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# Risk Management at the Latin American Observatory

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Additional information is available at the end of the chapter

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## 1. Introduction

The *Observatorio Latinoamericano de Eventos Extraordinarios* (OLE<sup>2</sup>), or *Latin American Observatory*, is a regional collaborative network that, in addition to the existing infrastructure in each country, aims to ultimately increase the efficiency of the decision-making processes, especially in terms of getting more accurate environmental information and exchanging experiences on data, methodologies and scientific products, all of which are done with a standardized methodology and a Web-sharing service.

Present partners of this collaboration are national weather services, universities and research institutes of Central America, the Andean countries and from Southeast South America (see Figure 1). Nowadays, the Centro de Modelado Científico (CMC) of Universidad del Zulia, the founder of the initiative, regionally coordinates the OLE<sup>2</sup>. The coordinating role involves, among other tasks, the suggestion of (a) methodologies for the provision of scientifically based tools and products, (b) mechanisms for the successful use of the environmental information in the policy making process at the different levels (e.g. national and province governments, private sector), (c) facilitation of continuous and effective communication of the different partners and (d) the interchange of experiences and products (by means of the Observatory's products web interface<sup>1</sup>, wiki page<sup>2</sup>, forum<sup>3</sup> and email list<sup>4</sup>). For more information see references [1] and [2].

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<sup>1</sup> <http://ole2.org>

<sup>2</sup> <http://mediawiki.cmc.org.ve>

<sup>3</sup> [http://laft.cmc.luz.edu.ve:8080/foro\\_ole2](http://laft.cmc.luz.edu.ve:8080/foro_ole2)

<sup>4</sup> [ole2@cmc.org.ve](mailto:ole2@cmc.org.ve)

The goal of the OLE<sup>2</sup> is to monitor and forecast key environmental variables and develop accurate products based on different scientific tools in order to help decision makers improve risk management and set up efficient early warning systems. The Observatory provides several model outputs for meteorological, seasonal, and hydrological forecasts, 5-day high-resolution oceanographic prediction for the eastern Pacific, droughts, fire and flood indices, ecosystem dynamics (like duckweed/algae occurrence in Lake Maracaibo), and climate and health applications (e.g., regarding malaria), among others.

The Observatory is organized in interconnected working groups (WGs) or axes: namely, meteorology; climatology; hydrology; air quality; climate and health; and climate change and variability. Each WG has its own methodologies and products, but all of them exchange information and results with other axes and countries if necessary. It is also regionally divided in three branches: the Observatorio Andino, Observatorio Centroamericano and Observatorio del Sudeste de Sudamérica (Andean, Central American and the South Eastern South America Observatories). They operate using the infrastructure already in existence in the different regions by consolidating the collaboration networks through the recognition of common needs and the provision of interdependent solutions. The final products, be it a seasonal forecast or an early warning system for the last-mile user, is built between different partners by sharing their experiences and expertise on different fields. This has created a strong identification between the participating institutions and the Observatory's products. This fact and the continuous need of collaboration to provide regionally successful decision-making tools on time, have proven a natural way to guarantee the sustainability of the initiative, originated in 2007 in Venezuela as a national observatory.

Advances and difficulties are shared and discussed through e-mail lists and videoconferences. The purpose of the videoconferences is to discuss the ongoing projects, products, and new methodologies, and to provide special assistance on models and several other technical issues.

The Observatory has also provided a Grid Technology Infrastructure since 2010, known as AndesGrid [3] to help institutions with less computational power to increase their capabilities using other institutions' available computer resources. The initiative enables the partners to share not only model outputs and, but also their local observations (e.g. rain gauge and temperatures) in "real time". For additional details, see [3].

Of the OLE<sup>2</sup>'s main achievements in this period, the most important is the enhancement of the institutions' human resources by means of continuous technical support for forecast, modeling, verification, risk assessment and management and many other issues, all of which is done in their native language. The project has also succeeded in standardizing forecasts, data formats, and methodologies, providing common models, tools, and procedures that are used on a daily basis in all the involved institutions. A key tool has been the wiki, which contains all of the needed steps for each task, which by itself is another of the most important elements for ensuring the long-term continuity of the OLE<sup>2</sup>.

## Observatorio Latinoamericano de Eventos Extraordinarios



**Figure 1.** The Observatorio Latinoamericano's partners (as January 2012) are mainly national weather services, universities and research and development institutes. (The red line links the countries participating in the AndesGrid initiative [3]. See main text).

Among the different efforts, risk assessment and management are some of the most important tasks targeted by the Latin American Observatory partners. Even when a general framework is used by the OLE<sup>2</sup> on this field, the different institutions develop tailored applications to take advantage of the local experience and mechanisms already in existence in their countries. However, the general framework closely follows the ideas discussed by Mora [4].

Risk management is from a wide perspective, a policy system that, among its components, permits stakeholders in several levels, to identify, analyze and quantify the probability of human, material and ecosystem losses, as well as to provide metrics and technical criteria for prevention, mitigation, reduction or transfer of risk [4]. A key idea to be still implemented

in most parts of the world is that risk management needs to be understood and addressed as an investment, not as a cost. [4] It is clear that nowadays the establishment of efficient risk reduction plans does not possess a real priority on the agenda of decision-makers and stakeholders, except *a posteriori*. This is especially true in most parts of Latin America, as is exposed in some case studies included in this chapter. Moreover, in general, there are no consolidated cultures incorporating risk management throughout decision-making processes for public and private investment and planning (see [4] and references therein). Also, private sector involvement in this process presents several unique challenges to be overcome [5].

Since 1975 in Latin American and the Caribbean (LAC), the costs of losses attributable to major natural hazards have been estimated at around US\$300 billion, with more than 280,000 human deaths and affecting more than 160 million people [6-8]. Table 1 references the major natural disasters in LAC in the last three decades.

Year	Hazard/Event	Countries
1983	Floods	Argentina, Bolivia, Brazil, Peru
1983	Earthquake	Chile, Colombia
1985	Earthquake	Mexico
1998	Floods, landslides associated to hurricanes George and Mitch	Central America and the Caribbean
1999	Floods and landslides	Venezuela (Vargas State)
2005	Most active hurricane season recorded in history [8]	Central America and the Caribbean
2009	Drought (strong El Niño event)	Venezuela, Colombia and Ecuador
2010	Earthquake	Chile
2010, 2011	Floods (strong La Niña event)	Panama, Colombia and Venezuela

**Table 1.** Major natural disasters in LAC between 1983 and 2011 [6-8].

Consequently, it has been an urgent need for the Latin American Observatory’s partners to address the establishment of effective policies for risk assessment and management in their respective countries. To this end, an implementation plan was suggested by CMC and this chapter presents briefly the adopted definitions and general ideas (sections 2-4), as well as case studies for different managerial sectors in Latin America (section 5) in order to discuss in some detail, present risk assessment/management policies and methodologies. Finally, we discuss the benefits of sharing experiences among different countries to address common problems in geographically complex regions, as well as how to achieve success in countries where the scarcity of economic and trained human resources imposes serious limitations on the effectiveness of risk management systems.

## 2. Risk definition and management

In this and the next section the main definitions related to risk management, hazards and vulnerabilities are discussed in order to provide the foundations chosen by the Observatory in these matters. We don't pretend to address all the details in this complex field, but to outline the main ideas for future reference.

