# THE ROLE OF GEO-SPATIAL DATA AND INFORMATION IN POLICY MAKING FOR CLIMATE CHANGE RELATED DISASTERS

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**ABSTRACT:** Recognizing that data and information relevant to policy and decision making is key to reduce the uncertainty of climate change and the vulnerability it poses to emerging communities, this papers discusses the role of space-based data and information in policy-making for climate change related vulnerability and adaptation, and the different entry points they can have in the policy-making cycle.

Providing a number of examples and case studies, the paper highlights the role and usefulness of spatial data and information along each step of the climate change policy making cycle, unfolding various aspects and applications of spatial data and information that can be of service in climate change policy making, from the identification of the problem, through the different phases of policy formulation, to decision making, policy implementation and evaluation. Finally, a section is dedicated to some of the challenges presented by the science-policy interface and interaction, as one of the fundamental aspects of how relevant information feeds in the policy making cycle.

## 1. INTRODUCTION

Climate change poses a unique challenge for the development of countries and people. Repeated disasters and effects of climate change threaten the gains of years of investment and development efforts in affected areas, in addition to placing new demands for reconstruction and land restoration (UNESCAP and UNISDR, 2010; Ahmad et al., 2011).

The recent assessment of impacts, adaptation, and vulnerability by the Working Group II of the IPCC's Fifth Assessment Report (WGII AR5), asserts that human interference with the climate system is occurring and climate change poses risks for human and natural systems. It further stresses the challenges related to understanding future vulnerability, exposure, and response capacity of interlinked human and natural systems due to the number of interacting social, economic, and cultural factors, which have been incompletely considered to date. These factors include **access to technology and information**, the quality of adaptive responses, societal values, and governance structures (IPCC, 2014). In stating principles for effective adaptation, the WGII mentions the **provision of information**, policy and legal frameworks as actions that national governments can undertake in support of adaptation efforts of local and sub-national governments. Since adaptation is place- and context-specific, with no single approach for reducing risks appropriate across all settings, the availability of salient, place-specific **environmental data, information and knowledge** are increasingly being valued as necessary components in formulation of effective risk reduction and adaptation strategies that consider the **dynamics of vulnerability** and exposure, and their linkages with climate change.

While the intensity of natural hazards can hardly be reduced, their related impacts might, as proper planning can indeed limit losses. The WGII AR5 report highlights governments at various levels are beginning **to develop adaptation plans** and policies, and to integrate climate-change considerations into broader development plans. Spatial data and information are useful in this regard, as they enable **knowledge of risks and vulnerability** to be included in the planning process. However, spatial approaches, methods and tools to assess and manage climate related risks are not enough; to be effective they have to be accessible to policy-makers and incorporated into future decision-making processes.

This paper analyses the role of space-based data and information in policy-making for climate change related disasters and adaptation plans, and the different entry points it can have in the policy-making cycle. After briefly reviewing key concepts, we analyse the role of space-based data and information in the policy-making cycle using selected case studies from Latin America and the Caribbean, and draw relevant concluding remarks.

## 2. SPATIAL DATA AND INFORMATION IN POLICY-MAKING FOR CLIMATE CHANGE ADAPTATION

The collection, analysis, and dissemination of decision-relevant information is of foremost importance to address vulnerability, and therefore risks by means of plans and policies. The Hyogo Framework for Action advocates that: *“Countries able to develop and track progress through specific and measurable indicators, have greater capacity to manage risks and to achieve widespread consensus for, engagement in, and compliance with disaster risk reduction measures across all sectors of society*” (ISDR, 2007).

Spatial data establish the geographic context within which decisions can be made (Andrienko et al., 2007), and can assist in the process of:

- Identifying problems or issues in need of policy responses (e.g. measure snow cover, vegetation coverage and density, glacier and land cover changes, changes in the sea-surface temperature);
- Planning for adaptation strategies by increasing awareness and comprehension of vulnerability (e.g. mapping infrastructure vulnerability, socioeconomic vulnerability, ecosystem vulnerability, etc.), and the development of disaster risk indices (Peduzzi et al., 2009);
- Relief coordination during and after hydrometeorological events by mapping and monitoring humanitarian help and evacuation;
- Implementing and monitoring the progress toward development goals (i.e. access to safe drinking water or forest cover).

The benefits of information visualization for science policy have been documented (McInerny et al., 2014), providing evidence on the potential of spatial analysis and geographic information technology to improve policy-making processes (Andrienko et al., 2007). Five potential contributions of space-based data on the improvement of policy-making process have been identified (ESPACE, 2008; Schneider et al.,2009; UNEP,2009):

- Help policy-makers to literally “see” and “value” vulnerabilities, and priorities for action, and therefore increasing awareness;
- Facilitate and consolidate long term decisions (e.g. enables decision testing through “what-if” visualizations, spatial representation of scenarios outcomes);
- Help applying a balanced set of criteria for proper land allocation or adaptation measures (e.g. constraints areas, at-risk sectors, protected areas);
- Improving policy performance and reporting mechanisms by monitoring decisions (i.e. show progress, reveal needs for modification, etc.).
- Integrating disparate datasets and represent them on a single platform (e.g. socio-economic, environmental, financial feasibility, projecting ESE implications of policy options).

