0
MANABI	13	82	488	1905	0	6832	12213	35258	0	0	0	0	240	0	0
MORONA SANTIAGO	14	8	0	0	0	0	0	0	0	0	0	5000	0	0	0
NAPO	15	11	300	0	400	0	35	1754	0	0	0	0	1	0	0
PASTAZA	16	3	0	0	0	0	0	0	0	0	0	0	0	0	0
PICHINCHA	17	23	4	12	0	39	2040	155177	0	44	0	770	3	0	0
SANTA ELENA	24	8	0	0	0	15	37	302	0	30	0	0	0	0	0
SANTO DOMINGO DE LOS TSACHILAS	23	26	0	0	0	304	324	4	0	0	0	0	43	0	0
SUCUMBIOS	21	2	2	20	0	0	0	3177	0	0	0	0	0	0	0
TUNGURAHUA	18	17	3	15	0	0	50	255	0	30	0	0	1	0	0
ZAMORA CHINCHIPE	19	2	0	0	0	0	1	0	0	0	10000	10000	0	0	0

http://www.desinventar.net/index_www.html

Fig. 5 : Distribution of disasters related with earthquakes by provinces in Ecuador (1970-2017)

However, focussing on the province of Esmeraldas itself reveals once again unexpected information. It gives the impression of having (fortunately, at first sight) rather low damages intensities when considering the fact that this province is clearly one of the most prone to earthquake related disasters. This is especially the case for mortality experienced during earthquakes, which is not mentioned as such (**Fig. 6A)**. For the province of Esmeraldas, the frequency of earthquake related disasters is assessed at 4% only of total disaster frequencies all types of disasters considered (**Fig. 6A**). The comparison with the information available at the world scale is, once again, instructive (**Fig. 6B**): the statistical position Esmeraldas province has (once again, fortunately, at first sight!) is low when compared with its potential to experience a major disaster.

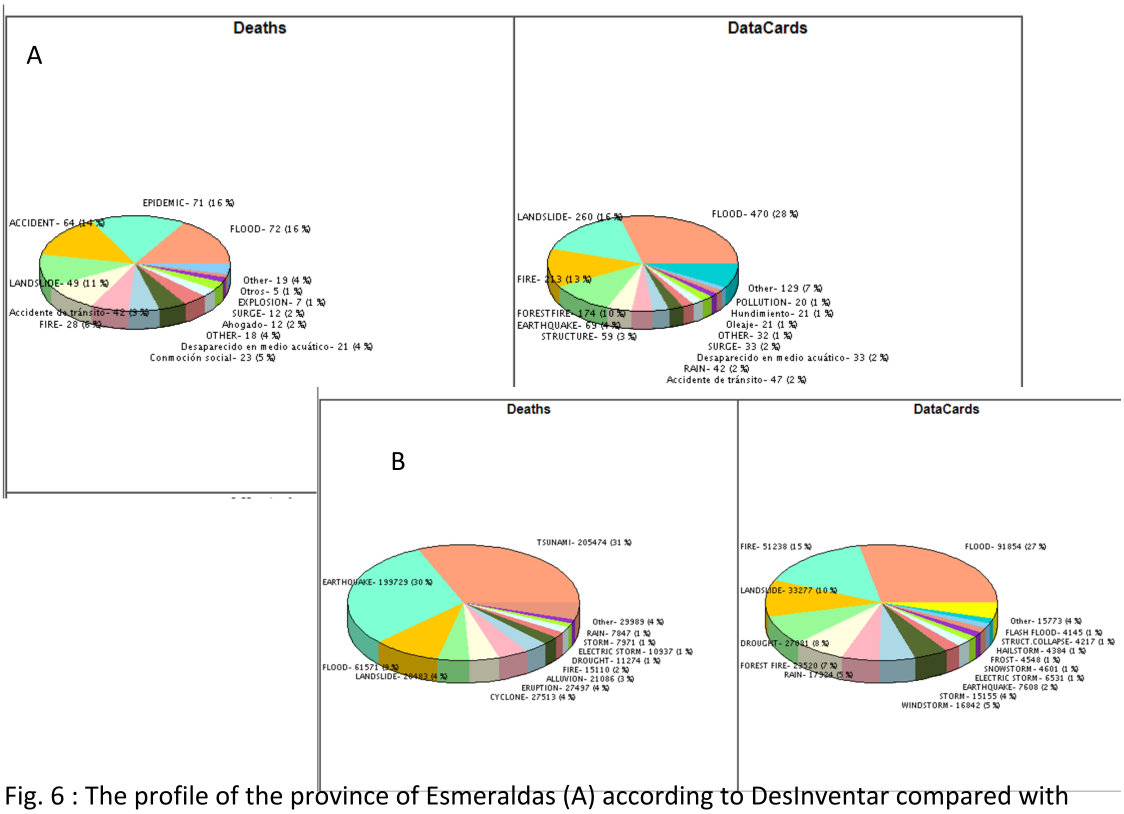


Fig. 6 : The profile of the province of Esmeraldas (A) according to DesInventar compared with the world profile of earthquake related disasters (B).

The position of the province of Esmeraldas is more in line with what is expected for such a disaster-prone province when we come to the information concerning damages to the buildings (**Fig. 7**). Yet, even in that case, damages reported to the building amount only to 12% of the total of damages for all types of disasters, far below damages related with floods. This result looks unexpected, especially when compared with the situation at the world scale.

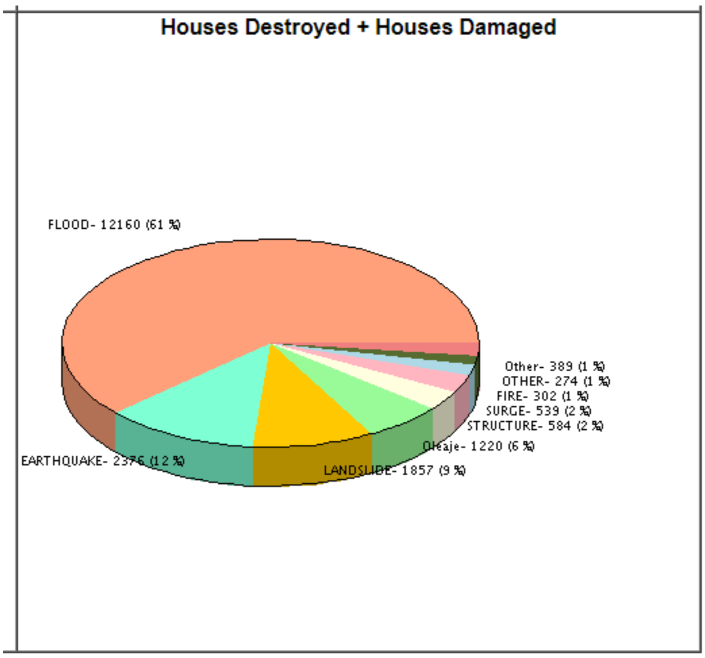


Fig. 7 : DesInventar multi-hazard profile for the province of Esmeraldas, 1970-2017.

