Natural and societal-induced environmental hazards: integrate interdisciplinary long–term research strategy for developing countries *

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Abstract

Natural stochastic and societal-induced hazard events (S-IHEs), such as meteorological, climate, hydrological, geophysical and biological, are part of the so called *"science of natural and societal-induced hazards and disaster risk"*. In the past 50 years world impacts due to natural and NS-IHEs have increased about one order of magnitude, showing severe increases in economical damages. Moreover, over 90% of the population affected by them refers to events such as flooding, windstorms and droughts, with a mean of about 200,000 people directly affected per year. In my view the "hard-science" behind natural and S-IHEs involve basic disciplinary research as well as in the so called mission integrative and multidisciplinary research. In the are of natural hazards and S-IHEs there is an urgent need for disciplines to truly "talk-each-other" in an integrative way. Chile is a developing country facing numerous and dreadful natural and S-IHEs and therefore, scientific research (preparation, response, recovery, mitigation) and linkages with policy making and government, need to be part of integrate interdisciplinary long–term scientific research strategies. The paper describes, with details, a research multidisciplinary initiative (FONDAP Programs) highlighting long-term results regarding first world class publications, that may serve as an example for building natural and S-IHEs investigative and the design of public policy strategies in other developing countries.

Keywords:

Environmental hazards, disasters, integrative multidisciplinary research, mission oriented research model, developing countries, Chile.

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1. Introduction and definitions

Natural stochastic and societal-induced hazard events (S-IHEs), some times sudden and violent and extreme in magnitude such as: a) meteorological (wind-storms, typhoons, hurricanes extreme temperatures); b) climate (droughts, wildfires); c) hydrological (flooding, landslides); e) geophysical (earthquakes, volcano eruptions, tsunamis); f) biological (infectious diseases), are part of the so called *"science of natural and societal-induced hazards and disaster risk"* (other type are the so called technological impacts, such as those related to oil spills, explosions, transport , other). When these events cause severe damage to society are called disasters or catastrophes (in the last case referring to an extreme disaster event). According to the International Agreed Glossary of Basic Terms to Disaster Management [1] the definition for disaster is: *"Situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance"*. Although, natural disaster specialists (www.atlantisinireland.com/hazards.php) had suggested and alternative definition as following: *"A physical natural event (*and/or societal-induced event*) that kills people or overwhelms local capacity for damage control or recovery"* (parenthesis introduced by the author).

In this paper I have introduced the concept of societal-induced hazard event as a complement to fully natural hazard events. The goal is to call attention not only to the fact that there is an increase interaction between natural hazards and societal conditions (i.e. due to poverty, overpopulation, human modification of the environment, inadequate human settling areas, other), that has led to an every-day increase risky hazard-prone areas; but moreover, to the fact that the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [2] reported that: *"The IPCC is now 95% certain that humans are the main cause of current global warming. In addition, the SYR finds that more human activities disrupt the climate, the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems, and long lasting changes in all components of the climate system"*. This, indeed, is directly linked to several of the above listed recurrent "natural hazards", particularly those related with meteorological, hydrological, climate and biological factors. Furthermore, the IPCC [2] Report indicates: "a*nthropogenic green house gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of* CO_2*, methane and nitrous oxide that are unprecedented at least in the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20 century"*.

So, today there is ***"a very likely probability"*** (= 90-95%; [2]) that many extreme weather and climate changes events are linked to societal influences. For instance: decreases in cold temperature extremes, increases in warm temperature extremes and abnormal heavy precipitations, have been observed in numerous regions of the world, and many of them are directly linked to flooding, waves of droughts, wildfires and landslides hazard events; ought to be considered as societal-induced or driven environmental hazard events.

Between 1960 and 2009 hazard impacts due to natural and NS-IHEs have increased from 450 in the decade 1960-1969 to 4308 in the decade 2000-2009; showing highly severe increases in economical damages (Fig.1). Moreover, for the period 1994-2013 over 90% of the population affected by these hazards refers to: a) flooding, b) windstorms, c) droughts; with a mean of about 200,000 people directly affected per year. For that period reports show over 1, 300, 000 people deaths; with over 50% referring to earthquakes and tsunamis [3, 4].

