Returning social context to seismic risk knowledge and management

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Lessons learned from an interdisciplinary research in the city of Esmeraldas, Ecuador

Remettre le contexte social dans l'étude et la gestion des risques
Retours d'expérience d'une recherche interdisciplinaire sur Esmeraldas, Equateur

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Finding a holistic and integrative – yet applied and manageable – framework for both understanding and reducing disaster risk has been at the forefront of the most challenging disaster risk research for decades. Still, the search for what some consider unachievable involves multiple challenges, from institutional or cultural site-specific obstacles to more structural complications, including social conditions of knowledge-production and competing epistemological framings.
As part of the ongoing REMAKE programme (Seismic Risk in Ecuador: Mitigation, Anticipation and Knowledge of Earthquakes), contributions from the social sciences provide a contextual approach to enlighten the understanding and management of seismic disaster risk, especially in Esmeraldas after the 2016 Pedernales disaster. Analysing experience reports and feedback from REMAKE allows the authors to highlight the contribution of geosciences and social sciences to the field of risk prevention. Such analysis also emphasizes the relevance of interdisciplinary research. Further, looking more deeply at this research experience shows the importance of underlying social conditionings in producing prescriptive knowledge on disaster risk. The search for more integrative research and action frameworks cannot avoid addressing an epistemological debate on approaches and conceptual models of disaster risk. Such a level of reflexivity within the discourse of research programming and risk management is consistent with the Risk Society thesis and the primary challenges that it posits. Lessons learned from REMAKE offer some insights to nurture the very first steps towards interdisciplinary research programmes and integrative disaster prevention policies, so that a significant difference might be made in disaster risk reduction.

Risk assessment; reflexivity; social sciences; earth sciences; knowledge; risk management; Ecuador.

L'élaboration d'un cadre d'analyse ouvert et inclusif – autant que maniable et opérationnel – pour interpréter et réduire les risques de désastres est une priorité de la recherche sur les risques depuis plusieurs décennies. Mais les obstacles sont toujours nombreux, qu'ils soient institutionnels ou culturels, spécifiques aux territoires d'étude ; ou plus structurels et génériques, impliquant les conditions sociales de production des connaissances ou la diversité des approches adoptées. Par une approche territoriale, la contribution des sciences sociales au programme de recherche REMAKE (Risques sismiques en Equateur : réduction, anticipation, connaissance des séismes), initialement de géosciences, livre un éclairage contextualisé sur la situation de risque sismique très paradoxale d'Esmeraldas (Equateur), mise en lumière par le séisme de Pedernales 2016. L'expérience de recherche du programme REMAKE permet de mettre en avant apports et limites des géosciences comme des sciences sociales à la prévention des risques, en plus de justifier l'intérêt des recherches interdisciplinaires. Mais une démarche réflexive permet aussi de souligner le poids des conditions sociales de production des savoirs sur les risques de désastres. L'élaboration d'un cadre de recherche et d'actions plus intégrateur et cohérent pour améliorer la connaissance et la gestion passe par un positionnement dans le débat épistémologique sur les approches et les modèles conceptuels du risque considérés. La démarche réflexive de cette expérience est conforme à certains traits de la « société du risque », et nourrit modestement les efforts en cours vers des programmes de recherche fondamentalement interdisciplinaires, mais aussi vers des politiques de prévention des désastres plus inclusives. Elle vise ainsi à rendre effective une « société du risque » qui n'en finit pas d'advenir.

Evaluation des risques; réflexivité ; sciences sociales; sciences de la terre ; production du savoir; gestion des risques; Equateur.

Introduction

Spurred by international frameworks and plans of action, disaster risk science seeks to improve knowledge with the objective of damage reduction (UNISDR, 2015a). Indeed, according to the international bibliography, the limits of prevention policies are partially explicable by the persistence of top down and hazard-centered approaches, as well as a lack of integration between several types of knowledge (Weichselgartner and Pigeon, 2015). It has been recognized that knowledge focusing exclusively on hazards is insufficient (UNISDR, 2015b). Still, the synthesis between different kinds of knowledge with respect to risk remains a contemporary challenge (Gall, Nguyen and Cutter, 2015), and contributions from the social sciences on this matter have not yet been fully established.

More broadly, in the Anthropocene era, environmental concerns explicitly motivate this need for knowledge-integration. In particular, the crucial role of social sciences in the production of knowledge and in the formulation of solutions should be acknowledged, notably with respect to climate change (Hulme, 2009), and global environmental change (Janssen and Ostrom, 2006). To be sure, various integrative approaches, theoretical frameworks, and methods already exist: Examples include systemic analyses (De Rosnay, 1975) using socio-ecological systems (Gunderson and Holling, 2002); analysis in the field of political ecology (Robbins, 2011); in the notion of geosystems developed in France (Bertrand and Bertrand, 2002); and – more broadly – in the emergence of environmental social sciences (Moran, 2010). However, despite that the challenge of interdisciplinarity is extensively discussed within many academic journals, research programs and institutional consortia (Pigeon and Rebotier 2016), some tensions and disputes persist, especially about the articulation of scientific contributions from both social sciences and geosciences (as it is discussed, for example, in political ecology: Vayda and Walters, 1999), and even sometimes about the exploitation of the former by the latter (Walker and Cooper, 2011).

Thus, the integration of different kinds of knowledge is crucial for all environmental considerations, including research on risk prevention. It justifies the injunctions to both interdisciplinarity and transdisciplinarity, even if some may consider this quest to be unachievable. As an interfacial discipline, geography seems well positioned to address the relationships between societies and environments (especially in terms of disaster risk). However, in practice, geography has not always been applied to such ends, and geographers are not the only ones to pursue this programmatic goal (Demeritt, 2009).

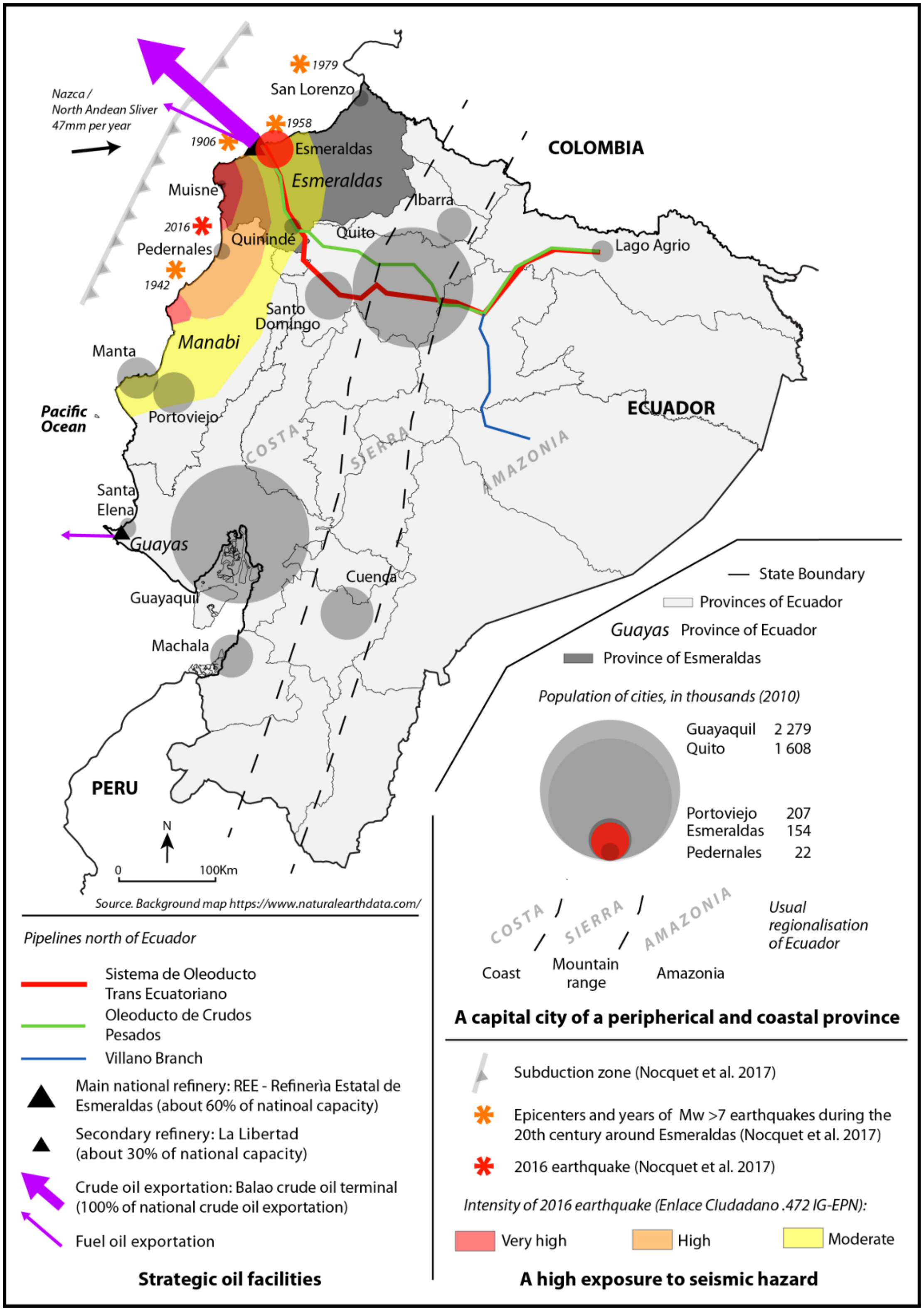
In the domain of risk studies, the production of integrated knowledge is manifestly difficult, even for the authors most convinced of the utility of such integration. The structure of At Risk, (Wisner et al., 2004), which is organized by hazard-type, clearly illustrates these difficulties. In the broader field of social science, Beck has documented the emergence of a "new modernity" as early as the mid-1980s (2001), which reconsiders social relations, and the relations between societies and environments, that are at the locus of the permanent and invasive risks in which humans live. Beck, like Morin, develops his thesis by rejecting modern specialization, fragmentation and "silo mentality" with respect to scientific knowledge. However, the "new modernity" probably serves less as a new horizon to reach for than as a criticism of our post-war 20th century productivist civilization (Boudia and Jas, 2007).