Different agents play a role in the occurrence of natural hazards, which derive from the damaging potential or a combination of them. These agents are frequently [4,6] classified in terms of their origin, namely

- hydro-meteorology: both global and local processes (hurricanes, floods/droughts, weather extreme events)
- internal geodynamics (seismicity and volcanism)
- external geodynamics (landslides, intensive erosion, torrential debris flows).

Following Mora [4], natural hazards ( $H$ ) can be formally defined in terms of the probability that an event becomes so intense ( $a$ ) within time and space frames that it produces significant damage ( $d$ ). The intensity and damage definitions depend on the region and timescale under consideration. Vulnerability ( $V$ ) can be associated with the probability that, according to the intensity of the natural event, damage might occur as a function of the degrees of exposure and fragility of the elements involved. Risk ( $R$ ) therefore is the combined probability (convolution,  $*$ ) that a hazard might cause significant damage, according to the following relationship:

$$\int_{h,d} p(R)da = \int_h p(H)da * \int_d p(V)da \quad (1)$$

The probabilities are not, in general, constant, so the spatial and temporal variability must always be carefully considered. Moreover,  $V$  and  $H$  are not independent.

Risk management involves not only the quantification of the probability of loss via equation (1) and the derived secondary effects, but also the generation and execution of policies for [4]

- identification, analysis and quantification of risk
- formulation and application of measures of prevention, reduction and mitigation of causes
- financial, social and environmental protection
- execution of related protocols (e.g. preparedness, response, rehabilitation, reconstruction).

Efforts to foster these processes may include the establishment of adequate policies and protocols to incorporate stakeholders into risk management, improvement of the climate/geodynamic information available, identification of the different sources of vulnerability and their evolution in time, definition of "acceptable" risk levels and the establishment of early warning and monitor systems, and the adequate ways to communicate their products to the end-mile users.



Risk management policies foster and integrate strategically balanced processes capable of providing decision-making tools in a synergistic, decentralized and participative way. In the OLE<sup>2</sup> this is a central philosophy, which also enables the treatment of risk in trans-boundary zones (e.g. the Observatory enabled the continuous exchange of climate services between the National Weather Services and decision makers during the 2010 floods that affected Panama, Colombia and Venezuela in similar ways).

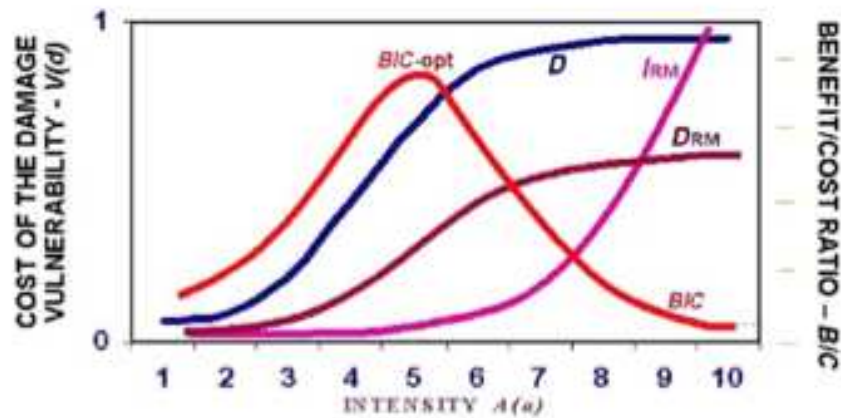
An important aspect of risk management is related to operative platforms that enable decision makers and users to interact and to obtain information useful to assess vulnerabilities, the impact of natural hazards and the risk probabilities for a certain region. This infrastructure is aimed at providing this kind of information *ex ante*, but it can also be used during or after an emergency. It usually includes

- macro- and micro-zoning of hazards and vulnerability and its probable evolution in time (see section 4)
- damage assessment
- identification of priority areas of intervention
- protocols for vulnerability reduction (hazards are not, in general, reducible)
- instruments for financial strategy and budgetary allocations
- identification of “risk bearers” and their responsibilities
- administrative and legal information (e.g. design, operation, lease, transfer and reclamation contracts)
- information on past events
- areas of further investments to reduce future disasters.

The implementation of these platforms in LAC is more advanced in a few countries (see section 5.1 for a Central American example). The Observatory’s partners are taking advantage of the experience developed by other members of the regional initiative to improve their own risk management infrastructure.

Finally, but no less importantly, the Observatory is now committed to following the International Research Institute on Climate and Society’s (IRI) Four Pillars for Climate Risk Management [31], namely

1. **Identify vulnerabilities and potential opportunities** due to climate variability/change for a given water, agriculture, or health system.
2. **Quantify uncertainties in "climate information"** in order to reduce uncertainties in using that information.
3. **Identify technologies and practices** that optimize results in normal or favorable years as well as technologies and practices that reduce vulnerabilities.
4. **Identify interventions, institutional arrangements and best practices** that reduce exposure to climate vulnerabilities and enable the opportunistic exploitation of favorable climate conditions.



**Figure 2.** Benefit/cost ( $B/C$ ) ratio defined as a function of damage expected without risk management ( $D$ ), reduced by applying risk management ( $D_{RM}$ ) and the investment involved ( $I_{RM}$ ). (After Mora [4])

### 3. Benefits of risk management

It is possible to use risk management as a tool for providing an idea of the economic value of potential damages caused by hazards and the actions undertaken to reduce vulnerabilities. Figure 2 sketches an accumulating damage curve  $D$  without risk management. If risk management policies are used, this same curve is reduced to a more optimistic distribution,  $D_{RM}$ . The reduction of damage due to risk management is then

$$RD = D - D_{RM} \quad (2)$$

The associated investment ( $I_{RM}$ ) for such a reduction depends on both the hazard and vulnerability involved (which, again, are not independent). On the other hand, the Benefit/Cost ( $B/C$ ) ratio allows for the finding of optimal levels of investment. It's possible to show [4] that the net benefit of risk management is

$$B_{RM} = (D - D_{RM}) - I_{RM} \quad (3)$$

and the Benefit/Cost ratio can be defined as

$$B/C = \frac{D - D_{RM}}{I_{RM}} - 1 \quad (4)$$

Having real distributions of the different quantities it might be possible to select optimal points (e.g. the saddle point named  $B/C_{OPT}$  in Figure 2) to limit profitable investments. See [4] and [6] for details.