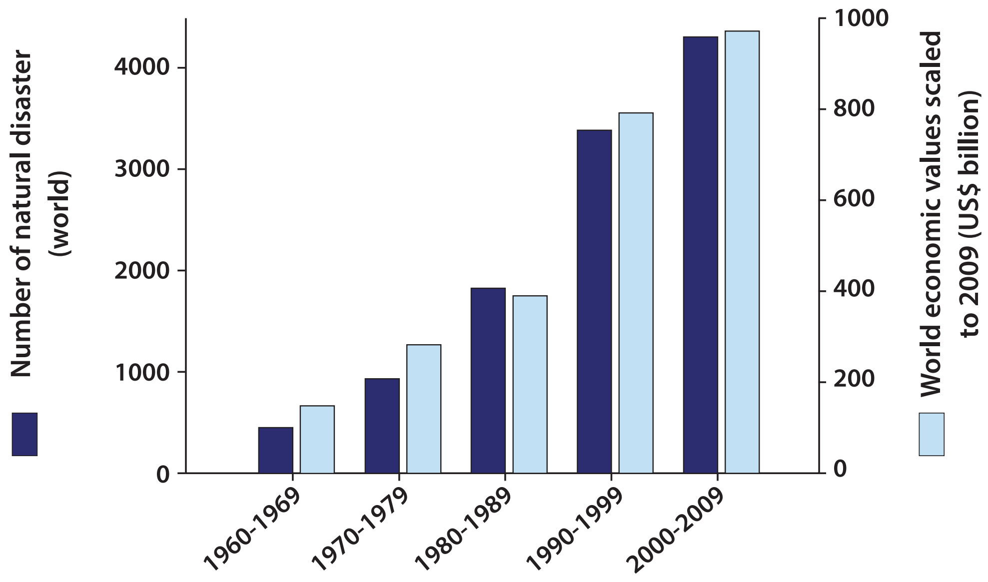

Figure 1. Total number of world natural disaster (meteorological, climate, geophysical and biological) grouped per decade and their economic values (losses) in US $, scaled in real prize to 2009 (information taken from [3]; scaled US $ to real prize from 1960 to 2009 by the author from www. measuringworth.com)

2. The scientific perspective of natural and S-IHE environmental hazard events

There are many possible approaches for the development of scientific research and linkages on environmental hazard studies and programs (academic, governmental, state, other institutions). They range, in one extreme, from extremely focal, specialized or disciplinary studies or, in the other extreme, to overarching multidisciplinary scientific approaches. In any case, most of international, and many regional or national strategies, research programs on environmental hazards tend to focus on disaster risks, disaster reductions, damage control and recovery [5]. Risks depend on the type and magnitude of the hazard event and on vulnerability (= the loss from natural or S-IHEs) and this makes environmental hazard research programs indeed a multidisciplinary discipline.

Among other, the discipline of risk analysis considers physical, biophysical, health, human and societal elements; incorporating humanities, education, social and natural sciences. This, includes the study, analysis and evaluation of the type and probability of hazard occurrence, the range of intensities, effects and modeling; as well as, human behavior, local ecological knowledge, societal impacts and importantly the political decision-making chain-process, from the hazard impact (ideally previous to the occurrence), all the way to control and recovery stages. Then, there is a need for integrated approaches, not only across disciplines but across spatial, temporal and the different levels of governance. Moreover, there is a critical need to be able to build strong data-bases on environmental hazards events [5].

In my view the “hard-science” behind natural and S-IHEs lays both in the Basic Research or Bohr´s Quadrant as well as in the Pasteur´s or Mission Oriented Quadrant [6, 7]. In fact, regarding environmental hazards events at the local scale (i.e. country or region) basic disciplinary science is much needed (i.e. geology, clime, oceanography, sociology, political science, economy, modeling, other). Nevertheless, interdisciplinary scientific approaches are critical and they can not be limited to the study of local situations but need to be integrated into wider national and international scientific approaches, and must be based on long–term research teams, strategies and funding [5].