It becomes necessary to change scale to go more into the details.

As expected, according to the data Desinventar displays, the distribution of damages differs depending on the parts of the province itself. We find the Western part of the province, which includes the city of Esmeraldas, more concerned by damages related with earthquakes than the Eastern part (**Fig. 8**). The information provided looks rather consistent with the one pertaining to affected people (**Fig. 9**). The map of disaster frequencies (as depicted here as data cards) also displays the east/west divide of the province (**Fig. 10**).

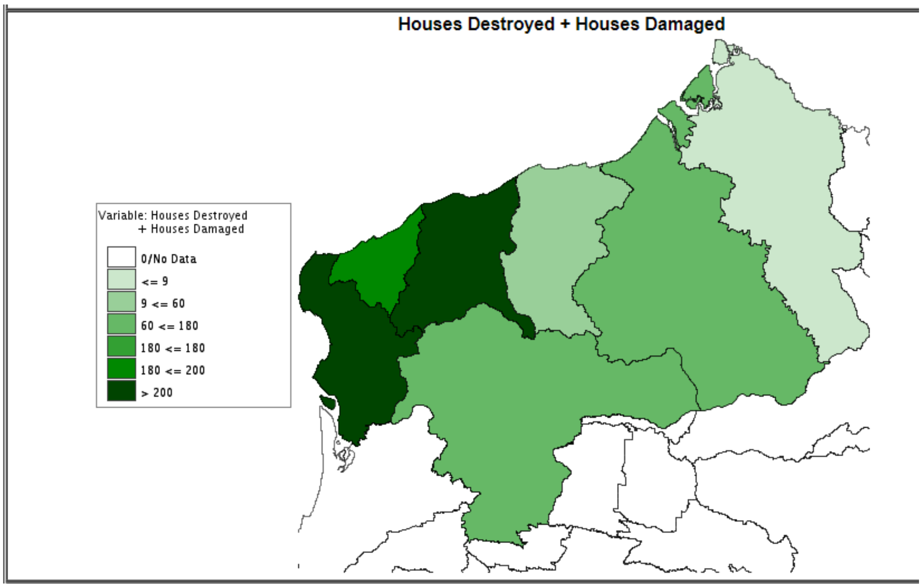


Fig. 8 : Distribution of damages implying houses during earthquakes in the province of Esmeraldas and for the period 1970-2017.

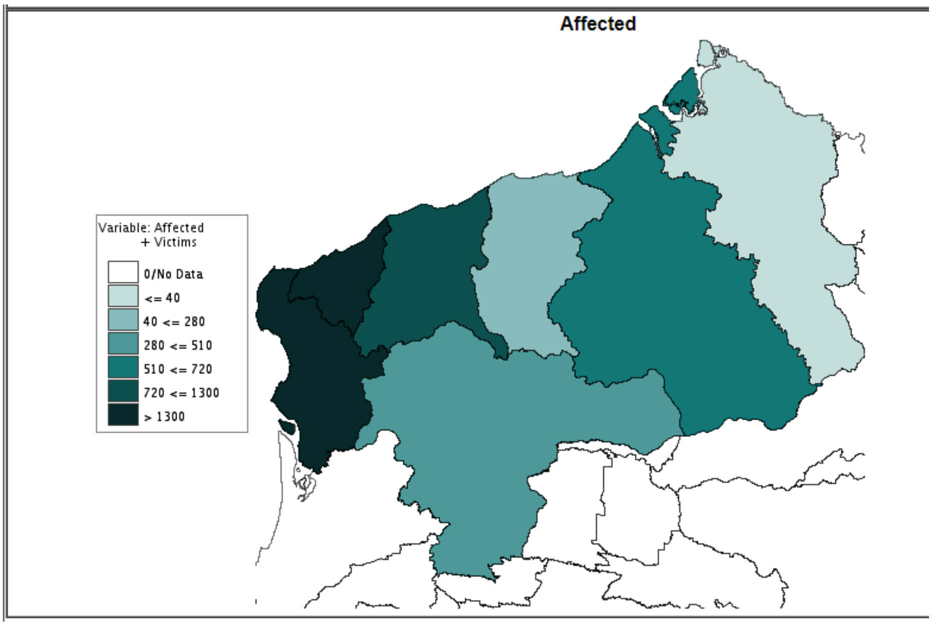


Fig. 9 : Distribution of affected people for the province of Esmeraldas, for the period 1970-2017, and implying earthquakes.

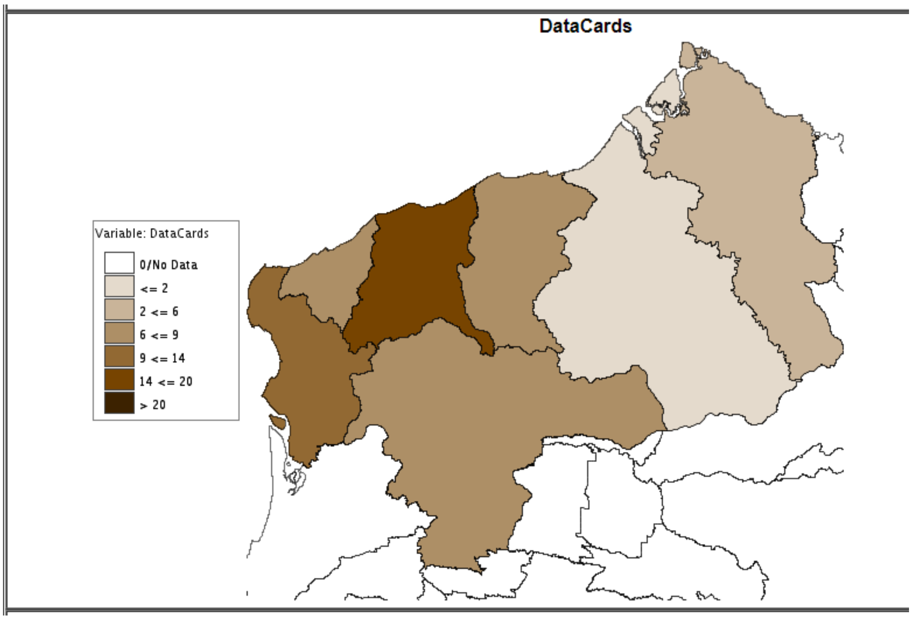


Fig. 10 : Distribution of data cards (disaster frequencies according to DesInventar) in the province of Esmeraldas and for the period 1970-2017, concerning earthquakes.