Thus, the diagnosis of the limits of knowledge fragmentation and the need for more integration is well established, but practical perspectives for research and action still need to be clarified. This article draws on a seismic risk prevention research program in Ecuador to illustrate the diagnosis and limitations that have been outlined.

The REMAKE program (Seismic Risk in Ecuador: Migration Anticipation, and Knowledge of Earthquakes) began in 2015 with the premise that a better understanding of expected earthquakes would strengthen seismic risk management in the Andean region (sierra), where the capital, Quito, is located. In April 2016, a 7.8 magnitude earthquake hit the province of Manabí on the Pacific coast. Nearly 700 people died on this occasion, and another 80,000 were displaced. Reconstruction costs were initially estimated at US$3.3 billion, equivalent to 3.5% of the national GDP that year.

The so-called Pedernales earthquake led our research team to focus on the country's coastal regions (costa), on the subduction zone. While REMAKE geoscience colleagues dedicate themselves to better understanding physical mechanisms, social scientists have focused on seismic risk assessment and management in the city of Esmeraldas (Map 1). Capital of the province of the same name, the port city of Esmeraldas appeared particularly interesting to us because of its extremely paradoxical risk situation. Although relatively unaffected in 2016, the city – due to its location – is highly vulnerable to major earthquakes, including those potentially associated with devastating tsunamis. Indeed, since 1900, five nearby earthquakes have exceeded a magnitude of 7 (Beauval et al., 2013). In addition Esmeraldas hosts major and strategic oil facilities, which are of utmost importance in a country whose economy heavily depends on crude oil exports. Despite this, disaster prevention policies and response capabilities appear to be particularly limited in the region, emphasizing the need for such a case study.

Map 1: The city of Esmeraldas in a critical seismic disaster risk situation



The experience reports and feedback which were generated from such research in Esmeraldas, within the REMAKE program, form the basis of this analysis on the importance of social and territorial context in the field of risk knowledge and management. This reflexive approach provides two main benefits. First, such an approach provides information on the role of social conditioning, explaining how it influences useful data, information and knowledge in terms of disaster prevention – including in the field of geosciences – thus contributing also to an explanation of Esmeraldas' paradoxical risk situation. Second, analysis of the experience reports and feedback further demonstrates the usefulness of moving from a classical or modern research approach to a more reflexive one. This epistemological shift emphasizes on the one hand the interest of interdisciplinarity, and on the other hand the importance of making the conditions of production of knowledge and context an object of study. We suggest some lines of inquiry (especially graphic ones) in response to the challenges posed by the REMAKE interdisciplinary program. More broadly, we identify an important advance for integrated research on risks and disasters.

In methodological terms, the article is based on a contextual approach to risk (Pigeon, 2005; Rebotier, 2012). For this, a "basic idea" of "the situation" (Wisner et al., 2004, p.11), or what is around it (i.e. the context), plays a crucial role in the study of vulnerability and, in a more doubtlessly surprising way, in the study of the hazard itself. This article also accounts for previous work on risks in Ecuador, including research conducted by D'Ercole, Metzger and other colleagues (Sierra, 2000; D'Ercole and Metzger, 2004, 2009), as well as more recent studies (Rebotier, 2016).

As part of reforms within the decentralized national risk management system in Ecuador (Rebotier, 2015), one of the major aims is to connect the territorial specificities to national risk management frameworks and policies. A more integrated and interdisciplinary approach to disaster risk assessment and management is, explicitly, on both national and local agendas. However, the major challenge is to ensure that such an approach is actually adopted. This is also why we share this experience feedback.

According to Pierre Bourdieu, "social reality exists, so to speak, twice, in things and in brains" (1992, p.103). The lessons learned from our research at Esmeraldas reflect these two forms of social reality introduced by Bourdieu, and place them into a broader perspective.

Firstly, we briefly present the diagnosis of a risk situation of seismic disaster that is both critical and extremely paradoxical ("in things"). Looking at this paradox through the examination of its context leads us to better understand not only the critical and paradoxical seismic risk situation, but also the type of scientific knowledge that exists and is produced about it. The knowledge that one has of risk ("in brains") is not absolute, but reflects social conditions peculiar to a time and space. Finally, our reflexive approach allows us to suggest more abstract analyses that epistemologically question experience feedback: the strength of social conditioning operates at the same time on things, on the knowledge produced, and on the actions envisaged.

The recognition and explanation of the influence of these conditioning forces on knowledge are a first step towards a more integrated risk assessment, but also towards a Risk Society (Beck, 2001) or a reflexive modernization (Beck, Giddens and Lash, 1994) that has yet to fully emerge.