Interdisciplinary research (overarching research on a particular problem or subject) is difficult to be achieved, since it usually considers both the quest for fundamental understanding as well as aspects aiming to bridge over applied and/or societal problems. The scientific programming on natural and S-IHEs is a case in point. But, also is the case for other societal problems or challengers, for instance interdisciplinary studies on: Biodiversity Losses and Impacts on Society; Sustainable Aquaculture and Feeding the Poor; The Challenge of Ageing or Drug Abuses and Society.

In developed countries, with long traditions and considerable research funding, interdisciplinary research, focusing on above examples and many other have flourished, particularly following the end of the Second World War [6]. Such appears not to be the case in many developing or emerging countries, where incentives for interdisciplinary research is absent or weak. Under those circumstances, and with limited research funding, the usual situation in these countries is one in which it may exist the development of several disciplinary sciences (depending on funding and trained scientific personnel), but where the disciplines "do not talk-each-other"; even if some of them are well developed. In this case research funding agencies (governments) need to develop new research strategies and above all to provide incentives.

3. A model to develop and incentive interdisciplinary studies: the Chilean strategy

In 1967 Chile, presently a country member of the Organization for Economic Co-operation and Development (OECD), started a plan to seriously develop science, technology, innovation and the training of human capital. That year it was established the Comisión Nacional de Ciencia y Tecnología (CONICYT) (National Commission for Scientific and Technological Research), under the Ministry of Education, as an advisory body to the President of the Republic. CONICYT mission is: *"advancing the training of human capital, and promoting, developing, and disseminating scientific and technological research….. aiming to contribute to Chile´s economy, social, and cultural development"*. CONICYT provides resources for highly competitive funding calls and creates opportunities for coordination, networking and designs strategies to implement scientific public awareness. Presently this agency administers a set of 12 different major programs, for example on: Equipment Funding, Science Divulgation and Fellowships (www.conicyt.cl).

Additionally, in 1982 was created the Fund for National Scientific and Technological Development (FONDECYT), that has financed several competitive research programs; out of which, one of the most important one is the so called "FONDECYT: Regular Scientific Program in all scientific disciplines: Natural, Cultural and Formal Sciences (www.fondecyt.cl), with financing windows of 2-4 years per project. Furthermore, this agency, manages a special fund that focus on long-term (up to 10 years per Center) interdisciplinary national scientific excellence and mission oriented scientific programs [6, 7], selecting Chilean priorities areas, call FONDAP "Fund for Research Centers on Priority Areas" (Fondo de Financiamiento de Investigaciones en Areas Prioritarias". FONDAP Programs started in 1997 and provide long-term funds for research centers of excellence for Chile´s development. The goal being to articulate teams of national outstanding researchers (selected on the basis of scientific productivity) in priority areas, aiming to consolidate them guided by interdisciplinary, national and international networking approaches and, centrally, aiming to the training of young scientists (human capital). A third Program is called FONDEF, directed to strategic-problem solving aspects of science, technology or industry, which is jointly financed with the industry (up to 4 years per project). The scientific policy behind these programs, especially behind the FONDAP initiative, is aiming for networking, first world class paper productivity and first world class personnel training [8, 9]. Selection of proposals and controls occur every 2-3 years under the responsibility of international panels of experts.

Among the main incentives for researchers engaged in FONDAP Centers are: a) Long-term temporal window of funding; initially 5 years and extended for another 5 years (based on international evaluations); b) Sustained funding of about 1- 1.5 million US dollars per year per Center; c) Economic incentives, on top of salaries, for researchers engaged in the Center, d) Interdisciplinary approaches, national and international

networking, e) Funding for Ph. D and Post-doctoral young scientists, f) Funding for equipment, g) Incentives to access matching, national and international, research funds.

Since 1997 funds for 20 FONDAP Centers have been allocated in Chile, and in 2015 there are 11 FONDAP Centers in operation, with an annual budget of approximately 18 millions of US dollars. Examples of such Centers are: a) *"Multidisciplinary Center for Intercultural and Indigenous Studies"*; b) *Center for Climate Change and Resilience*; c) "*Center for Solar Energy Research*"; d) "*Center for Sustainable Urban Development"*; e) "*Interdisciplinary Center for Sustainable Aquaculture Research*", f) "*Center for Astrophysics*"; g) "***National Research Center for the Integrated Management of Natural Disasters***" (www.fondap.cl).