However, the limited number of fatalities, once again, looks poorly reliable (**Fig. 11**).

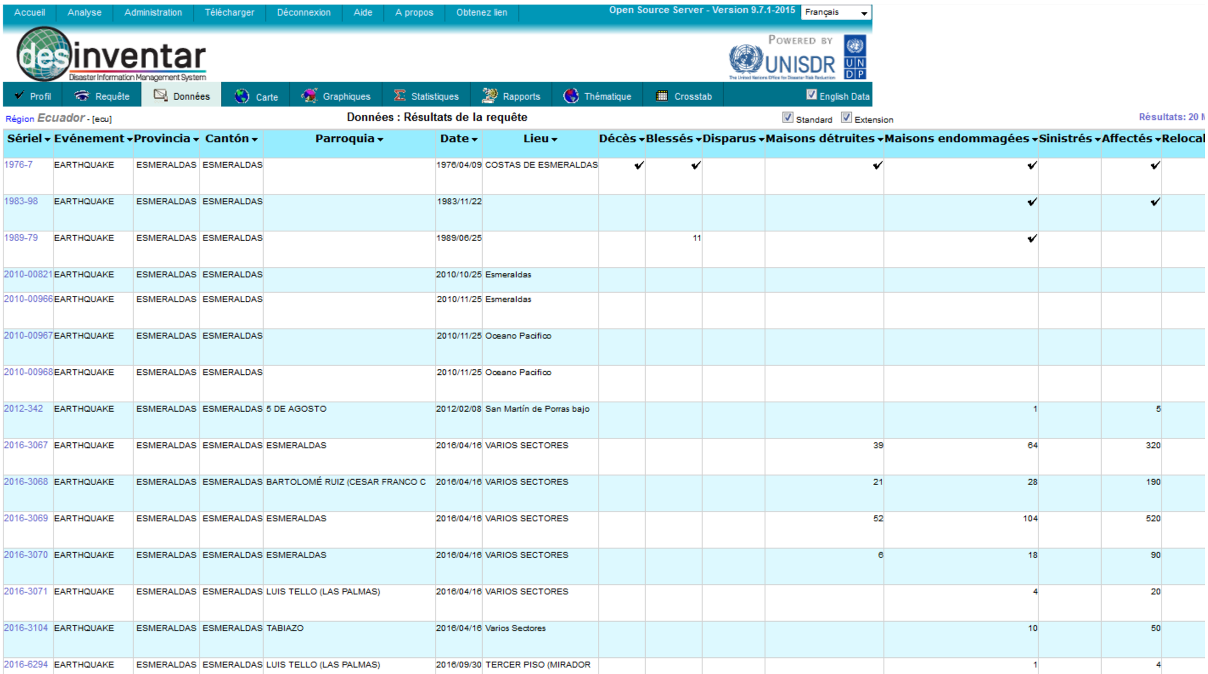
Temporal Behaviour get it as Excel

Year	DataCards	Deaths	Injured	Missing	Houses Destroyed	Houses Damaged	Affected	Relocated	Evacuated	Losses $USD	Losses $Local	Education centers	Hospitals	Damages in crops Ha.	Lost Cattle	Damages in roads Mts
1976	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	1	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	1	0	0	0	0	6	30	0	0	0	0	1	0	0	0	0
2010	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	4	0	0	0	0	4	8	0	13	0	0	0	0	0	0	0
2016	55	2	41	1	1116	1250	10569	0	827	0	0	46	0	0	0	110

Fig. 11 : The evolution of disasters related with earthquake in the Province of Esmeraldas according to DesInventar.

Considering those various elements allows to stress on a possible gap of information concerning the Eastern part of the province of Esmeraldas, but also for the city of Esmeraldas itself, in the face of its potential to experience more damages. This could be found even more consistent when taking into consideration the critical reading of the data seen above, and especially with the trend to declare more damages as time goes along (**Fig. 11**). This is also in line with the requirements to identify more the so-called small disasters, especially from researchers working for DesInventar.

Yet, the information Desinventar gives at the smallest scale is still rather poor and rough. For the request « Esmeraldas, canton, earthquakes, all damages », **Fig. 12** displays 20 events only over the period 1970-2016, 11 of them for the 2016 disasters and one in 2017. The location is mostly imprecise, with the dominant expression: « varios sectores », « various locations », even though, since 2012, it has become possible to discriminate the events at the scale of the parishes concerned. Doing so helps to notice a concentration of damages to the buildings reported mostly for the parish of Esmeraldas itself, with 98 buildings reported destroyed and 186 damaged. It is not possible to go further into the details. However, according to preliminary information coming from field survey and from the direction of planning in Esmeraldas, 437 buildings had to be destroyed after the 2016 earthquake. Of course, this information is not consistent with the information we have in Desinventar. This induces to stress, once again, on a most likely gap between damages and how damages have been reported.



Région Ecuador - [ecu] Données : Résultats de la requête

Sériel	Evénement	Provincia	Cantón	Parroquia	Date	Lieu	Décès	Blessés	Disparus	Maisons détruites	Maisons endommagées	Sinistrés	Affectés	Relocal
1976-7	EARTHQUAKE	ESMERALDAS	ESMERALDAS		1976/04/09	COSTAS DE ESMERALDAS	✔	✔		✔	✔		✔	
1983-98	EARTHQUAKE	ESMERALDAS	ESMERALDAS		1983/11/22						✔		✔	
1989-79	EARTHQUAKE	ESMERALDAS	ESMERALDAS		1989/06/25			11			✔			
2010-00821	EARTHQUAKE	ESMERALDAS	ESMERALDAS		2010/10/25	Esmeraldas								
2010-00966	EARTHQUAKE	ESMERALDAS	ESMERALDAS		2010/11/25	Esmeraldas								
2010-00967	EARTHQUAKE	ESMERALDAS	ESMERALDAS		2010/11/25	Oceano Pacifico								
2010-00968	EARTHQUAKE	ESMERALDAS	ESMERALDAS		2010/11/25	Oceano Pacifico								
2012-342	EARTHQUAKE	ESMERALDAS	ESMERALDAS	5 DE AGOSTO	2012/02/08	San Martín de Porras bajo					1		5	
2016-3067	EARTHQUAKE	ESMERALDAS	ESMERALDAS	ESMERALDAS	2016/04/16	VARIOS SECTORES				39	64		320	
2016-3068	EARTHQUAKE	ESMERALDAS	ESMERALDAS	BARTOLOMÉ RUIZ (CESAR FRANCO C	2016/04/16	VARIOS SECTORES				21	28		190	
2016-3069	EARTHQUAKE	ESMERALDAS	ESMERALDAS	ESMERALDAS	2016/04/16	VARIOS SECTORES				52	104		520	
2016-3070	EARTHQUAKE	ESMERALDAS	ESMERALDAS	ESMERALDAS	2016/04/16	VARIOS SECTORES				6	18		90	
2016-3071	EARTHQUAKE	ESMERALDAS	ESMERALDAS	LUIS TELLO (LAS PALMAS)	2016/04/16	VARIOS SECTORES					4		20	
2016-3104	EARTHQUAKE	ESMERALDAS	ESMERALDAS	TABIAZO	2016/04/16	Varios Sectores					10		50	
2016-6294	EARTHQUAKE	ESMERALDAS	ESMERALDAS	LUIS TELLO (LAS PALMAS)	2016/09/30	TERCER PISO (MIRADOR					1		4	