Seismic Risk in Esmeraldas: a paradoxical issue

A critical seismic disaster risk case

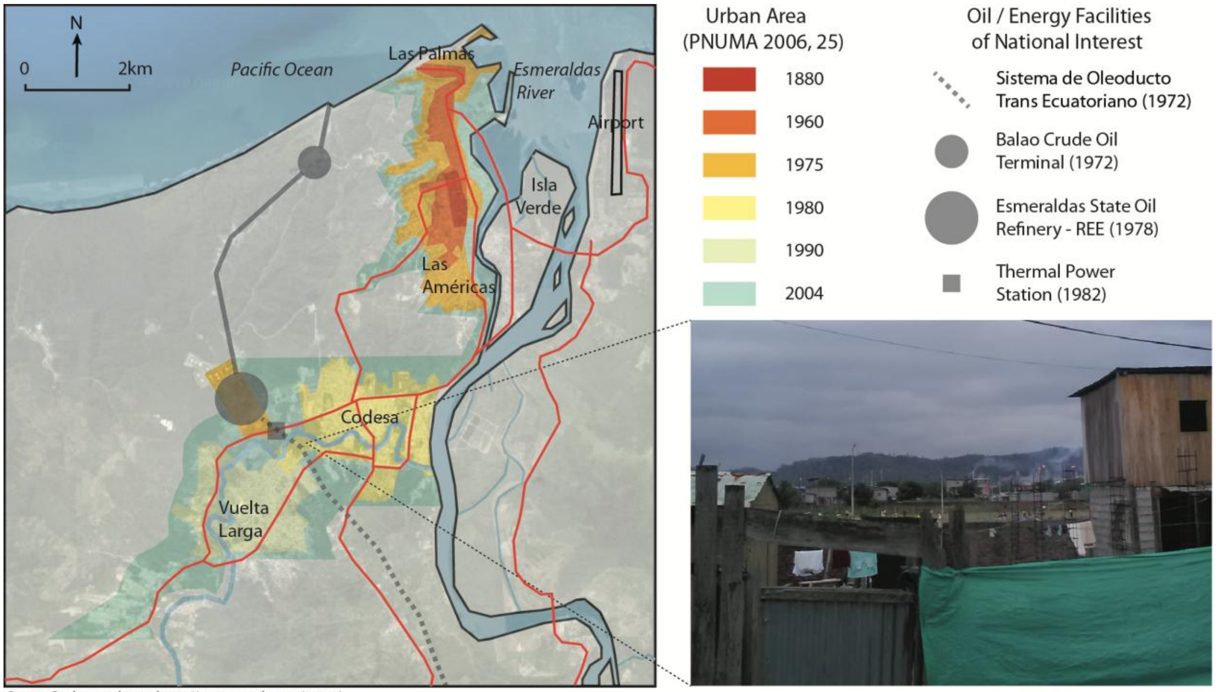
The city of Esmeraldas comprises around two hundred thousand inhabitants as well as strategic national oil facilities, and is highly vulnerable to earthquakes and related tsunamis. Exposure and vulnerability to such natural disasters increased during the 20th century, a trend that can be partially explained by considering the growth of Esmeraldas' port.

From the late 1940 to the late 1960, a banana boom deeply affected coastal regions of Ecuador, drawing people to the Esmeraldas River and its tributaries so that the "green gold" could be grown and exported by boat (Deler, 2007). During that period, Esmeraldas' commercial port handled up to 30% of Ecuador's overall exports (CONADE, 1980, p.68). An oil cycle commenced in the ensuing years. Today, Ecuador has an economy that mainly depends on raw materials, and particularly petroleum. Oil production sites are mostly clustered within eastern regions of the country (Amazonia); additionally, the trans-Ecuadorian oil pipeline system was built in the north of the country between 1970 and 1972. This network of pipeline (SOTE, in Spanish) brings heavy crude from production sites to export facilities on the Pacific Ocean (Map 1). The biggest refinery in the country was built in Esmeraldas between 1974 and 1977, and the Balao crude oil terminal stands here as well. A thermoelectric plant was constructed next to the refinery between 1978 and 1981, and supplies part of the required energy to surrounding industrial concerns, to the city, and beyond (Figure 1).

The construction of oil facilities attracted people from both the inner provinces and the outer regions of the country, which greatly increased the rate of urbanization. A new "popular strata" joined the ranks of urban inhabitants and the unemployed urban proletariat, as once the construction of oil facilities ended, the economic sector provided even fewer employment opportunities to local unskilled people (CONADE, 1980).

From 1970, the city expanded southward with minimal, if any, zoning or land occupancy regulation. According to the city planning department, in 2009, 60% of the buildings in the urban area lacked any title of property. Most of the city sprawl, like in many other Ecuadorian cities, consisted in spontaneous settlements encroaching on former haciendas, which themselves were located around industrial or historic urban areas (UN-Habitat, 2009).

Figure 1: Esmeraldas urban extension and main industrial facilities



Source. Background map: https://www.google.com/maps/

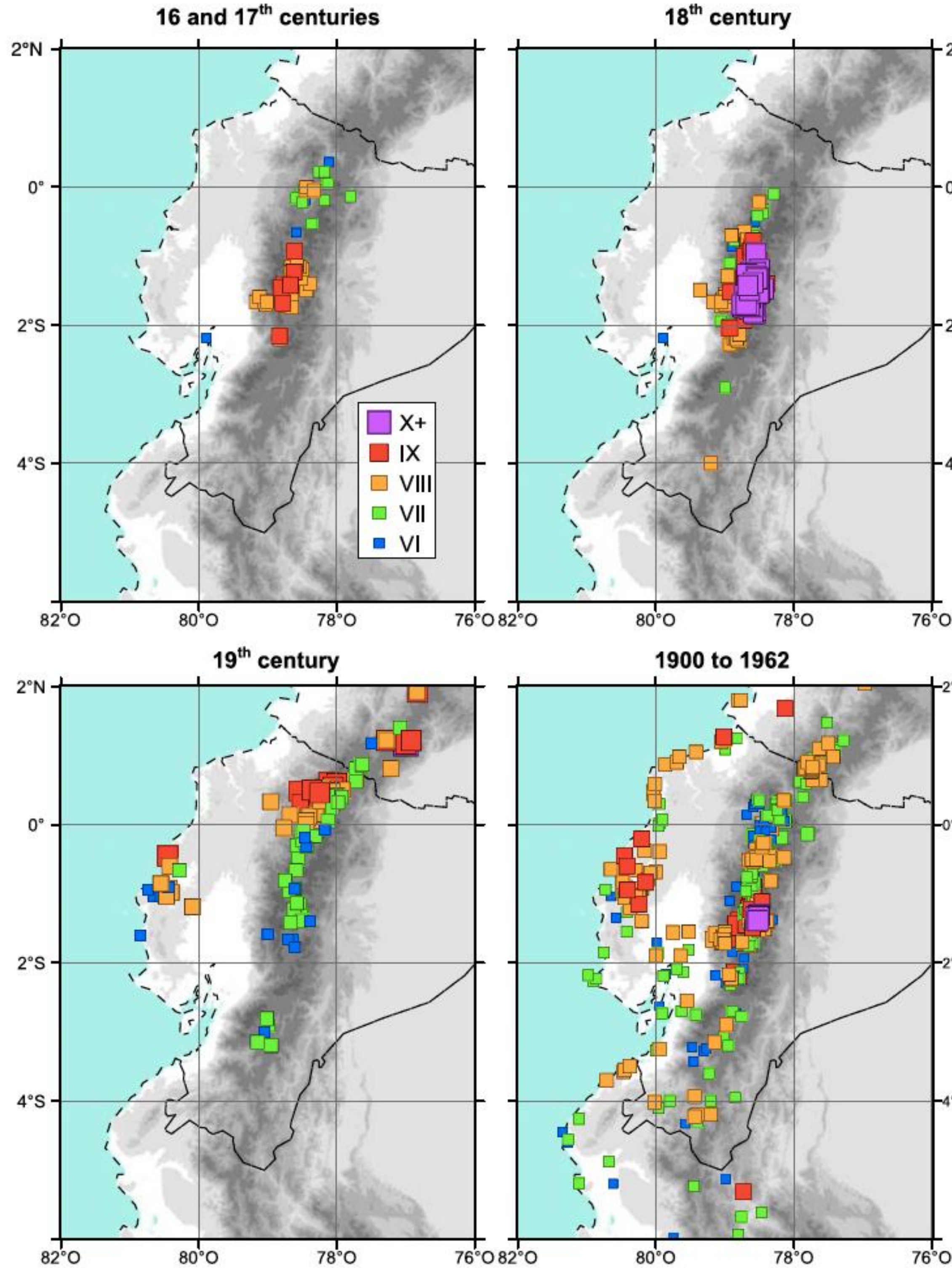
Regarding so many exposed elements in Esmeraldas, some of them highly strategic, as well as the concentration of vulnerable, poor households in the region, one would expect special attention – like practical measures to lower seismic risks in the area, or at least basic and reliable information on seismic hazard – to be a priority. However, that is far from being the case.

Literature on seismic hazard – including the most recent – identifies the Esmeraldas segment of the Pacific-type active continental margin as a place very likely to experience an extreme magnitude event, compared to segments elsewhere (Nishenko, 1991; Nocquet et al., 2017). Still, the need for more information is of no doubt (Beauval et al., 2018).