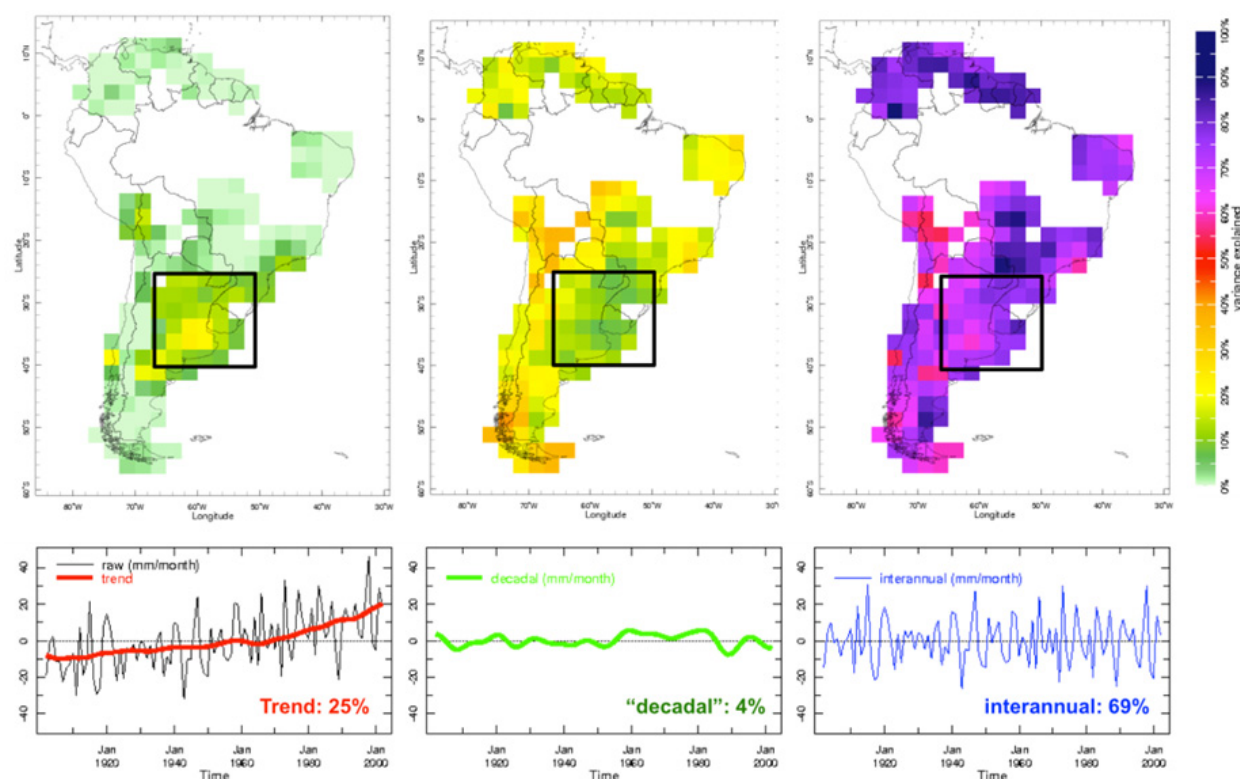
### 4. A Multi-scale approach for risk management

The traditional approach to computing risk probabilities using equation (1) involves the consideration of static or, in the best-case scenario, long-term mean vulnerability maps of



the associated hazards. Nonetheless, the probability density function associated with hazards in equation (1) is frequently computed from time series that may contain useful information at different time scales. Given the fact that a decision maker might be interested in a certain time scale (e.g. on the order of its own managerial period), a temporal decomposition of the original time series used to identify the hazard probability may be extremely helpful.

For example, Figure 3 presents such time-scale decomposition for Southeast South America's precipitation. The lower panels sketch the non-linear long-term trend (a proxy for climate change), and decadal and interannual variability time series [9]. The rationale is that in considering the interaction of the three climate signals (the explained variance being a way to ponder the specific weight of each one of them) it is possible to provide better climate services to decision-makers, that are more adequate for their scale of interest, e.g. next 10 years.



**Figure 3.** Decomposition for Southeast South America's precipitation (boxed region) for three different time scales: long-term trend (left panel), decadal variability (central panel) and interannual variability (right panel), with their respective explained variance (colors in the map and values in the bottom corner of each time series). Grid boxes in white are not statistically significant at a p-level=0.95. (After Goddard *et al.* [9])

As mentioned before, hazards and vulnerabilities are not independent. The latter encompasses exposure to hazards, sensitivity to these hazards and adaptive capacity. All of them, in fact, evolve in time. Therefore, a similar multi-scale time decomposition must also be done to correctly assess the related vulnerabilities. This provides a more realistic risk probability distribution, and thus better assessments and policies can be developed.

## 5. Cases of study

In this section a few state-of-the-art examples of risk assessment and management in several countries in Latin America are briefly described. Signatory and participant institutions of the Latin American Observatory operate over these structures, providing tailored methodologies based on what has been explained in previous sections.

### 5.1. Seasonal Climate outlooks applications for food security decision-making in Central America

In Central America, seasonal climate outlooks turn into risk scenarios used by food-related sectors to help support their decisions and prevent food insecurity. This is a coordinated effort with specialized entities of the Central American Integration System.

The Central American Climate Outlook Forum (CA-COF), coordinated by the Comité Regional de Recursos Hidráulicos (CRRH-SICA)<sup>5</sup> (Regional Water Resources Committee), has consolidated a process to issue three seasonal outlooks per year, bringing together the capacities of all seven weather services in the region. The CA-COF takes advantage of international and global sources of information, which it analyzes along with its own sources and historical data to produce Climate Outlooks for the Central American region. Over the last decade the Forum has issued 38 regional climate outlooks.

To facilitate the use of climate risk information for decision-making with the aim of reducing food insecurity risks, CRRH-SICA has fostered a mechanism over the past few years that turns the Outlook into risk scenarios for those sectors related to nutrition and food security, particularly agriculture, fisheries, potable water and public health, as well as cross-cutting areas like risk management and emergency response. These scenarios are used when deciding preventive measures to mitigate the impact of climate variability on food security.

In a joint effort between the specialized agencies of the Central American Integration System (SICA) and the Regional Food Security Program (PRESANCA II) funded by the European Union, immediately after an Outlook is issued, a group of regional experts is convened to enhance the Outlook with information from the different sectors mentioned above, turning the product into sectoral climate risk scenarios that could guide early warnings of actual and potential hazards to food security.

The working group, composed of CA-COF members and the experts, uses these scenarios to identify sector-specific preventive measures. The food security risk scenarios and the suggested measures are circulated among government entities and other organizations involved in addressing food and nutritional security through their own networks to ensure all this information reaches the most appropriate decision makers.

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<sup>5</sup> CRRH is the technical Secretariat of the Central America Integration System, responsible for the coordination of activities related to weather forecast, climate, water resources and climate change assessments with Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panamá.

This same method is used at the national level to produce specific recommendations for diverse sectors in each individual country. Those are then distributed among national authorities and stakeholders in private sector with the seasonal outlook map and lists of suggested prevention measures. An example of the matrix of climate risk for agriculture is presented in Table 2.

As part of the same, routine-specific measures are identified at a national level by similar working groups of climatologists and national experts, and suggested to authorities.

A process is now underway to evaluate the use of outlooks and climate risk information directly with the beneficiaries, both for the private and the public sectors, to strengthen decision-making efforts.

Climate Risk /potential damages for Main Crops. Quarter December 2011 -March 2012							
Crop	Country						
	Belice	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
Maize	Plantations in coastal areas likely to be affected by above-normal precipitation	No risk	No risk	Risk of post-harvest damages due to higher humidity associated with above-normal rainfall. Increased cost of post-crop product management	Risk in the Cari-bbean planting area due to above-normal rainfall. Second planting season likely to be affected	Second crop in the Atlantic Autonomo us Regions likely to be affected by above-normal rainfall. Exportation s likely to be impacted	Crop loss risk in Western Cari-bbean area. Possible impacts in food security of indi-genous population.
Beans	Plantations in coastal area likely to be affected by above-normal precipitation	Risk of crop damage for plantations in Northern Plains, Cari-bbean area and South Pacific	No risk	No risk	Risk in the Cari-bbean planting area due to above-normal rainfall. Second planting season likely to be affected	Second crop in the Atlantic Autonomo us Regions likely to be affected by above-normal rainfall. Yield reduction may reach 15% .	Loss of crop risk in Western Caribbean area. Possible impacts on food security of indigenous popu-lation.

**Table 2.** Central American Climate Outlook Forum risk assessment for two crops (maize and beans), for December 2011-February 2012.