Fig. 12 : Local distribution of disasters reported in Canton of Esmeraldas according to DesInventar.

The data directly available on Esmeraldas itself and during field survey, f.e., according to the information found in the local newspaper on the same period, should give a fine opportunity to test the reliability of Desinventar, and also the reliability of the unexpected assessment the database allows, in the face of such an earthquake and disaster prone area. Once again, Desinventar has been designed to provide information allowing to work specifically at the urban scale. Yet, in that case, the information Desinventar provides is not consistent with what is expected from Desinventar Database, and especially for such an urban agglomeration.

Under those conditions, the assessments arising from Desinventar databases draw even more attention on a likely gap between the information which is expected from such a highly disaster prone area and the information on disasters the database delivers. All in all, damage intensities are found, unexpectedly (and hopefully, at first sight), very limited. Yet,

once again, it could be a marker of a disaster in the making, especially when taking under consideration the fact that the urban agglomeration of Esmeraldas was also more than 50 km from the epicentre of the 2016 main earthquakes. A query on the USGS historical record of earthquakes with magnitude over 6 and in the vicinity of Esmeraldas proves that the urban agglomeration experienced a more potentially damaging event during the 20th century, at least the 1906 earthquake (Fig. 13).

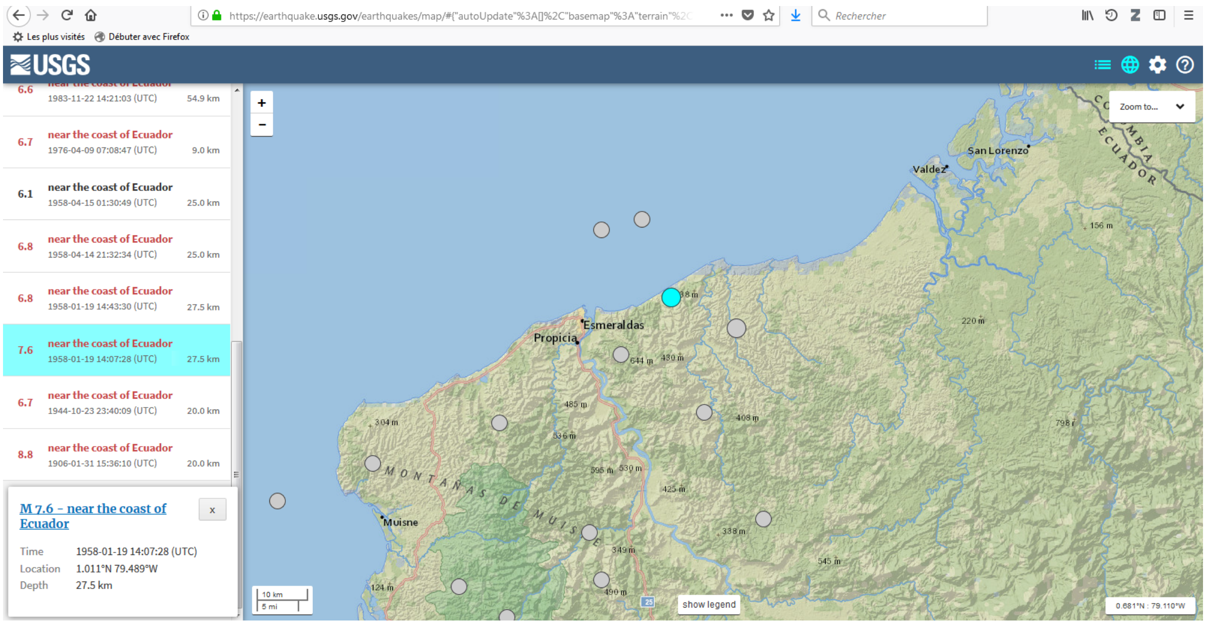


Fig. 13 :Distribution of epicenters concerning earthquakes of magnitude 6 and over since 1900 https://earthquake.usgs.gov/earthquakes/map/

It proves as well that no less than 11 earthquakes have shaken Esmeraldas since 1900, with magnitudes over 6, and within 50 km from the city (Fig. 14). This information is consistent with other sources, as are Espinoza (1992), Nocquet et alii (2016), Singaucho Armas (2009) and Gieseke at alii (2004).

Date	Magnitude	Focus
15/04/1958	6.1	25km
19/01/1958	7.6	27.5km
25/06/1989	6.3	15.1km
19/01/1958	6.8	27.5km
09/04/1976	6.7	9km
31/01/1906	8.8	25km
14/04/1958	6.8	25km
23/10/1944	6.7	20km
11/07/2016	6.3	33km
20/04/2016	6.0	10km
18/05/2016	6.9	29.9km

Fig. 14 : Earthquakes over magnitude 6 and with their epicentres less than 50 kilometers from Esmeraldas according to USGS database.
The events are ranked according to increasing distance of epicentres from the city.

Such information about the location and physical parameters of earthquakes is synthesized in the online IG earthquake catalog: http://www.igepn.edu.ec/mapas/mapa-catalogo-homogenizado and http://www.igepn.edu.ec/mapas/mapa-catalogo-en-revision (Beauval *et ali.*, 2013).

This is on this point that EM-DAT could be useful for a research on disasters at more local scale concerning the city of Esmeraldas, because it registers the most destructive events seen from the world scale.