Limited and poorly consistent earthquake and disaster databases

Ecuador benefits from the existence of a database on past earthquakes, which is produced and updated by the Geophysical Institute (IG in Spanish) in Quito. The database includes information drawn from direct monitoring, using seismometers. With respect to the pre-instrumentation period, the IG database draws on data gathered from intensity reports, which consist of historical records concerning past disasters (Beauval et al., 2010, 2013). Mapping the country-wide data gained by these various sources gives challenging results (Figure 2). Intensity reports barely concern the coast before the 20th century, during the pre-instrumentation period, while none concern the north coast of Ecuador. Such disparity draws attention on the causes of such uneven availability of historical information.

Figure 2: Historical intensity map for Ecuador and uneven distribution of intensity reports



Legend: The scale of intensity is MSK.
Source: Egred (2009), as it appears in Beauval et al. (2013, p.775)

The IG database indicates that no less than five earthquakes exceeding a magnitude of 7 have been recorded with epicentres in the vicinity of the city of Esmeraldas (Map 1), including a major event in 1906. That earthquake, which occurred on 31 January of that year, is considered one of the most powerful earthquakes ever registered by humankind (about 8,35Mw). However, we clearly see a major discrepancy on the Ecuadorian intensity map regarding historical information between the costa and the sierra, and especially for the period before 1906 (Figure 2). The lack of thorough damage reports in the coastal area is clearly related with the poor quality and limited historical information on past earthquakes for this region, especially the north, where Esmeraldas stands. Data, information and knowledge regarding past earthquakes are likely to be constrained by the local (if not national) capacity or willingness to report previous earthquakes and related damage. Indeed, most of the information concerning past earthquakes in Ecuador comes from the few external sources that collected local data. Regarding the 1906 earthquake, for example, most of the contemporary record derives from Colombian newspapers, or from the German consulate in Ecuador. By contrast, in 1868 – about 40 years earlier – a 7.25Mw earthquake occurred close to Ibarra, 70 kilometres north of Quito. The amount of local information about that earthquake, which can be found in national archives such as the Polit library in Quito, contrasts deeply with the very sparse information we find on the later, Esmeraldas earthquake of 1906.

The discrepancy observed between the costa and the sierra concerns the more recent period as well, and bears on the production and maintenance of databases specifically dedicated to such disasters.

Indeed, we rely on two primary databases concerning disasters: EM-DAT and DesInventar. Additionally, a contribution from Serrano and D'Ercole (2003) specifically targets disasters in the city of Esmeraldas. The EM-DAT database (http://www.emdat.be/database) defines a disaster according to a world scale approach: any event with more than 10 dead, and/or 100 people affected, and/or the necessity for external help in coping with the disaster. The inevitable limitations of such a database when it comes to studying and managing more local disasters justifies the existence of the second database: DesInventar (Menoni and Margottini, 2011). DesInventar (https://www.desinventar.org/) identifies what are named « small disasters » according to the definition López (2008) defends in light of the so-called radical approach to disaster risk reduction (UNISDR, 2015b; García-Acosta, 2005). Of course, viewed from the global scale, the « small disasters » which DesInventar records should be more frequent, but with lower intensities of damage, than the disasters contained within the EM-DAT database. The latter should be less frequent but with higher intensities of damage (Pigeon and Rebotier, 2016).

Yet, a comparison of both major databases draws attention to the paradoxical situation in which the city of Esmeraldas finds itself: DesInventar does not deliver more information on past disasters than EM-DAT does. This situation is unexpected, and inconsistent with what has been observed with respect to other cities such as Medellin, in nearby Colombia (López-Peláez and Pigeon, 2011).

Furthermore, regarding the December 1979 earthquake-related disaster, Serrano and D'Ercole mention that the city of Esmeraldas experienced "heavy losses" (2003, appendix IX.6). However, EM-DAT, as well as Egred (2009) – from which the IG database draws – records damage only for Colombia, and is consistent with other sources, such as Arreaga Vargas (2004). Similarly, in the Ecuadorian newspaper El Comercio (13 December 1979), we find limited and ambiguous information about damage related to this earthquake. The earthquake exceeded 7Mw, and it also gave rise to a tsunami. Even though the latter happened during low tide, poor households living on the banks of Esmeraldas River at the time should have experienced damage; yet none as such was recorded.

As for the city of Esmeraldas, earthquake-related disaster databases are found limited and poorly consistent, a situation unexpected when compared with existing assets in this city, and with the record of earthquakes, at least since 1906. Coping capacities appear to be very limited as well.

Limited and rarely enforced disaster prevention policies

Both national and local obstacles limit disaster risk reduction (DRR) policies in Esmeraldas, while the presence of its oil sector presents additional challenges regarding risk management there.

After 2008, national reforms in risk management took place in Ecuador as a consequence of the political Revolución Ciudadana process, which helped in strengthening public institutions generally (Ramírez Gallegos, 2010). Ecuador joined a continental trend in DRR policies of considering DRR as a development issue and not only as a problem of emergency management (Lavell, 2006). A national Secretary for Risk Management (SGR in Spanish) is now in charge of establishing parameters, coordinating resources and implementing the national decentralized system for risk management (SNDGR in Spanish) at the municipal level, across the country (Rebotier, 2015). Esmeraldas municipality is well identified as a hot spot in the national risk agenda; SGR officials, when surveyed, have often mentioned this point. But the SNDGR is far from being realized. The system faces structural and nation-wide obstacles (Rebotier 2016, p.71-73), including the weakness of public capacities at different scales, the uneven decentralization process, or the even more recent adoption of land-use planning regulation tools, such as the LOOTGUS (Organic Law for Planning, Land Use and Management), for which enforcement decrees are still pending in 2018.

Furthermore, after the 2016 earthquake, institutional capacities to deal with seismic risk in Esmeraldas proved to be even weaker what might have been expected, given the emergency resources available countrywide. National Army engineers; members of the Housing Ministry (MIDUVI) and the Transportation and Infrastructure Ministry (MTOP); extra staff managed by the SGR or individuals coordinated by the academia, like the Escuela Politécnica Nacional; all gathered information on damage for this city. By crisscrossing sources, surveyors established that a rough number of 430 buildings appeared to have been destroyed in the urban area as a result of the shaking. Yet, in June 2018, even after officially requesting information from the most recent SGR's GIS files dedicated to the 2016 earthquake, it was not possible to access the list of destroyed buildings in Esmeraldas – whereas other coastal cities' information is available (Marrero et al., 2018). In October 2017, only one architect hired by the municipality was officially in charge of reporting structural damage to local authorities. And there was no instrument for measuring the structural vulnerability of buildings in municipal service at this time.

Historically, risk assessment in Esmeraldas focused on floods and landslides in the urban area, and involved the cooperation of international actors in the production of reports (Perrin, Janeau and Podwojewski, 1998) or in the funding of structural interventions (GADME, 2012a, p.75-76). UN agencies introduced urban environmental benchmarks in the early 2000s (PNUMA, 2006) and promoted climate change and adaptation topics later that decade (UN-Habitat, 2009, 2011), as well as institutionalizing various municipal services. Most of these technical reports were used as the bases for municipal documents (GADME, 2012a, p.37). Regarding risk, an Oxfam initiative drew on existing works (GADME, 2012b, p.10-13). In cooperation with the municipal environmental service, Oxfam helped to create a municipal risk management unit (GADME, 2012c) – as required by law since 2008 – and to develop risk-related municipal regulation (GADME, 2014). UNDP-Ecuador also provided the municipality with a place-grounded assessment of risk (PNUD, 2013). National entities added sectoral documents, relating to floods (after the 2008 Niño episode, Min. Lit., 2009) or to tsunami alerts (after the 2004 tsunami in South-East Asia, INOCAR, 2010). Those various contributions remain of uneven quality and, furthermore, they are highly fragmented. According to a municipal official in charge of risk issues in 2018, there is no such thing as a coordinated municipal initiative about risk assessment or DRR policy implementation in Esmeraldas. Municipal risk regulation in the area is far from being even slightly enforced.

Besides, the many oil facilities in Esmeraldas (Figure 1) make a significant difference in terms of seismic risk. The oil sector remains centralized, as a strategic asset of the State. National actors within the oil sector directly manage potentially very dangerous industrial enclaves, which undermines Esmeraldas' territorial integrity. It was only in 2015, when the Cotopaxi volcano threatened to erupt, that the oil sector moved to organize itself with respect to so-called natural risk (Min. Hidr., 2016). In April 2018, according to our surveys, risk information was still being acquired or updated among various oil facilities. At this stage, relations with local public authorities (Esmeraldas municipality is particularly concerned) were not even mentioned.