## 5.2. A flood early warning system for Vargas, Venezuela

In Venezuela, heavy rains represent a significant problem for human populations, not only in rural areas where farms and crops are affected, but also in some urban settings where many inhabitants reside in poorly-constructed houses that are highly vulnerable to floods and landslides, or that are sometimes located on steep terrains and floodplains.



**Figure 4.** Aerial view of Caraballeda, Vargas state (Venezuela), after mudslides and debris flows event on December 15 1999.

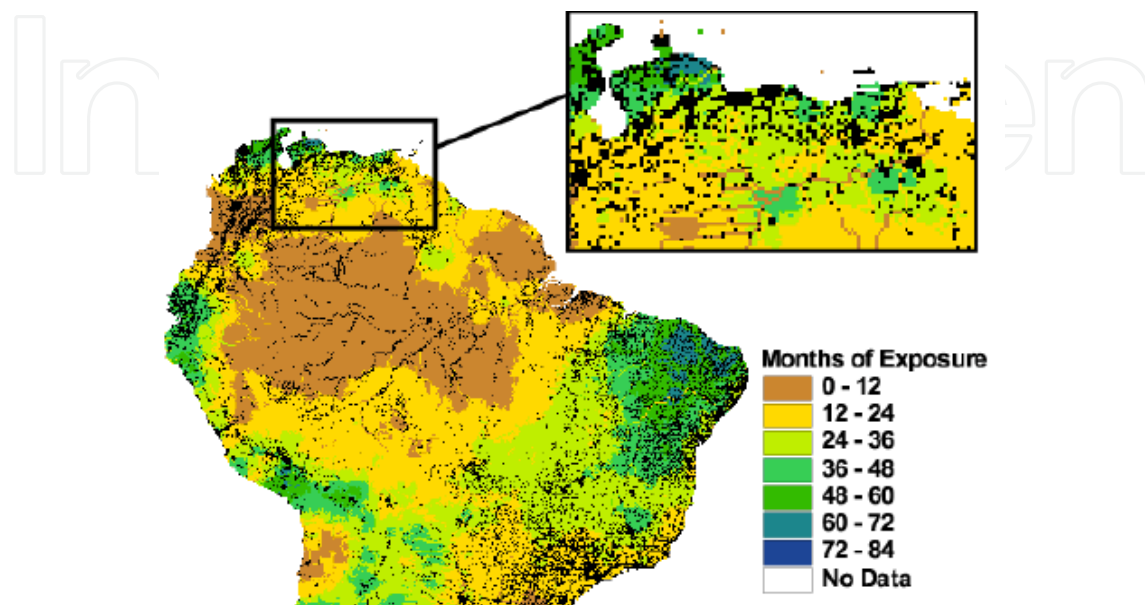
On December 15, 1999, on the northern coast of Venezuela, torrential rains led to flash floods and debris flows that killed tens of thousands of people, destroyed thousands of households, and meant the complete collapse of the area's infrastructure (see Figure 4). The “Vargas disaster”, as it has been known ever since,, is considered the worst natural disaster in Venezuela’s last half century (Table 1). Even though flood prediction is an essential piece of Climate Risk Management, Venezuela did not have, at the time, a consolidated early warning system that could alert decision-makers and stakeholders about this extreme event. In this section, the implementation of an early warning flood system for Vargas state is described in some detail. It is a completely general methodology, so other regions in LAC can benefit from the experience described here.

The Vargas disaster is also an important case study on flood prediction, not only because of its unusual rainfall amounts, but also for the nature of the terrain where it took place. The basin is located in a mountainous region of metamorphic rock, coarse soils and steep slopes, making the area highly vulnerable to floods and debris flows [10].

The early warning system involves the estimation of vulnerabilities and probabilities related to heavy precipitations and mudslides. Guenni *et al.* [11] has computed the vulnerabilities using the total affected and exposed people, considering both the spatial and temporal variability, as discussed in section 4. As an example, Figure 5 presents a zoom-in for most parts of Venezuela showing months of rainfall exposure in colors and the population density as black pixels (for details see [11]). Regions near the Venezuelan coast are in general



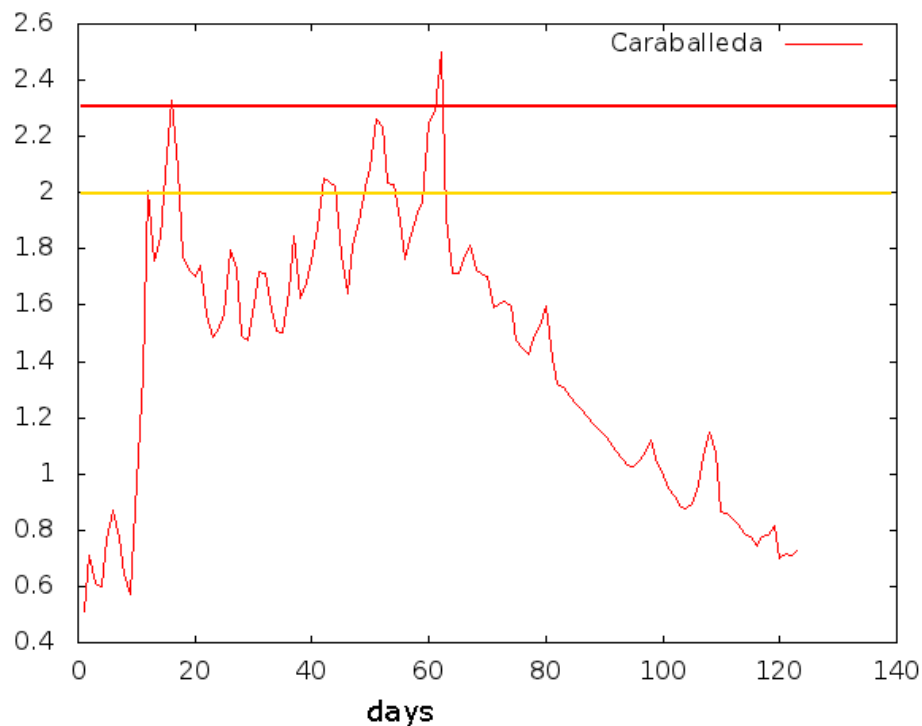
more vulnerable (due to more population density and exposure). Using map algebra in a Geographical Information System (GIS), the map is then intersected with other maps containing information about the terrain (e.g. water holding capacity or mudslide probabilities). Following equation (1), the final map, in sketching homogeneous vulnerability zones, must be written in terms of probabilities for different hazard intensities.



**Figure 5.** Map of exposition (in colors) and population density (pixels in black) for Venezuela. After Guenni *et al.* [11]

On the other hand, in order to compute flood risk probabilities, hazard probability maps must be produced (also in terms of intensities). In this case, Torres and Muñoz [12,13] have suggested a methodology based on hindcasts involving an off-line coupling of a regional climate model, a process-based hydrological model and a routing model.

The Climate Weather Research and Forecasting model (CWRF) was used to simulate 13 years (1996-2008) of data, paying special attention to the Vargas disaster atmospheric conditions. Rainfall and maximum and minimum temperatures were bias corrected using observed values. Then they were used as input data along with soil properties and vegetation parameters for the Variable Infiltration Capacity model (VIC). This energy and mass balance model was finally coupled to the Lohmann routing model to produce realistic stream flows that adequately considered the local topography (for details about the different models and procedures see [2,12,13] and references therein). Simulation outputs were consistent with the flooding event of December 1999. The study was able to reproduce how long rains, along with low evapo-transpiration due to high cloudiness, contributed to saturate soil layers. Moreover, the study was able to identify critical values (see Figure 6) in order to establish “yellow” and “red” alerts in the Vargas flood early warning system, using the statistics obtained for the 13 years simulation and local stream flow data provided by the National Weather Service. Model outputs were then used to create hazard probability maps in terms of hazard intensity.