What can we learn from EM-DAT concerning disasters related with earthquakes in Ecuador / Esmeraldas?

As expected, we find much more limited information reported in this database than what is the case for DesInventar, for the period 1900-2018. However, the comparison between both databases is still useful in spite of the various limitations already mentioned.

The query “disasters, Ecuador, geophysical/earthquake, period 1900-2018” gives 19 results, with 9 disasters for the period 1900/1980 and 10 for the period 1987-2008. This result could induce to think that there would be an increase of frequencies of disasters related with earthquakes, and also an increase of earthquake frequencies, which is most likely not the case, as mentioned before (Singaucho Armas, 2009), even though the point will be reconsidered in the light of Nocquet et alii (2016). The access to the information and also the declaration of damages increase as time goes along, which explains firsthand the trend observed in the statistics (Espinoza, 1992). This trend should not be considered as if human settlements and human societies were not changing, which is of course not the case.

Concerning deaths, EM DAT reports more fatalities than Desinventar (**Fig. 15**) and considers disasters related with earthquakes as major ones at the scale of the country. The discrepancy between both databases is obvious here, when we compare Fig. 1 and Fig. 15. However, the number of fatalities ranks lower for the most recent disasters. It would induce to think that prevention policy could help explaining this trend, an argument D'Ercole and Trujillo (2003) defended. But research also mentions the limitations coming from the way mortality is reported or not, with various biases impacting statistical data (D'Ercole & Pigeon, 1999).

Save table as CSV file

Disaster No.	Disaster type	Date	Total deaths
1949-0010	Earthquake	05-08-1949	6000
1987-0070	Earthquake	05-03-1987	5000
2016-0117	Earthquake	16-04-2016	672
1969-0068	Epidemic	00-05-1969	400
1991-0138	Epidemic	13-06-1991	343
1982-0116	Flood	00-11-1982	307
1993-0013	Landslide	09-05-1993	250
1997-0526	Flood	00-10-1997	218
1992-0460	Epidemic	00-01-1992	200
1993-0014	Landslide	28-03-1993	200

Fig. 15 : Ecuador country profile concerning death in EM DAT http://www.emdat.be/database

The basic assessment is similar when we come to economic losses (**Fig. 16)**. The trend is to have more damages reported, which cannot be considered the sole consequence of prevention policies lacking or being limited, at least, not only. The increase of exposed goods has also to be taken under consideration, among other various factors (Pigeon & Rebotier, 2016).

Save table as CSV file

Disaster No.	Disaster type	Date	Damage ('000 US
2016-0117	Earthquake	16-04-2016	2000000
1987-0070	Earthquake	05-03-1987	1500000
2008-0048	Flood	30-01-2008	1000000
1993-0014	Landslide	28-03-1993	500000
1997-0526	Flood	00-10-1997	271000
1982-0116	Flood	00-11-1982	232100
2006-0373	Volcanic activity	14-07-2006	150000
1949-0010	Earthquake	05-08-1949	20000
1992-0024	Flood	24-03-1992	20000
1989-0256	Flood	00-06-1989	15000

Fig. 16 : Ecuador country profile concerning economic damage http://www.emdat.be/database

Concerning Esmeraldas itself, we don't find information at the scale of the city, as expected for such a database as EM DAT is. However, we find Esmeraldas mentioned in the following disasters related with earthquakes: 1906, « costa de Esmeraldas », magnitude 6 ; 1976 (magnitude not reported) ; 2016 (16 April, Esmeraldas Province, magnitude 7.8) ; 2016 (18 May, magnitude 6.8).

Finally, EM DAT stresses more on the 2016 disasters than Desinventar does, but the information given is still very imprecise (even though it is still useful). Concerning Esmeraldas, EM-DAT does not give any information on some disasters Desinventar reports (see Fig. 11). The information looks as if there were some disasters lacking, especially if we cross the information coming from earth sciences (Fig. 13 & 14) with the information both databases deliver.

Indeed, the CERESIS database as well as various researches coming from geosciences all together check how DesInventar as well as EM-DAT are limited in accounting for earthquakes related damage in the case of Esmeraldas and the Ecuadorian pacific coast.

Contribution from CERESIS database and geophysics: more major earthquakes disaster prone during the 20th century in the province of Esmeraldas.

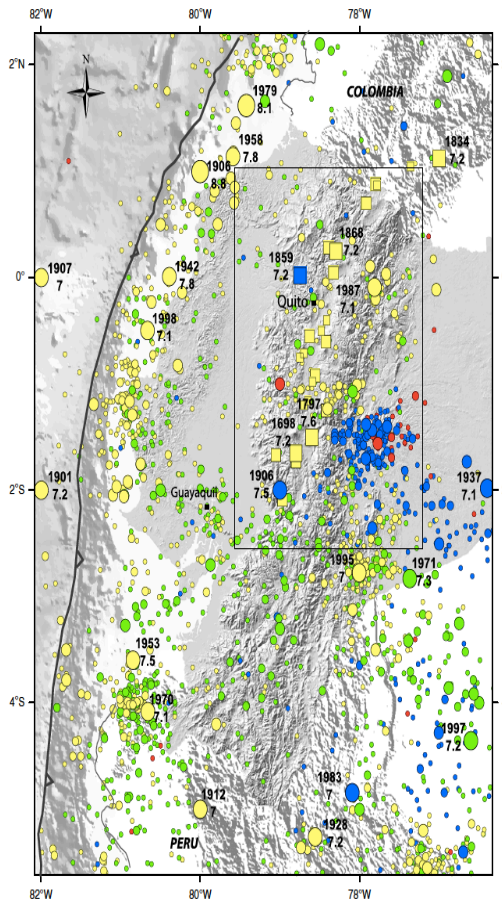
A presentation of the contribution CERESIS database, introduced above, made to the knowledge of past earthquakes can be found in Beauval et alii (2010):

"Much work has been done over the last 40 yr to gather information on Ecuadorian past events and assign MSK intensity to the available observations (CERESIS 1985; Egred 2009a,b). This intensity catalogue covers the last 470 yr with the earliest events reported dating back to the XVIth century, a few years after the arrival of the Spaniards in Ecuador. Earthquakes are reported if the maximum intensity reached at least the degree V."

On this basis, Beauval et alii (2013), find that:

"The first entry in the historical database corresponds to the year 1541, shortly after the arrival of the Spaniards. Until the end of the nineteenth century, the historical information mostly describes effects of earthquakes in the Cordillera. The first coastal event for which several intensities are reported is in 1896 (Fig. 2)."

Indeed, we plainly see on **Fig. 17** a major discrepancy between Cordillera and Pacific coast, because we don't find any major earthquake reported there before the very end of the 19th century.