Drawing on the Esmeraldas paradox, it is all the more striking that risk knowledge and management appear to be so flawed. The paradox reveals a broader context that not only characterizes a critical seismic disaster risk situation, but also influences and shapes municipal knowledge and management. Such context calls for interdisciplinary research in Esmeraldas.

Unbundling the paradox by thinking beyond restricted disciplinary fields

Crucial, though partial, contributions of earth sciences to DRR

Contributions to disaster risk prevention policies emerging from the field of earth sciences are to be expected, and are considered as a prevailing (if not commonplace) resource by a wide range of international and national institutions (UNISDR, 2015b). Conceptual models in the DRR research field may reconsider the place given to hazards in disaster risk definition, in light of more radical thinking or of more socio-ecologically focused conceptual systems. However, hazard knowledge is still considered key, if not primarily so, in the basic definition or understanding of what disaster risk is. This still-dominant position explains the framing of most research programmes existing on DRR today (Michellier et al., 2016; Pigeon, 2017).

In the case of Esmeraldas, the REMAKE programme has been structured accordingly, and gives research on seismic hazards a prominent place. It offers geophysicists the opportunity to reconsider databases on earthquakes, with the intent to gain better information, to improve the knowledge of past earthquakes, and to contribute that knowledge toward risk prevention. Both the IG database (Beauval et al., 2018) and the already mentioned disaster databases aim at the same goals.

Still, specific attributes of the city of Esmeraldas shed light on the understanding of earthquake frequencies observed since 1906, and also on the lack of information about earthquakes before then. This second point leads a third, already exposed, which is related to the poor consistency of databases and archives on disasters. Indeed, historical reports of damage are a major source of information about earthquakes which occurred before the existence of instrumentation.

Geophysicist records of past earthquakes for this active margin display an unexpected pattern. Due to the very high magnitude of the 1906 earthquake, no other major earthquakes should have been expected to occur afterwards, according to the Gutenberg-Richter law (Nishenko, 1991, p.199). On the contrary, the IG database shows no less than four earthquakes with a magnitude approaching 8 occurring in 1942, 1958, 1979 and 2016 (Map 1). Such an unexpected situation leads Nocquet et al. (2017, p.4) to defend an alternative understanding of the dynamics of this active, pacific-type continental margin:

"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 ($M \geq 8.5$) 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."

The distinctive notion of a « super-cycle » bears further on Esmeraldas' specific circumstances: the next reactivation of major regional faults is expected to happen in the vicinity of the city. Knowledge from the earth sciences sheds light on the high exposure of the city of Esmeraldas, notwithstanding the existence of other major factors with respect to the area's vulnerability and coping capacities. Such knowledge should induce local authorities to further adopt and adhere to preventive policies concerning adaptation to seismic risk.

However, a single linear and top-down transfer of knowledge from the earth sciences to the framing of DRR policies is of necessarily limited value. The sheer number of experience reports has shown how restricted, if not problematic, such a transfer can be when it comes to the improvement of DRR policy. Difficulties arise when a hazard is addressed only as if human societies were structured with respect to that hazard's particular risk, which calls for a focus on multi-risk and multi-stakeholder analysis. Such analysis is out of the scope of earth science contributions, at least in REMAKE research.

Even more, in the specific case of Esmeraldas, our understanding of the pre-instrumentation period needs to be integrated with contemporary knowledge about geodynamics and related topics. For that period, the quality of data that geophysicists use for tracing the frequencies and physical characteristics of historical earthquakes depends on the availability and quality of archives accounting for earthquake-related damage. In these cases, the transfer of information and knowledge does not depend on earth sciences only. Such a transfer integrates a contribution from the social sciences, one that accounts for context framings. The situation calls for, at least, a multidisciplinary approach; even if social sciences can partially contribute to DRR policies improvement.

Bringing the context forward: specific contributions of social sciences

Contextual characteristics stemming from the Esmeraldas' paradox influence not only its risk situation, but also knowledge and management. The latter can be assessed in Science and Technology Studies (Latour, 1987; Jasanoff, 1998; or with regard to climate change: Oreskes and Conway, 2010), or by addressing the way the scientific field is structured (Bourdieu, 1976). By presenting historical sources with which earth sciences work, sub-section 2.3 (below) will show how subtle such influences can be. The present sub-section is dedicated to those contributions from social sciences which, potentially, can broadly assess the ways social and spatial context influences risk.

Certain methodologies are sensitive to social and contextual construction of risks (e.g., García-Acosta, 2005; Wisner et al., 2004), while other place-grounded approaches rely more on spatial analysis (Cutter et al., 2008). A territorial analysis seems appropriate to reveal the significance of Esmeraldas' contextual characteristics. Territory does not only refer to a spatial area under judicial control. It also incorporates the many ways the area is appropriated, represented, or used, by various groups of actors at different scales (Antonsich, 2011). Symbolic, cultural or social elements are involved in addition to analyses of power relations or economic factors. Territorial analysis is more an approach than a methodology. It consists in identifying what contributes to the framing of risk in a particular place, in accordance with what makes this place a territory: social and cultural relationships, history, and the articulation of spatial scales (Rebotier, 2012; Simon and Dooling, 2013).

In Esmeraldas, like anywhere else, many contextual drivers are unevenly tied to the assessment of risk situations. It is not easy to gauge whether some of these factors are locally specific (eg, the importance of the burden of territorial and social marginality). Other conditions are characteristic of Ecuador as a whole (like a low skill level among public workers, or the lack of land use regulation tools: Rebotier, 2016). Some of them are even common to challenges associated with risk reduction worldwide (like accountability, governance, or shared knowledge: UNISDR, 2015b).

Thus, it is not easy to evaluate how a territorial characteristic is specific to a place, or how significant it is in influencing risk. Indeed, in Esmeraldas – as in France, Sri Lanka, or Ecuador generally – DRR policies are clearly limited in spite of their contribution to disaster risk prevention (Pigeon and Rebotier, 2016). Still, it is not possible to put the blame solely on territorial or social marginality. Obviously, reducing marginality mechanisms (for people or territory) is not enough to reduce risks. There is no doubt that racism is a factor in both institutional and individual relationships in Esmeraldas with regards to the rest of Ecuador (Minda, 2015). But how specific to Esmeraldas is racism towards black people in the country as a whole? And how much does it matter with respect to DRR policy, or even to hazard knowledge? Basically, territorial analysis does not quantify those relations which it identifies. It highlights the multiplicity of contextual risk drivers in a broader plan – racism is one example of the many drivers at stake – instead of establishing (often mono-) causal links. Precise answers to the above questions are not necessary to account for the most significant drivers in assessing risk, its knowledge and management. Yet a major question remains: What can a context-forward approach bring to interdisciplinary research and DRR policies? At the heart of the territorial approach remains a tension between a complex and situated understanding of multi-causal risk, and the necessity to act – or feign to act – to reduce risk.

Reflexive interdisciplinary research is required in accounting for contextual influences in order to acknowledge local specificities as well as more general mechanisms, all of which shape knowledge and decision-making. Still, it is not easy to maintain the tension between universality and particularity without addressing certain epistemological issues. Research experience in Esmeraldas puts together different scientific fields by drawing on historical sources, and leads to consideration, more broadly, of interactions between social sciences and earth sciences (part 3).

How social sciences directly contribute to earth science knowledge

The understanding of the active continental margin Nocquet et al. (2017) propose relies firsthand on a geophysical interpretation of the monitored information about earthquakes collected since 1906. However, this understanding also integrates information on earthquakes before the pivotal 1906 event. Tracing back such information requires not only access to existing archives, but also consideration that the information contained within such archives is not necessarily factual per se. Here is a direct contribution of social sciences to the geophysical understanding of this active margin, a contribution that should lead to a kind of interdisciplinary knowledge not only on earthquake frequencies, but also on disaster frequencies more generally.