**Figure 6.** Caraballeda's simulated runoff time series for the Vargas disaster event using CWRf, VIC and the Lohman routing model (see main text). The runoff has been normalized using the standard deviation. The critical day (December 19, 1999) corresponds to simulation day 62 in this plot. The yellow and red lines at  $2\sigma$  and  $2.3\sigma$ , respectively, were defined as the "yellow" and "red" alerts in the designed early warning system. (After Torres and Muñoz [12,13])

As a final result, series of maps are provided with the hazard's probability of occurrence in terms of the hazard intensity. They are produced computing the convolution between the corresponding hazard and vulnerability maps, following equation (1). For additional details see [12,13].

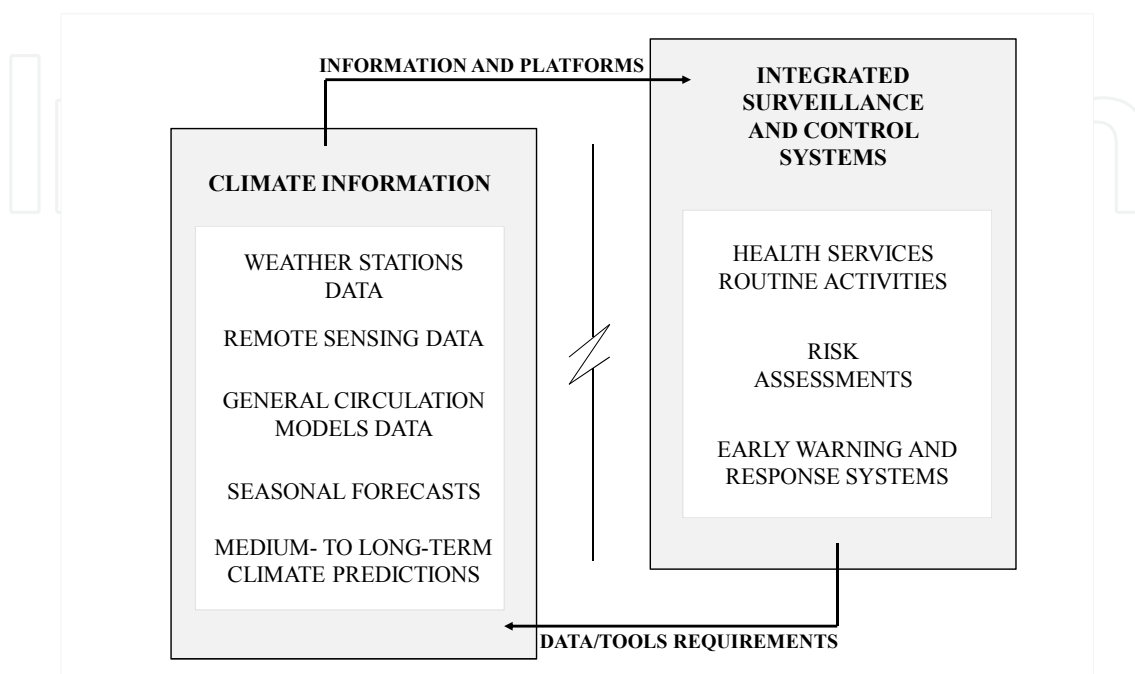
This probabilistic approach has an important advantage: it takes into consideration the possible uncertainties related to each one of the processes involved in the final flood risk probability map.

### 5.3. Bridging the gap between climate information and health services in Colombia and Ecuador

Climatic factors play a significant role in the transmission dynamics of several infectious diseases [14]. Therefore it should be a critical priority to incorporate climate information into disease risk assessments and early warning and response systems. (See figure 7.) This, in fact, has been one of the goals of the Colombian and Ecuadorian meteorological and health services in recent years. In Colombia, in particular, the National Institute of Health (INS) recently teamed up with the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) and several universities and research centers to design and implement a proactive, collaborative, multidisciplinary, Integrated Surveillance and Control System –



ISCS [15,16]. This initiative is part of a set of measures and policy options that the Colombian adaptation strategy to climate change proposed for three areas of primary concern: the high-altitude Andean ecosystems, the insular and coastal areas, and human health (see Integrated National Adaptation Pilot [16]).



**Figure 7.** Climate information and human health integrated surveillance and control systems.

The aim of the adaptation strategy for the health sector is to have a better-prepared institutional arrangement for increased exposure to malaria and dengue fever, two climate-sensitive, vector-borne diseases that are still considered human health burdens in Colombia [17]. According to the scientific literature, the potential increase in the incidence of these two diseases is likely to occur not only in the already endemic malaria and dengue fever prone areas, but also on the fringes with the Andean regions where local communities have not been exposed to pathogens before. Thus they lack the immunity against these microorganisms. The approach has been to assist the health sector to better cope with current climate variability and climate-related events, as a means to make it better prepared against future climatic conditions likely to be brought by the ongoing long-term global climate change. As a result, Colombia has been working on reducing people's vulnerabilities to the negative impacts of malaria and dengue outbreaks, as well as developing an Early Warning System framework, supported by seasonal forecasting capabilities, weather and environmental monitoring, and statistical and dynamic models [18-23].

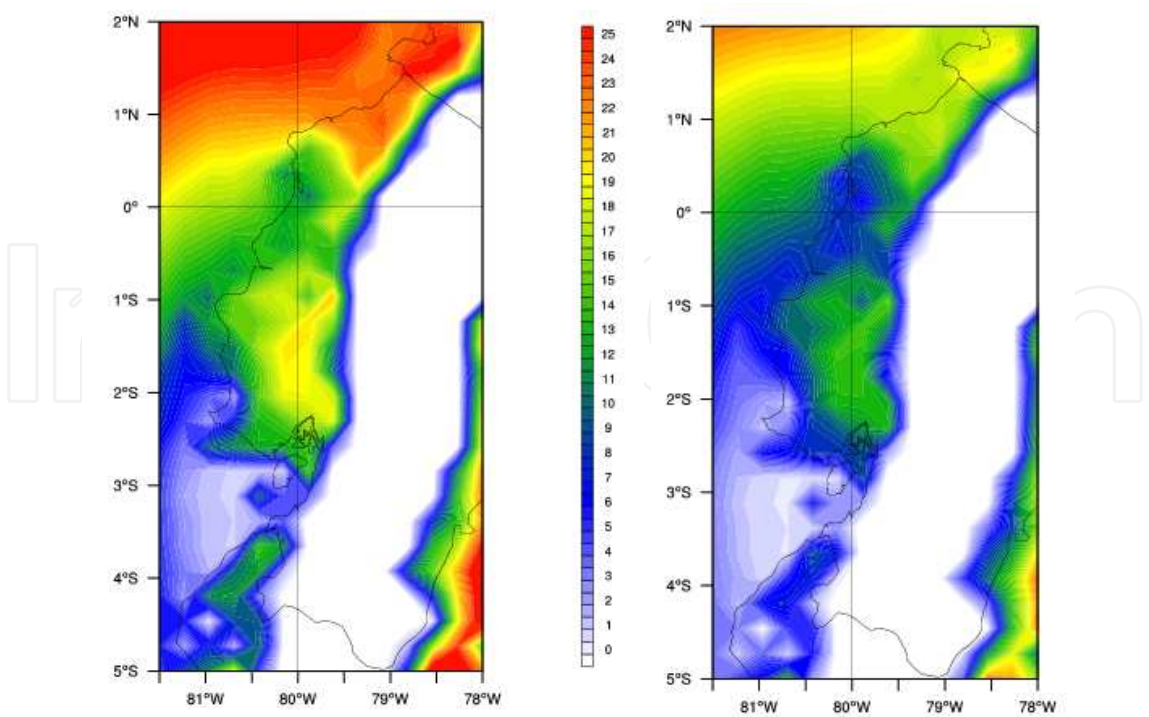
This effort required linking what had previously been two largely separate analytical domains: the field of public health, traditionally dominated by human health experts and practitioners; and weather and climate science, usually lead by meteorologists, climatologists, engineers, and environmental science experts. Several biologists, entomologists and social experts have also joined this collaborative, inter-institutional and