Furthermore, in 1999 it was initiated a second and similar set of Scientific Research Centers of Excellence, now under the Ministry of Economic Affairs, call the Millennium Scientific Institutes (MSI) and the Millennium Scientific Nucleus (MSN) [10]. Further, promoting outstanding research, the training and reinsertion of Chilean scientists. In the future, it is hope, that both initiatives, FONDAP and MILENIO, will be merged.

4. The FONDAP "Center National Research Center for the Integrated Management of Natural Disasters" (CIGIDEN)

CIGIDEN (2012-2017) is a recently financed FONDAP Center of excellence; in this case is based at the Pontificia Universidad Católica de Chile, School of Engineer, and has 3 other associated Chilean Universities. With a total of about 50 researchers and 6 main research lines; under 6 main principal investigators and 6 associated investigators. Some of research lines are: Surface waters; Disaster Risk Vulnerability-Physical and Sociological Systems; Management of Disaster and Risk Mitigation. The Center is linked to main national services (i.e. geology, seismology and climate) and Hazard-Disaster National Offices. One of the main objectives of CIGIDEN is to develop, integrate, and convey knowledge allowing the creation of a system that can respond effectively to extreme natural phenomena, achieved through the preparation, response, recovery, and mitigation stages. CIGIDEN is an integrating, interdisciplinary research initiative, which contributes to address the need of mitigating the impact of natural disasters on Chilean society, physical infrastructure, and economic development. CIGIDEN is the basis to generate new knowledge and technology that will enhance the understanding and mitigation of the global implications of natural and societal-induced disasters in the country, along with the establishment of territories that are less exposed and of communities that are more resilient (www. cigiden.cl).

5. Developing countries: science, technology investment, research strategy

Chile is an emerging country (*ca*. 20,000 US dollar per year, per capita), and member of the OEDC. In the area of Science and Technology (S&T) Chile operates, so far, with research financing agencies (see above) and has not contemplated a Ministry of Science and Technology. In 2012, S&T Chile´s investment was of around 0.35% of GDP (*ca*. 700-800 million of US dollars); while the mean S&T investment for OEDC countries was of 2.4% of GDP. The low Chilean investment in S&T means that research strategies need to be thoroughly thought. Hence, it is my view that experience gained along nearly 50 years of well organized and highly respected (by scientists and society) S&T funding system in Chile has paved its academic and societal way to maturity. Part of that has been to maintain a major basic research program (Regular FONDECYT Research Program; with investment of around 50 million of US dollars per year; as well as a S&T Research Strategic Programs, Fellowships, other), based under a predictable and regular financing system. On the other hand, the FONDAP initiative can be highlighted as the most scientifically successful program in Chile and of high world standard. For instance, 85% of FONDAP Centers originated papers that are published in Quartile 1 (Q1) indexed journals and the normalized impact of those publications are about 10% above the world mean. Furthermore, Chile is a leader country in scientific publications (and paper impacts) within the Latin-America subcontinent [9].

Figure 2. Impacts of the February 27th 2010, 8.8 Mw mega-earthquake and tsunami hitting Central Chile [see 11, 12, 13]. **A**. Rock uplifted >2 m in Isla Mocha, Central Chile (former brown intertidal algae can be seen at top of the rock). **B**. Tubul bridge, Central Chile, destroyed by the earthquake. **C & D**. Damages and losses due to tsunami in small-scale artisan boats at Isla Santa María and Tubul villages.

Chile is a country facing numerous, repetitive and dreadful natural and S-IHEs, such as earthquakes and tsunamis (Fig. 2; [11, 12, 13]), volcano eruptions, flooding, drought and large wildfire and landslide events. Therefore, scientific research (preparation, response, recovery, mitigation) and linkages with policy making and government agencies need to be part of integrate interdisciplinary long–term research strategies. The Chilean S&T FONDAP initiative is one of them; and a highly successful one; that perhaps it may be used as a model by other developing or emerging countries. Above all the FONDAP model may be used as a template to incentivize and get going interdisciplinary S&T research of first world class in third world countries. The scientific disciplines (Natural, Cultural and Formal sciences) have to talk-each-other. Moreover, this is a must in developing world countries, where the number of scientists is low and showing rather poor financing schemes.

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