The capacity to improve DRR policies by transferring earth science knowledge to action is limited, as major earthquakes do not necessarily correlate with major disasters, directly. Such is the case in Esmeraldas. But explaining such discrepancies could help in identifying the kind of knowledge required to potentially improve disaster risk prevention. One of the reasons for the discrepancy we found in Esmeraldas is the low consistency of the historical information about damage. This is a key issue, as earth science knowledge has to partly draw on such records, and extensively so for the pre-instrumentation period. But to what degree is such information reliable?

To check the reliability of the existing information on past disasters, we compared databases on earthquakes and disasters, as well as information we gathered from various historical sources. Regarding Esmeraldas, we consulted historical archives, monographs, and a selection of editions of the main newspaper in Ecuador, El Comercio, since 1906.

The main results contradict the preconceived idea that the poor availability of information on damage stems from a limited number of population and assets. As for the 1906 event, many sources show that such a notion cannot be proven: indeed, the city of Esmeraldas and its port existed at that time. Furthermore, the poor availability of information remains – unevenly – a factor with respect to more recent events (like in 1979), even as population and assets increased.

Rather, the conditional availability of information in this case reflects the city of Esmeraldas' fluctuating status with regard to the history of Ecuador, as well as the fact that the city belongs to a province considered in Ecuador as marginal. The disaster related to the 1942 earthquake was much more broadly documented by El Comercio than the 1979 disaster. For the 1942 disaster (Mw7.8), we find extensive information on damage concerning the city of Esmeraldas between 14 May 1942 and 24 May 1942. At that time, during World War II, the harbour of Esmeraldas was critical for Ecuador, as it provided international stakeholders with ivory palm (tagua) and rubber. On the contrary, the 1979 disaster was hardly documented in the same newspaper. We find scarce and vague information for a period of three days, with a reference to "a big fear caused by the earthquake" (13 December 1979, section C). The 1979 earthquake (Mw8.1) was followed by a tsunami, which was not the case in 1942. Such an unexpected discrepancy between earthquakes and damage has already raised attention (Nevarez Mendoza, 2015, p.153).

Therefore, the lack of historical damage reports cannot be considered sufficient for proving a lack of high-magnitude earthquakes around Esmeraldas. A possible key to assessing the data might be to acknowledge that the "super-cycle" thesis could also apply to the period before the major 1906 earthquake. Indeed, in spite of its magnitude (8.35Mw according to IG database), the damage that earthquake caused has hardly been documented, similar to the case of the 1979 disaster. Such a discrepancy could also bear on other, previous events not precisely documented in historical damage reports, even though we can find hints of their existence. Among many examples, Molina Serrano (1959) mentions two « destructive events » belonging to the same category as the 1906 earthquake, close to the city of Esmeraldas. Yet, the information provided shows a contradiction between the data reported on the map (22 January 1854), and that given in the text (22 January 1859). Additionally, in 1871, various witnesses report the formation of small islands or peninsulas "of 10 to 30 meters" due to landslide cliffs close to Cabo Pasado and Pedernales on the coast south of Esmeraldas (Wolf, 1871). Wolf associated such phenomena with major earthquakes. Yet, none of those potentially "destructive events" are considered in the IG database.

Multiple considerations of the social context contribute to frame historical information on earthquake-related damage. Consequently, earth science knowledge integrates these elements, at least at some point, as part of the information used for producing such knowledge, which itself is not merely factual (or supposedly objective, for being instrumental) but socially conditioned. This situation draws attention to the need for DRR policies to consider relevant, city-specific characteristics about Esmeraldas in greater depth, as such attributes influence data collection, information and knowledge coming from the academic world (be it from the earth sciences or the social sciences). Further, the Esmeraldas case study allows for the examination of broader epistemological issues surrounding interdisciplinary research on risk and site-specific DRR policies.

What interdisciplinary research for what knowledge, and for what types of action?

Formalizing the relations between science, knowledge, and the social world

To understand the paradoxical conditions we encountered in Esmeraldas, we postulate the importance of context for a dual purpose: The social world conditions not only the knowledge of place and risk, but also its management. This perspective on risk addresses, on the one hand, the production of knowledge, and, on the other, the relations between this knowledge and the social world – that is to say, mostly, public policies and representations of risk. Knowledge on risks is influenced by the actors who produce it, but also by the conditions in which it is produced. These influences also weigh on reducing the risk of disasters. The status of knowledge is a field of research in itself (Mercer, 2012; Weichselgartner and Pigeon, 2015), to the point that specific mechanisms are envisaged to better integrate knowledge and action (Renaud, Sudmeier-Rieux and Estrella, 2013; Poljansek et al., 2017). Here, we will focus on the social conditions for the production of scientific knowledge related to disaster risk reduction. As such, we adopt a reflexive approach, which focuses on its own research practices to question the relations between the scientific field, scientific knowledge, and the social world.

Based upon interdisciplinary research conducted around Esmeraldas – especially via database analysis – we aim at reconsidering the classical scheme of scientific knowledge production on risks. Relations between science and society, and between the scientific field and the objects of its knowledge (but also between scientific disciplines) play a large role in such reconsiderations. The concept of "scientific field" here refers to all the structures, positions and dispositions that guide scientific practices, as well as to the distribution of scientific capital in a particular social universe that is the scientific world (Bourdieu, 2001).

By doing so, we hope to engage with a more epistemological – albeit concrete in its own right (O'Brien et al., 2007) – aspect of the current debate on risk. Our approach allows us to look reflexively at what interdisciplinarity can generate, i.e. how it is able to produce a new knowledge, one that combines objects, problems and benefits from diverse disciplines in a different way.

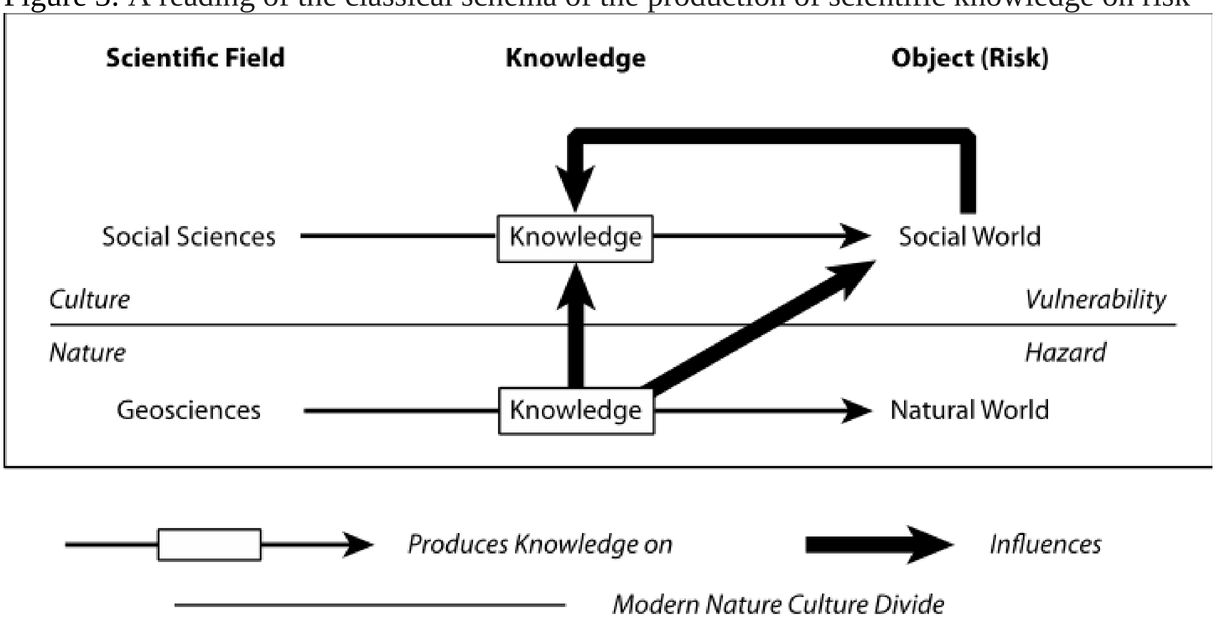
Here, the idea is to formalize that which has generated – within the framework of REMAKE – an interdisciplinary approach between earth sciences and social sciences, by schematizing the relations between the scientific field, scientific knowledge, and the social world. First, it is a matter of analyzing these relations in accordance with our understanding of the classical approach of risk analysis (Figure 3). Second, we will demonstrate how the input of social sciences with respect to Esmeraldas modifies this classic scheme (Figure 4). Thus reconsidering the production of scientific knowledge about risk leads us to consider another conceptual model of risk (Figure 5): one that is understood as the schematic representation of a complex object, its components and their relations.