interdisciplinary effort. The implementation of the ISCS has required, among many other activities, analyzing the local eco-epidemiological settings of various malaria- and dengue fever-prone pilot sites, implementing process-based biological and statistical models, and strengthening the local capacity of health authorities. It has also required strengthening the IDEAM capability to routinely and systemically produce and disseminate, relevant, continuous, homogenous, and reliable climate information that could support the decision-making process of health authorities. Such information includes ground-truth historical records, modeling simulation outputs, seasonal forecasts, El Niño Southern Oscillation forecasts, and climate change predictions. All this information, along with disease morbidity profiles, entomological conditions, socio-economic drivers, and impacts of interventions and control campaigns, is now steadily becoming a core part of routine activities and disease control plans of health services at regional, municipal and local levels, and is starting to facilitate a better allocation of health resources and more cost-effective preventive responses. On a broader scale, measures proposed as part of the adaptation plan have been mainstreamed into the Colombian political agenda to ensure their sustainability. They have reached, for instance, the 2010-2014 National Development Plan, the 2010-2014 Environmental Action Plan, the Colombia's Poverty Reduction Plan, and the Public Health National Plan.

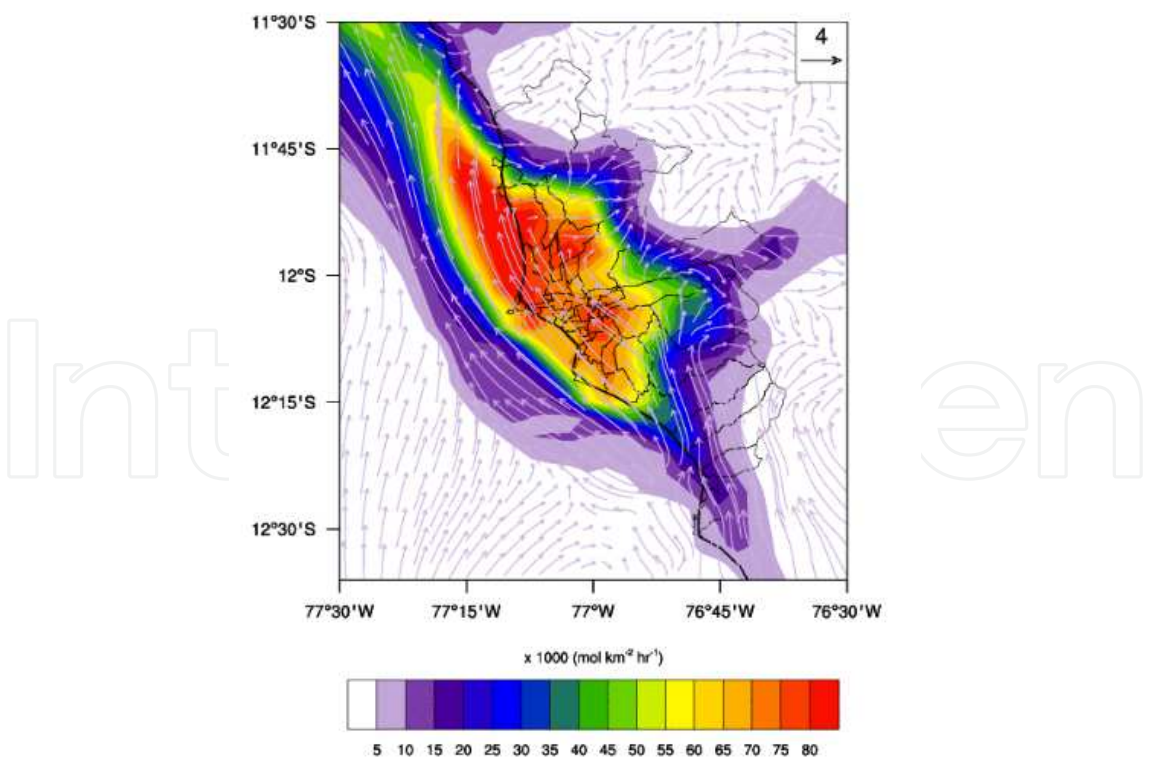
In Ecuador, in turn, the National Institute of Meteorology and Hydrology (INAMHI) has conducted various research activities [24,25] on the analysis of potential increases in the incidence of malaria and dengue fever in key lowland provinces. Activities have included the implementation and coupled analysis of the 30 km WRF (Weather Research and Forecasting), dynamic downscaling regional climate model, and the Ross-Macdonald malaria infectious disease process-based model, to reproduce the spatio-temporal variability of primary positive cases reported by the National Malaria Eradication Service over a recent 13-year historical period (see figure 8). They have also included a first design of an Early Warning System for malaria and dengue fever outbreaks, which is now developing into an integrated surveillance and climate modeling for malaria and dengue fever predictability in rural and urban settings. The INAMHI has also joined efforts with several research groups to broaden the understanding of the complex transmission dynamics (in both space and time) of these vector-borne diseases, in order to improve decision-making processes in regional and local health authorities and, in a more general sense, to strengthen the already solid surveillance and control activities of infectious diseases conducted by the Ecuadorian health sector.

#### **5.4. Air quality risk assessment for Lima and El Callao (Peru)**

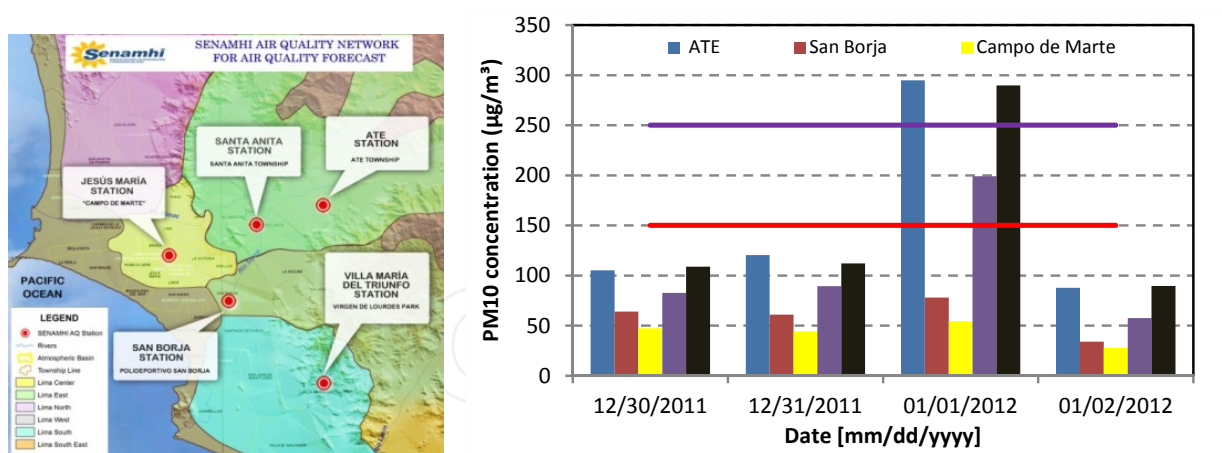
Poor air quality conditions can cause many respiratory problems including asthma and severe allergies and can also pose serious health problems such as cancer. In order to issue public warnings of high pollution episodes, the Peruvian National Service of Meteorology and Hydrology – SENAMHI is working on the design and implementation of an air quality forecast system for the cities of Lima and El Callao. The system maps out current and future ambient air quality conditions based on hindcast simulation runs of the BRAMS model and the Weather Research and Forecasting coupled with Chemistry (WRF-Chem) model (see figure 9), as well as on *in situ* measurements of main air pollutants, such as particulate