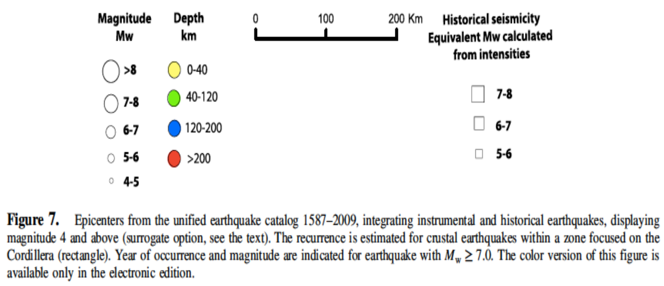


Fig. 17 : Epicenters from earthquake catalog and calculated from intensities (Beauval et alii, 2013)

Indeed, we barely find any square on the coast. Squares correspond to the estimated seismicity of past earthquakes according to intensity as it appears in historical sources. Even if intensities accounted for in historical sources are more and more common from the very end of the 19th century on (**Fig. 18**), the information is still not consistent enough to estimate magnitudes.

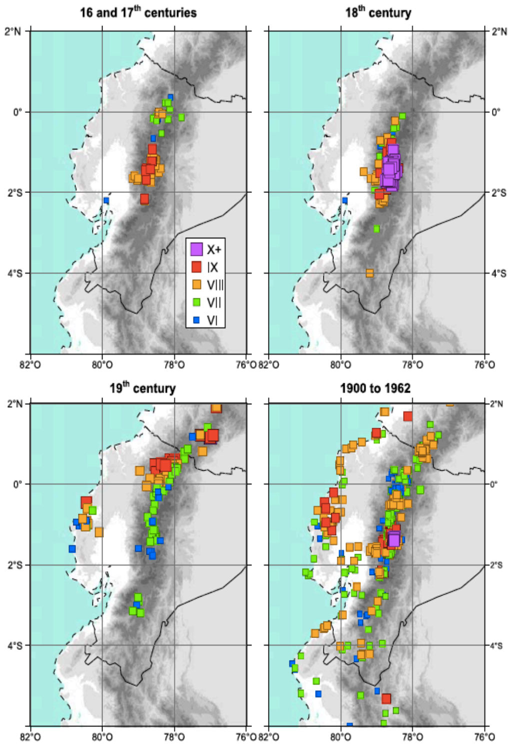


Figure 2. Intensity database for Ecuador (Egred, 2009), containing events with at least one intensity VI reported. All individual intensity assignments are plotted on the maps, considering all earthquakes reported in the database. First information for coastal events at the end of the nineteenth century. The color version of this figure is available only in the electronic edition.

Fig. 18 : Location of intensities data points (IDP) according to historical sources – mainly Eger, 2009 (Beauval et ali., 2013)

On the contrary, the 20th century experienced the 1906 (Mw 8.8) as well as no less than three major earthquakes since then: 1958 (7.8); 1979 (7 .9), 2016 (7.8) (Fig. 17).

This assessment induced Nocquet et alii (2016) to defend that:

> « The high rate of seismicity observed since 1906 contrasts with the lack of historical records of large earthquakes in coastal Ecuador before the twentieth century. Cities such as Portoviejo and Manta were founded during the sixteenth century and reported intensity III damage for the 1797 M7.5–7.9 Riobamba crustal earthquake, located 230 km inland. Both cities were heavily damaged during both the 1942 and 2016 earthquakes. There is only a remote probability that an earthquake similar to the 2016 event would have hit them every century or so without leaving any historical account."

Under those conditions, the situation for Esmeraldas would not meet the requirements of a seismic gap. It is understood by Nocquet et alii (2016) as follows:

> "Seismic hazard assessment models commonly assume that the probability of occurrence of a large earthquake (7 < M < 8) in the decades following a great

earthquake (M ≥8.5) is reduced locally, because of the time required to reload the fault. As several subduction segments are now in the wake of a great earthquake, the lesson learned from the Ecuador–Colombia subduction zone is that a great earthquake can also have the opposite effect of initiating a phase of enhanced seismic release, with large earthquakes occurring more frequently than during the centuries prior to the great earthquake.” (Noquet et alii, 2016).

According to this understanding of the situation, a major earthquake could be expected in the vicinity of Esmeraldas, especially where the coupling of lithospheric plates is low, having a potential of major energy release, which is the case near Esmeraldas (**Fig. 19**).

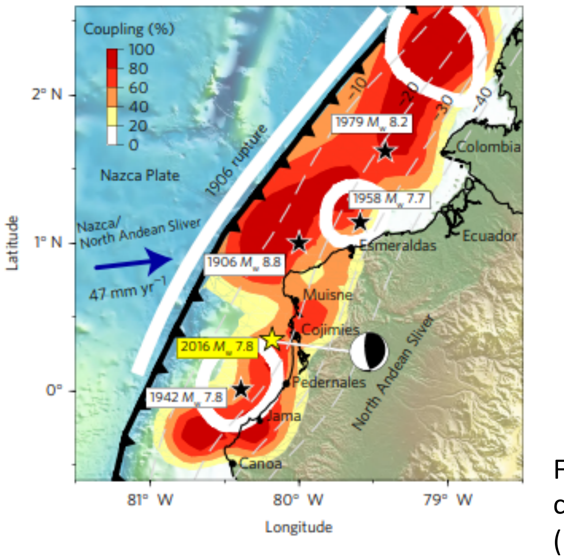


Figure 1 | Previous large earthquakes and interseismic coupling map along the central Ecuador–southern Colombia subduction zone. The black line with triangles indicates the location of the trench. Black stars indicate locations of epicentres of twentieth-century large earthquakes. The thick white lines delimit the area of major moment release for the earthquakes[5], whereas the white line following the trench shows the proposed rupture extent for the great M_w 8.8 earthquake of 1906[2]. The epicentre (yellow star, this study) and focal mechanism of the 2016 April 16 Pedernales earthquake are shown. The colour scale in the top-left corner indicates the interseismic spatial coupling derived from 1994–2013 GPS measurements. Dashed grey lines are depth contours of the subduction interface every 10 km (ref. 41).