Earth science knowledge influences the social world

The classical approach of seismic risk analysis is mostly hazard-centered, in the sense that it relies partially – if not mainly – on the knowledge of physical phenomena developed by geosciences. This classical conceptual model (risk = hazard x vulnerability), which is at the basis of our knowledge on risk, leads to a division of research labor between those who focus on hazard (geoscientists) and those who focus on vulnerability (social scientists) (Figure 3). This conceptual model has been deeply criticized for its inconsistencies and inadequacies (Wisner et al., 2004). However, though it is not the only one, it remains the theoretical and practical basis of most research (Kuhlicke and Steinfuhrer, 2010; Shi and Kasperson, 2014). In that sense, it is dominant and significant, and is qualified as classical. Additionally, the classical model tends to reproduce a kind of segmentation within the scientific field itself: Hazard (the object of earth sciences knowledge) is separated from vulnerability (the object of social sciences knowledge), as public policies are generally altogether absent from this model (Pigeon, 2017).

However, the sense of segmentation common to the scientific field is counterset on a regular basis by the very process of knowledge production (Figure 3). At the center of classical research about risk is the knowledge of physical processes which draws from the geosciences, insofar as such processes impact the social world, or sometimes lead to disasters. Here, the social world is passive. It suffers from the consequences of disasters that are presumed to be caused mainly (or at least initially triggered) by external natural phenomena. Therefore, geosciences – in mobilizing such knowledge – are regarded as the privileged interlocutor of public authorities with respect to guiding and defining risk prevention policies. As a further consequence, the bulk of research investment required by the social world relates to hazard, with the aim of restraining or avoiding hazard (Hardy, 2013). The reduction of vulnerability is determined by the knowledge of hazard and its control. In other words, the knowledge produced by geosciences on hazard directly influences the public policies implemented in the social world, as well as the kind of knowledge expected from the social sciences.

Figure 3: A reading of the classical schema of the production of scientific knowledge on risk



On the other hand, knowledge produced by social sciences about the social world only marginally influences public policies, if it does so at all. Indeed, such knowledge – about the social world, stemming from the social sciences – is most often considered secondary, both by geosciences and by public authorities. This despite the many references – often rhetorical – to the social construction of risk (García-Acosta, 2005; UNISDR, 2015b) and the existence of important areas of research convinced of social sciences' relevance (Janssen and Ostrom, 2006; Lavell and Maskrey, 2013). This situation reflects the fact that social science research generally proceeds after research conducted by earth sciences, in line with the hazard-centered approach (Castree et al., 2014). As a result, social science models are largely influenced by geosciences, which have a strong social legitimacy, and therefore convey the classic conceptual model risk = hazard x vulnerability, in which hazard is dominant. Most social science research then reproduces this conceptual model. Vulnerability is mainly understood as exposure to hazards, as structural susceptibility with respect to engineering, or in terms of response capabilities to a disaster. Vulnerability is most often analyzed in the space of hazards that is delimited by geosciences.

In this context, the kind of knowledge specific to social sciences is useful in understanding the context in which the knowledge about the hazard is received, as well as the conditions for implementing the prevention policies that are drawn from it. This is where research on perception, acceptability, poverty or inequality is justified. Social sciences are solicited in particular to "translate" geosciences knowledge on risks. They are expected to diminish the supposed ignorance or irrationality of the population, via sensitization and training policies designed to develop a "culture of risk", that is to say, behaviors or conducts that would be appropriate according to the scientific knowledge on risk that has been produced (Mitchell, 1995).

In this case, the sort of knowledge produced by social sciences is not directly mobilized by the social world as something useful for understanding what constitutes the risk. Rather, it is an instrumental skill – "knowing how to talk to people" – which follows a kind of knowledge about risk that is mobilized to achieve operational goals. Thus, the approaches of geosciences, as well as their epistemological framing effects, shape and influence both scientific knowledge of risk (including that produced by social sciences) and also public policy.

Two factors can explain this situation. On the one hand, natural phenomena appear to be evident, and – in line with a "modern tradition" (Compagnon, 1990) – one tends to interpret risks and disasters as consequences of natural events. On the other hand, earth sciences benefit from a higher perceived legitimacy and better social recognition than social sciences, due to their reputation for producing knowledge about the "natural" world, all imbued with scientific neutrality and objectivity, in accordance with a certain idea of modern science (Jaspers, 1970). Conversely, from the point of view of the social world as well as within the scientific field itself, social sciences are reputed to be biased, contingent, critical, influenced by political context, even partisan or inclined to defend a political goal (Forsyth, 2012; Robbins, 2011).

So, there is a schema that establishes a relationship of influence from earth sciences onto public policies directly, or indirectly via the mediation of social sciences, based upon a physical knowledge of the hazard (Figure 3). This schema echoes a classic vision of risk, which refers principally to a primary hazard, outside the social world, and to the impact of the natural phenomenon on the social world. It also reflects the legitimacy of a division of the world – modern and technicist – maintained by the scientific field and the hierarchy of disciplines, and inherited from a positivist conception of science (Bourdieu, 2001).

Earth science knowledge is influenced by the social world

In this context, the REMAKE project is no exception. Its initial conception is part of a classical approach, in the sense that it relies on the conceptual model risk = hazard x vulnerability, with a classical division of labor between social sciences and earth sciences. Originally, REMAKE is a research project whose problem was motivated by geoscience concerns. The contribution of the social sciences responds above all to the formal need for interdisciplinarity. But concerning the seismic risk per se, the expectations (in terms of what scientific knowledge is likely to influence the social world and public policies) focus primarily on the earth sciences.

However, REMAKE research is producing an interdisciplinary work of scientific knowledge about earthquakes by using disaster archives (damage intensity reports - part 2.3), but also via broader social conditioning with respect to the production of scientific knowledge about disasters (section 2.2). This research experience has contributed to modifying, or at least questioning, the classical approach, thanks to the adoption of a knowledge approach (Figure 4) which is part of Beck's (2001) reflexivity. In developing a reflection on the relationship between scientific fields, scientific knowledge and the social world (part 3), two things are made clear: On the one hand, there is the need to develop a conceptual model of risk alternative to the classical model. Such a model would integrate public policies and articulate a broader social context that conditions their use (Figure 5). On the other hand, we emphasize the central place of epistemological questions around the production of scientific knowledge, even if this point is often neglected (as its social utility is not obvious at first glance). If the first point is often acknowledged (without any real solution – Know.4.DRR programme[1], Weichselgartner and Pigeon 2015), the second is less commonly so, especially as, in this case, the concern has emerged from the experience of empirical and interdisciplinary research.

As a matter of fact, research on political, social and spatial context is a usual contribution from social sciences research on risks. But our reflexive work also focused on the conditions of knowledge production. In short, this research has identified the Esmeraldas paradox and has shed light onto the social conditions of production for all data, information and knowledge related to it, including that of the hazard itself. These contextual elements pose the question of risk outside the classical conceptual model (risk = hazard x vulnerability), as our analyses takes as its point of departure the strategic importance of Esmeraldas, which is neither related to hazard nor to vulnerability. Moreover, these paradoxes invite us to develop a comprehension of risk that aggregates both local and national scales, since the presence of strategic concerns in the region contributes to the vulnerability of the country itself.

The central paradox here is that the place in question is both central and marginal, both in the social and political sense, as well as in terms of research and the production of scientific knowledge (in this case, around seismic risk). Existing policies and current knowledge are both clearly limited with respect to Esmeraldas' considerable importance, justifying REMAKE’s particular focus on this part of Ecuador. Starting from this paradox, the research no longer takes hazard as its primary concern, but rather serves to reveal the process of risk production over time. It is this process, related to the local context, that becomes of central importance. Thus, the reasons for which the knowledge on disaster preparation is so limited, fragmented or heterogeneous became a central element of research in the reflexive approach to knowledge that was developed.