**Figure 8.** January *Plasmodium vivax* (left panel) and *P. falciparum* (right panel) basic reproductive rates on the Ecuadorian coast, simulated for the period 1996-2008 and for *Anopheles albimanus* mosquito species. (After Muñoz and Recalde [24]).



**Figure 9.** 4-km spatial resolution hindcast WRF-Chem model simulation outputs of NOx concentration fluxes in the geographic domain 12°30'S – 11°30'S and 76°30'W – 77°30'W. Typical NOx concentration fluxes are expressed in thousand mol/km<sup>2</sup>/hr. The reference arrow represents wind speeds of 4 m/s.



**Figure 10.** 10 micrometer or less particulate matter (PM10) concentrations (right panel) gathered at the SENAMHI air-quality monitoring stations Ate, San Borja, Campo de Marte, Santa Anita, and Villa María del Triunfo (see locations in left panel) over the period spanning from December 30, 2011 through January 2, 2012. The red solid line depicts the health-based daily air quality standard concentration of 150 µg/m³. The violet line depicts, in turn, the 250 µg/m³ daily concentration threshold above which high pollution episode warnings are issued. Air quality is considered 'good' when daily concentrations do not exceed 50 µg/m³.

matter smaller than 10 and 5 micrometers (PM10 and PM5, respectively), nitrogen oxides (NO<sub>x</sub>) and ground-level ozone (O<sub>3</sub>). Modeling outputs and real-time information allow the SENAMHI to issue public warnings that could activate municipal plans to help keep pollution levels down and alert local residents in Lima districts to the potential health threats.

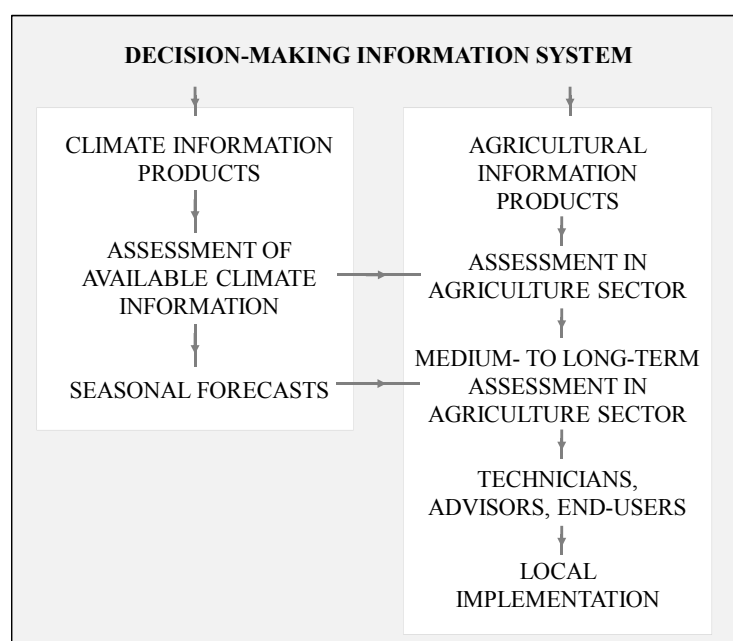
Up to date, the air quality network includes five high-precision monitoring stations located in the surroundings of the aforementioned two densely populated cities. (See figure below.) High pollution episode warnings include events such as the one that took place in the localities of Ate and Villa María del Triunfo on January 1, 2012. *In situ* air quality measurements (figure 10) suggested that PM10 concentrations reached 295 and 290 µg/m³, respectively, which exceeded in 45 and 40 µg/m³ the 250 µg/m³ daily concentration threshold. In the monitoring station Santa Anita, in turn, the PM10 concentration reached 199 µg/m³, also exceeding the health-based daily air quality standard concentration of 150 µg/m³. The air quality stations San Borja and Campo de Marte reported moderate daily concentrations of about 78 and 54 µg/m³, respectively.

## 5.5. The agrometeorological bulletin and improved decision-making processes in Paraguay

Extreme weather events such as river floods, severe storms, droughts and below-freezing low temperatures are strongly linked to the onset of El Niño Southern Oscillation (ENSO). Extreme events primarily affect river streamflow and cause numerous direct and indirect impacts on many key sectors of the Paraguayan economy: agriculture, ground and river transportation, potable water, construction, electricity, and recreation. Several studies have demonstrated that the potential impacts of these extreme events and their economic consequences are directly



related to the magnitude of ENSO episodes. Historically, Paraguay has experienced above normal mean temperatures and rainfall amounts, as well as unusually heavy rainfall events, during El Niño (or ENSO positive phase) episodes. The resulting floods have affected thousands of individuals, damaged numerous houses, public buildings and highways, and submerged entire crops, cattle grasslands and livestock farms. Recent examples include the catastrophic events that took place in the Paraguay and Paraná rivers, particularly during the El Niño 1982-83, 1991-92 and 1997-98 years. In the flat Paraguayan savannahs, rainfall extreme events have also caused a proliferation of *Aedes aegypti* mosquito breeding sites, increasing the incidence of classic dengue fever. This has been particularly true in the central, northeastern and eastern portions of this country, where climatic conditions are suitable for the successful development of *Aedes* mosquitoes. During La Niña events (or ENSO negative phase), the country usually experiences the opposite (i.e. rainfall deficits and well below normal ambient temperatures). The concomitant droughts cause a decline in dairy production, an increase in the rate of desertification of arable land, and a rise in the occurrence of grassland and forest fires. They also decrease hydropower generation, increase the pollution of rivers and pools of stagnant water, and limit fluvial transportation, thereby increasing import/export transport fees and diminishing the trade of goods. Moreover, long dry spells affect sunflower, maize, soy, cotton, and wheat production, thus reducing the revenue from these key agricultural activities. All these impacts, although mainly the ones affecting the agriculture sector, prompted the creation of a multidisciplinary group led by the Paraguayan Meteorological and Hydrological Service, and the Risk Management Unit at the Ministry of Agriculture and Livestock Farming. Collaboratively, the group issues an agro-meteorological bulletin, every month or at other intervals depending on specific needs, following the approach presented in the decision-making information system below. Activities include (see Figure 11) the



**Figure 11.** The Paraguayan monthly agrometeorological bulletin (available online at: <http://www.meteorologia.gov.py/>) and the decision-making information system.

assessment of available climate information, seasonal and ENSO forecasts, and medium- to long-term potential impacts on local agricultural production. Key information is then shared with local farmers and smallholders through technicians, advisors and on-the-ground experts.