Fig. 19: Past large earthquakes and coupling map along the Esmeraldas coast (Nocquet et al., 2016)

However, this situation does not explain why we find so limited information in EM-DAT and DesInventar databases concerning at least the 1979 earthquake. Even if part of the explanation, as concerns the tsunami, is related with the time of the event (the tsunami came by low tide). But, in that case, the poor information available on most likely damages and intensities cannot be explained by the limited exposure of population and assets, as commonly referred to by various authors, such as Espinoza: « debido al escaso o ningún desarrollo de la costa ecuatoriana hasta 1960 »… This explanation is even more given for the lack of historical information on past earthquakes:

“Given the variable earthquake history and the sparse settlement along the coast of Ecuador and Columbia during the 19th century, recurrence time estimates based on historic records, are difficult” resulting in « lacking a complete historic record prior to 1906 (Nishenko, 1999, p. 199).

The assessment is also consistent with the findings of Singaucho Armas (2009): he finds back 36 historical disasters related with earthquakes in Ecuador, with intensities exceeding 8 MSK, since the 16th century. But he mentions 3 earthquakes concerning Esmeraldas only (1906, 1958, 1976) and 4 more in Manabi (1896, 1942, 1964, 1998), the whole amounting to 7 on 36, almost all of them for the 20th century.

Therefore, as concerns Esmeraldas, we face a situation for which we have a very limited range of historical information on past damages related with earthquakes. This seems consistent with a long period during which **major** earthquakes did not happen, since 1906, but also with the poor capacity of Ecuadorian settlement to report possible damages experienced. Indeed, the poor information on disasters seems to extend well into the 20th and 21th centuries, in spite of having this period experiencing major earthquakes very disaster-prone, and of course, in spite of seeing exposure and vulnerability increasing in that part of Ecuador.

This underreporting of damages, at least for the 20th and 21th centuries, in the face of major and potentially disastrous earthquakes, is challenging.

Discussion and conclusions

As expected, we find more information on disasters reported by Desinventar than by EM DAT. But both databases report less damages than expected, especially when considering the information coming from CERESIS database.

EM DAT stresses more on the 2016 disasters than Desinventar does, especially as it concerns Esmeraldas as a province. This points out the limitations Desinventar meets as concerns damages reported for the city of Esmeraldas itself.

Indeed, we find more numerous yet still very imprecise and comparatively limited pieces of information reported for the city of Esmeraldas in Desinventar, which is clearly unexpected. This situation is consistent with the information D’Ercole & Trujillo (2003) deliver. Indeed, they notice that

> « En resumen, la zona central de la Sierra (Ambato, Riobamba), la Sierra norte **y las zonas costeras de las provincias de Esmeraldas** y Manabí son las que mayores perdidas han sufrido por terremotos durante los últimos 4 siglos en Ecuador » (D’Ercole & Trujillo, p. 12).

The assessment they provide takes the form of a table criss-crossing the information related to risk related with earthquakes in Ecuador, at the scale of local administrative units named « cantones »: « cantones donde el riesgo por sismos es mayor » (pp. 82-84, Fig. 20). The global assessment concerning the « canton » of Esmeraldas is: high level of earthquake related hazard (« alto nivel de amenaza sísmica »), AND low level of vulnerability in regard of various criteria, in line with a high level of institutions implied in disaster risk prevention (« alto nivel de presencia institucional »).

Cuadro 20 (continuación)

Cantón	Provincia	Región	Nivel de amenaza sísmica	Nivel de amenaza global	Nivel de vulnerabilidad global	Nivel de vulnerabilidad por salud	Nivel de vulnerabilidad por agua y saneamiento	Nivel de vulnerabilidad por educación	Nivel de vulnerabilidad por pobreza	Nivel de vulnerabilidad por % de la PEA agrícola	Nivel de presencia institucional
Grado de amenaza: relativamente alto Grado de vulnerabilidad: relativamente alto											
Celica	Loja	Sierra	2	2	2	2	2	1	3	2	3
El Guabo	El Oro	Costa	2	3	2	3	1	1	2	3	3
Huamboya	Morona Santiago	Amazonía	2	3	2	2	2	2	2	3	3
Las Lajas	El Oro	Costa	2	2	2	2	2	1	2	3	3
Macará	Loja	Sierra	2	2	2	1	2	1	3	2	3
Palora	Morona Santiago	Amazonía	2	3	2	3	2	2	1	3	3
Paltas	Loja	Sierra	2	2	2	2	2	2	3	3	3
Puebloviejo	Los Ríos	Costa	2	2	2	3	1	2	2	3	3
Santa Clara	Pastaza	Amazonía	2	1	2	1	3	2	1	3	3
Tena	Napo	Amazonía	2	3	2	2	2	2	3	2	3
Ventanas	Los Ríos	Costa	2	3	2	3	1	2	2	2	3
Vinces	Los Ríos	Costa	2	2	2	1	2	2	3	3	3
Alfredo Baquerizo	Guayas	Costa	2	2	2	3	1	2	2	2	2
Balao	Guayas	Costa	2	2	2	3	2	2	2	3	2
Balzar	Guayas	Costa	2	2	2	3	2	3	2	2	2
Bolívar	Manabí	Costa	2	3	2	1	1	2	3	2	2
Caluma	Bolívar	Sierra	2	2	2	2	2	2	3	3	2
Daule	Guayas	Costa	2	2	2	1	3	2	2	2	2
Echeandía	Bolívar	Sierra	2	2	2	2	2	2	3	3	2
El Carmen	Manabí	Costa	2	2	2	2	1	2	2	2	2
El Empalme	Guayas	Costa	2	2	2	3	1	2	3	2	2
El Triunfo	Guayas	Costa	2	2	2	3	1	1	2	2	2
La Maná	Cotopaxi	Sierra	2	3	2	3	1	2	3	2	2
Lomas de Sargentillo	Guayas	Costa	2	2	2	3	1	3	3	2	2
Naranjal	Guayas	Costa	2	3	2	3	1	2	2	2	2
Naranjito	Guayas	Costa	2	2	2	3	1	1	2	2	2
Nabol	Guayas	Costa	2	2	2	3	2	2	2	2	2
Palestina	Guayas	Costa	2	2	2	2	2	3	2	2	2
Pichincha	Manabí	Costa	2	2	2	2	1	3	3	3	2
Samborondón	Guayas	Costa	2	2	2	3	2	1	2	2	2
Santa Lucía	Guayas	Costa	2	2	2	3	1	3	3	3	2
Simón Bolívar	Guayas	Costa	2	2	2	3	2	1	2	3	2
Yaguachi	Guayas	Costa	2	2	2	3	1	1	2	2	2
P. Vicente Maldonado	Pichincha	Sierra	2	2	2	2	2	2	3	3	1
Pucará	Azuay	Sierra	2	2	2	2	2	3	2	2	1
S. Miguel de los Bancos	Pichincha	Sierra	2	3	2	3	2	2	2	2	1
Grado de amenaza: alto a muy alto Grado de vulnerabilidad: relativamente bajo a bajo											
Tulcán	Carchi	Sierra	3	2	1	1	1	1	2	2	4
El Chaco	Napo	Amazonía	3	3	1	1	1	2	1	2	3
Ibarra	Imbabura	Sierra	3	3	1	1	1	1	2	1	3
Quijos	Napo	Amazonía	3	3	1	1	1	1	1	2	3
Ambato	Tungurahua	Sierra	3	2	1	1	1	1	2	1	2
Baños	Tungurahua	Sierra	3	3	1	1	1	1	2	2	2
Chone	Manabí	Costa	3	3	1	1	1	2	2	2	2
Jipijapa	Manabí	Costa	3	3	1	2	1	1	2	2	2
La Libertad	Guayas	Costa	3	3	1	3	1	1	2	1	2
Manta	Manabí	Costa	3	3	1	1	1	1	1	1	2
Montecristi	Manabí	Costa	3	3	1	2	1	2	2	1	2
Patate	Tungurahua	Sierra	3	3	1	1	1	2	2	3	2
Playas	Guayas	Costa	3	3	1	2	1	1	2	1	2
Portoviejo	Manabí	Costa	3	3	1	1	1	1	1	1	2
Riobamba	Chimborazo	Sierra	3	2	1	3	1	1	2	1	2
Rocafuerte	Manabí	Costa	3	3	1	1	1	2	2	2	2
Santa Elena	Guayas	Costa	3	3	1	2	1	1	2	2	2
Sucre	Manabí	Costa	3	3	1	1	1	2	2	2	2
Esmeraldas	Esmeraldas	Costa	3	3	1	2	1	1	1	1	1
Quito	Pichincha	Sierra	3	3	1	1	1	1	1	1	1
Rumiñahui	Pichincha	Sierra	3	2	1	1	1	1	1	1	1
Mejía	Pichincha	Sierra	3	3	1	1	1	1	2	2	1