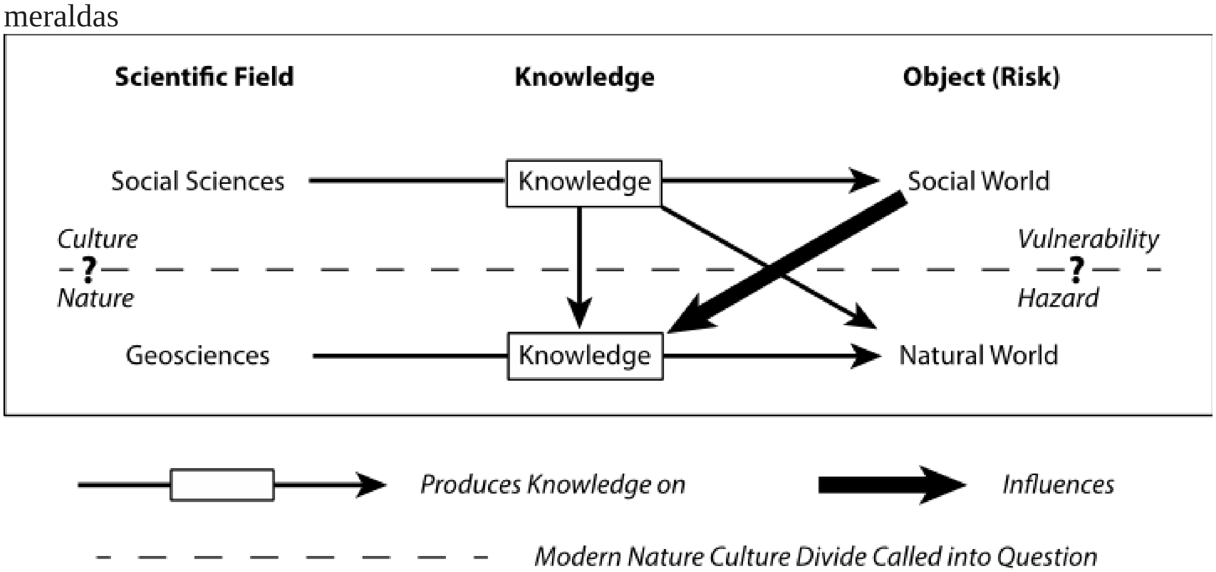
Even more specifically, by discussing the knowledge produced by geosciences on the occasion of the historical reconstruction of disasters (part 2.3), the social sciences "socialize" the hazard, (or, more precisely, the knowledge of the hazard) and at the same time demonstrate that they can con-

[1] http://www.know4drr.polimi.it/; https://www.preventionweb.net/publications/view/50228

tribute to the knowledge of hazard itself. So we have a form of redefinition, or hybridization, of the knowledge of the hazard, which is no longer the sole prerogative of the earth sciences (part 2.1). In other words, in this case, the social sciences take as their object not only the natural world itself (through the reports of damage intensity), but also the social world, as well as the very knowledge of the hazard as it is produced by the earth sciences (Figure 4). The direct influence of the earth sciences on the social world (Figure 3) is explicit, and can be recognized in the influence of the social world on highly legitimate hazard knowledge, and more broadly in the influence of the functioning of the scientific field, which itself cannot escape the social world (Bourdieu, 1976). Recognising such an influence – of the social world on hazard knowledge – allows one to question the "silo mentality", as well as the modern divide between nature and culture in risk understanding. If in the field of science studies (Pestre, 2006), this type of questioning (of the social production mode of knowledge) is common, it is an aspect of research largely ignored in regard to the problem of risks, including in social science research on public risk management policies. By focusing on such questions, we show how disaster knowledge is built and embedded in the social world. If the influence of social conditioning is discarded, it produces a narrative that naturalizes and depoliticizes risk issues.

Thus, the schematization of the reflection on objects of research, the scientific field, knowledge, the social world, and the relations between these elements (Figure 4) partially unveils some epistemological blind spots, and allows us to produce new knowledge. This is the case for the contribution of the social sciences to the knowledge of hazards specific to REMAKE research and to the study of seismic risk. This is also the case, more broadly, for the influence of the social world on the production of knowledge, notably within the field of Science and Technology Studies (STS) (Jasanoff, 2004), but whose stakes are replaced here in the experience of an interdisciplinary research project on risks.

Figure 4: A reflexive approach to the production of scientific knowledge on seismic risk in Esmeraldas

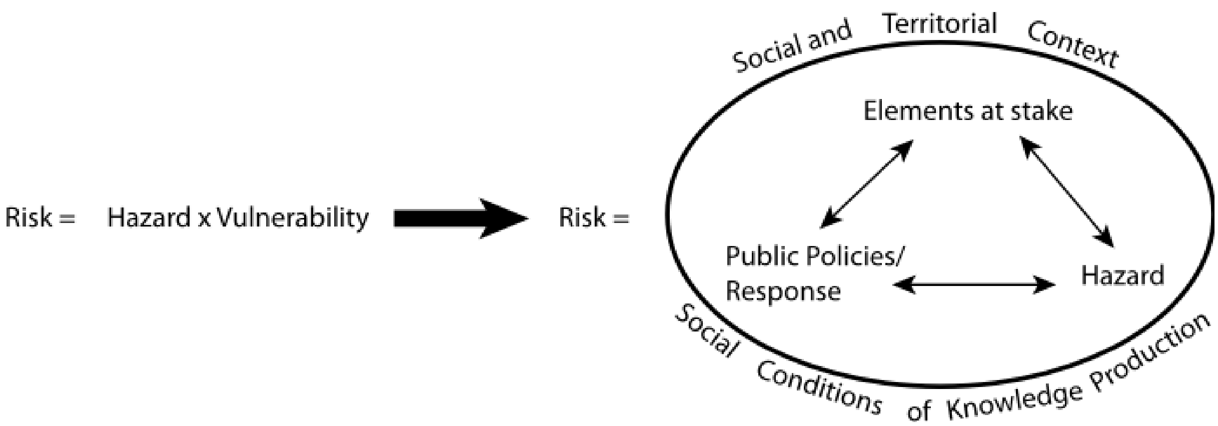


Conclusion

Reconsidering different implications of social context with respect to risk research in the case of Esmeraldas provides three lessons:

- First of all, it is necessary to reconsider the classical conceptual model of risk, and to depart from the classical paradigm (risk = hazard x vulnerability) that gives precedence to the hazard itself (Figure 5). We recognize the importance of feedback, and of lessons learned (or discarded) from public policies in the production and management of risk situations (Pigeon and Rebotier, 2016). We also know how difficult it is to account for these forms of interaction and feedback with the social world in a simple but effective way (Pigeon, 2017).

Figure 5: Towards a conceptual model of risk that accounts for the social conditions of knowledge production



- Next, we are compelled to reformulate the objectives of social sciences related to risk, within the framework of a less classical and more reflexive approach: no longer in terms of perception, acceptability or poverty, but rather according to varying social and territorial contexts, and in terms of justice or domination. The reflexive approach of knowledge by the social sciences, carried out within the framework of REMAKE, frees itself from the classical framing of hazard-centered approaches. This is a real opportunity to produce less ordinary knowledge, with the potential to direct action differently.
- Finally, this research in Esmeraldas, and the epistemological perspectives we draw from it, invites us to discuss more openly how to work on risk from an interdisciplinary perspective. The discussion of collaborative means between disciplines must be a prerequisite. Such collaboration matters as soon as the conceptual risk model is defined (whether the classical risk paradigm = hazard x vulnerability, or the taking into account of prevention policies), and delineates the perspective of research to be adopted (from one classical approach to another, more reflexive one, able to identify the effects of context and the influence of the social world on the production of knowledge).

Identifying the forms and social conditions for the production of scientific knowledge on risks is all the more crucial because these forms and conditions also have a very real impact on risk management. The epistemological work, peculiar to the social sciences, could be applied much more extensively than is currently the case. In this sense, the shift in the Society of Risk (Beck, 2001) by the implementation of reflexivity, and by the socialization of science and technology, remains to be accomplished, including in terms of research.

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