Up to date, the total number of end-users has reached over 2,000 local, regional and international groups including, among many others, the South American Common Market (MERCOSUR) and organizations in the United States of America, Canada and European countries. Numerous technicians, decision-makers, researchers, and students also use this sectoral information in their individual routine activities.

### 5.6. Climate risk of droughts in Chile and its effect on agriculture

In central Chile, the *secano* zone involves a total surface of 4.362 km<sup>2</sup>, and a human population of 54.450 habitants (6.25% of the regional population). Considered as a rural area, the *modus vivendi* depends basically on agriculture. In the coastal secano of the O'Higgins Region, the total surface designated to crops and plantations is on the order of 22.800 hectares. The majority of this land possesses forage plants (27%), cereals –especially wheat- (21%), fruits (20%), vines and vineyards (25%), and in lesser proportion legumes (5%) and vegetables (2%) [26]. Presently, the cattle production is on the order of 536.170 animals, most of them being sheep.

The secano zone shows a dry season that varies between 6 and 8 months per year. Precipitations take place between April and September, with values around the 500-600 mm/year [27]. Reports on droughts in Chile go back to the times before the Spanish Colonies, with a strong impact in the agriculture production throughout the history of the country [28]. In a period of 400 years, 25% has been reported as dry and half of them as extremely dry [29]. The mean probability is therefore on the order of one dry year every 4 years. Quintana and Aceituno [30] have recently discussed trends of decrease in precipitation for central Chile of 10-30% for the second half of the XX century.

Traditionally, the drought management in Chile has been contingent. Nonetheless, in the first decade of the XXI century, government actions in this regard have increased, orienting efforts towards an integrated management of extreme climate events. For example, this originated the National Plan for Civil Protection in 2002. The formal approval of the National Climate Change Strategy in 2006 and the respective Action Plan in 2008 have revealed the adaptation needs of the different productive sectors of Chile, but also the most vulnerable territories and populations. All this created a positive scenario for the establishment of improved policies for climate risk. Three important examples after the extreme drought of 2008 are the creation of the Comité Interministerial de Recursos Hídricos (Inter-ministry Water Resources Committee), the Comisión Nacional de Emergencias Agrícolas y Riesgos Agroclimáticos (National Committee for Agriculture Emergencies and Agro-Climate Risk) and the Sistema Nacional de Gestión del Riesgo Agroclimático (the National System for Agro-Climate Risk Management, found at [http://www.minagri.gov.cl/agroclimatico/comision\\_nacional.php](http://www.minagri.gov.cl/agroclimatico/comision_nacional.php)).



The public risk management initiatives implemented by the Chilean organizations involve one or several of the following mechanisms. While excellent initiatives, some of them can still be further improved. Some suggestions are pointed out in those cases.

#### *Early Warning System*

Chile possesses a modern early warning system that is able to detect and send alerts about natural disasters. It uses information produced by the Dirección Meteorológica de Chile (DMC), Dirección de Obras Hidráulicas (DOH), Dirección General de Aguas (DGA), Servicio Hidrográfico y Oceanográfico de la Armada (SHOA) and others. The Ministry of Agriculture via its Regional Centers for Agro-meteorological Information interacts with the climate information providers and generates tailored products for the corresponding sector. Nonetheless, these products do not always arrive on time to the farmers.

#### *Agriculture Emergency Announcements*

The Agriculture Emergency Zone (ZEA, in Spanish) announcements for droughts are fast and the corresponding institutional instances are efficient. However, the criteria used for announcing the ZEAs, which is based on the agriculture impact, may require modifications. The impacts are assessed in terms of a combination of factors: e.g. losses reported by a technical organism, request of a local authority and help requests from affected farmers. Specifically, ZEA announcements may require a criteria homogenization for both monitoring the evolution of the drought, as well as the emergency declaration itself. The announcement must adjust to regional realities and take into consideration the potable water supply and its effects on agriculture activities.

#### *Budget Availability for Emergencies*

Even when the budget allocation for emergencies is normally made through the utilization of funds already directed to other activities, in the last years, there has been an increasing amount of money in Chile properly directed to environmental emergencies. For instance, the emergency drought budget made available for the 2007-2008 case enabled the development of a higher number of implemented policies. In the Ministry of Agriculture, different mechanisms (e.g. emergency bonds, accident benefits, livestock health operations, agriculture emergency employment programs and a special incentive fund program for the recovery of degraded soils) were able to take care of around 161,000 beneficiaries.

A final comment can be included here about the implementation of an additional system to monitor the success of the risk management process in Chile. Presently there is neither an evaluation of the loss levels associated with a drought, nor an *ex post* diagnostic of the implementation mechanisms. It is necessary to possess adequate metrics to assess the effectiveness of applied strategies and the recovery of the affected populations. It is important to develop and to implement a protocol for the evaluation of the impacts of droughts. In addition, this will help with emergency management policies and the development of *ad hoc* prevention and mitigation measures focused on the vulnerability reduction of certain territories. A continuously updated registration of the users and affected people during an emergency is also required; this information will help to project

estimates of the offer and demand under similar circumstances. The associated database will consolidate the emergency monitoring system and also will provide useful information for future studies and experience-sharing with other institutions.

## 6. Discussion and concluding remarks

The Latin American Observatory partnership has been able to improve several aspects of the way decision-making tools are created and provided to stakeholders and end-mile users in different institution of Latin America in the past years, increasing the dissemination of available services for assessing and –when possible- forecasting hazards and vulnerabilities. This allows advisement of authorities in taking the right course of action in order to protect human populations from the direct or indirect effects of hazards.

In this chapter, we have presented the general methodologies that are used in the OLE<sup>2</sup> for risk assessment and management, along with a few case studies for different countries. The main innovation is related to the way the partnership interacts to share data, products, experiences, helping institutions with lesser human resources and capacities to take advantage of the strengths of other partners, but also sharing efforts at a regional level so the work is divided among a greater number of experts, even when they don't belong to a certain institute, or even when they are not present in the same country. This interdependence has proven a key component of the long-term sustainability of the Observatory.

In terms of the methods employed, important learned lessons arise in relation to the use of probability maps when working with vulnerabilities, hazards and risk management. A probability approach involves the consideration of the related uncertainties of every step of the methodology, which are always present in this kind of analysis. This introduces an *a priori* spectrum of possible immediate actions to decision-makers, even if the real intensity of the hazard is not known until the moment of the emergency. The whole system is aimed at improving the response times and also benefit/cost ratios.

Providing services that take into consideration different scales (e.g. interannual to decadal to climate change scales, as well as from basins to nation-wide to continental scales) and the evolution in time of both hazard and vulnerability probabilities has proven in our experience to be a more adequate practice when assessing and managing risk.

The recognition of the local chains of dissemination of the information, institutional relationships and their adequate use and promotion instead of creating new ones is another lesson learned. The Observatory as a “boundary institution” is paying special attention to these issues and also to the importance of “translating” methods and products so the final services can not only be adequately understood but also be properly assimilated by decision-makers and stakeholders.

Finally, there is an increasingly growing culture on risk assessment and management in LAC, but as Baethgen has pointed out recently [31], it is also important to consider the benefits that may arise if there is also preparedness to take advantage of probable “positive”

natural events (e.g. a natural event may be a hazard for certain sectors of production, but may be positive for others). The Observatory must therefore consider also Opportunity Assessment and Management policies in the near future to address such profitable scenarios.

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