Fig. 20:
Disaster risks levels related with earthquakes and the national position of « canton Esmeraldas » bearing the city of Esmeraldas.
D'Ercole & Trujillo, 2003, p. 84.

Concerning the situation for the city of Esmeraldas itself, the information D'Ercole & Trujillo deliver should not be really different. Indeed, the « canton » which is also named Esmeraldas, and which contains the city of Esmeraldas, appears at the end of the table. Its assessment is very close to the assessment Quito has (p. 84, Fig. 20). However in view of recent field survey, this assessment is likely to be reconsidered.

<u>**Under those conditions, we could expect to see more precise information related with the history of disasters concerning the city of Esmeraldas during the 20th century, because D'Ercole & Trujillo used various historical sources for the need of their assessment. However, once again, the information is still poor and very limited.**</u> If we consider the map on historical disasters (1541-1998), we observe that at least 4 disasters related with earthquakes and tsunamis were reported; yet not bearing any date (Fig. 21).

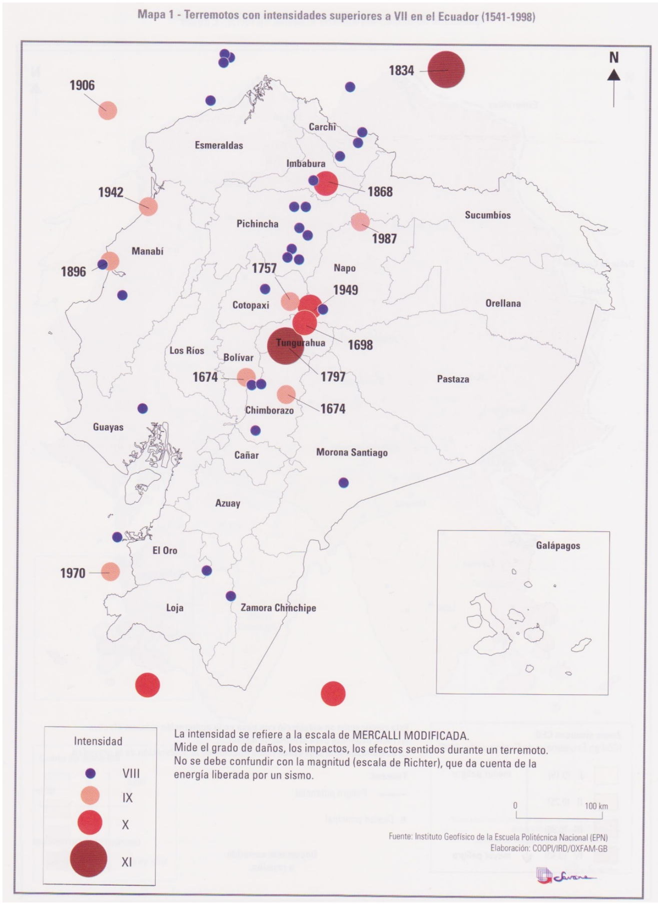


Fig. 21: Historical disasters related with earthquakes in Ecuador. D'Ercole & Trujillo, 2003, p. 15

Compared with the situation for the coastal province of Manabi and also for the provinces of Tungurahua or Cotopaxi, the province of Esmeraldas, and even more the city of Esmeraldas itself, display a gap between the potential to experience a disaster, because of the existence of a high hazard level, a city highly exposed, and the very limited information on past disasters. Let us also notice that the high level of institutional presence D'Ercole & Trujillo stress on for the province of Esmeraldas and the majority of its « cantones » (Fig. 20) would also logically allow to expect more information on disasters themselves, which is not the case at all.

Therefore, it is very likely that damages and disasters are under reported as concerns Esmeraldas and especially the city of Esmeraldas. This assessment is striking if we take under consideration the exposure of Esmeraldas to earthquakes, justifying the position of the canton Esmeraldas on Fig. 22. This preliminary assessment looks similar when we also take under consideration national and international stakes related with the harbour of Esmeraldas. The existence of the harbour and its economic significance should have increased the official recognition of damages and disruptions.

Of course, testing and refining further this preliminary assessment would require to investigate local archives, especially from local and national newspapers, especially around the dates when there is a likely gap between the information coming from geosciences and information coming from databases and D'Ercole & Trujillo (2003) assessment.

The specific objective remains to investigate **why we find this gap between information coming from three databases**, as EM-DAT or Desinventar on one side, and CERESIS on the other side; and **why the information is lacking consistency when compared and integrated**: indeed, we should have much more damage reported by EM-DAT and DesInventar in the light of the information coming from CERESIS database, for the period following the 1906 earthquake, at least!

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