## 3. FROM MONITORING THE STATE OF THE ENVIRONMENT, TO MONITORING THE PERFORMANCE OF ENVIRONMENTAL POLICIES

Policy-making is a process by which governments address a particular social, economic or environmental issue using regulatory, economic, expenditure and institutional instruments (Swanson and Bhadwal, 2009). Composed of various stages and sub-stages integrated in an iterative process, policy-making is considered as a cycle, without a definite starting or ending point. The neat division into multiple stages is mainly theoretical; the reality is far more complex with problems redefined several times during the policy cycle and with stages overlaying or blending into each other (McNie, 2006; Swanson and Bhadwal, 2009). Nevertheless, the policy cycle conceptualization offers an overall relevant methodological scheme as it enables the matching of information needs and gaps with the stages of the policy process (de Leeuw et al., 2010).

Geo-spatial data, information, spatial visualizations and monitoring have proved beneficial to stimulate environmental awareness and concern as well as to evaluate the adequacy of responses. The potential of spatial data to support policy formulation and monitoring has been documented; however, few reviews analyze the link between geo-spatial techniques and specific stages of the policy cycle (de Leeuw et al, 2010). Through case studies, the following section explores the role that geo-spatial data and information can play in each phase of the policy making cycle (i.e. **problem identification, policy formulation, decision-making, policy implementation and evaluation**) and the niche and need for different spatial products.

### 3.1 Problem identification

Identification and definition of problems or issues that might become the target of policies, is the first phase of the policy-making cycle. A problem may arise from the emergence of a situation (e.g hurricane threat), scientific breakthrough (e.g. confirming the human-drivers of global warming), public opinion or lobbying (e.g. carbon-intensive industry lobby), or be driven by an economic incentive (e.g. adapt Caribbean coasts to ensure sustainable tourism development) (Likens, 2010). By shedding light on issues that may not be part of daily life, remotely sensed imagery can provide useful information to enhance broad *system understanding* and potential impacts across a range of scales (de Leeuw et al., 2010; UNEP, 2007) (see case study 1). Land cover and land use change mapping supported by satellite imagery and Digital Elevation Models can, for instance, inform policy-makers on land degradation occurrence on steep slopes, therefore enabling greater understanding of hydrometeorological hazards and associated risks (Tralli et al., 2005; Metternicht et al, 2005). Mapping of short-- and long-term sea-level change (e.g. using Jason-1 and Jason-2) could similarly point out “at risk” areas, therefore providing science-based information for policy-makers to design climate-resilient strategies and policy, addressing adaptation in coastal areas at national, sub-regional or regional levels.

**Case study 1: Problem identification - Multi-temporal comparison of satellite images**

The Cotopaxi Volcano in the Andean Cordillera is located some 75 km to the southeast of the city of Quito. The Cotopaxi Glacier has considerable economic, social, and environmental importance, since its meltwaters provide freshwater to Quito city for both human and industrial consumption, in addition to supplying part of the city’s electrical energy needs. The retreat of the Cotopaxi Glacier has accelerated in the last 25 years, increasing the “glacio-volcanic” risk and threatening the water resource base of the region. This phenomenon is tightly linked with global climate change. The ice mass decreased 30 per cent between 1956 and 1976, and another 38.5 per cent between 1976 and 2006. Rapid retreat of glaciers might cause frequent flooding and debris flow disasters. A comparison between 1986 and 2007 Landsat satellite images shows a reduction in the extent of the glacier at the summit of the volcano; these multi-temporal images enable visualizing the spatial extent of the retreat area, exposing vulnerability of populations and ecosystems; such visualization can raise awareness for policy-makers to take actions. Further information is nonetheless necessary to better understand the issue and formulate an appropriate response. The following questions relevant to policy formulation might therefore be addressed:

- *To what extend is this a climate adaptation policy problem*?; Model forecast precipitation, hydrological monitoring as well as vulnerability mapping could provide valuable information in answering this question;
- *Who or what will benefit (or suffer) from this problem being (or not being) addressed?* Land-use and land cover mapping and/or in mapping of population, infrastructures, services, crops, etc. could offer decision-makers an overview of potential extent of consequences.
- *What is the time scale in addressing this situation (short, medium, long term)?* Scenario planning methods linked to a GIS or real-time hydrometeorological observation could help understand the significance of the threat.

Cotopaxi (Ecuador) 1976 (left) – 2006 (right). Source: UNEP and CATHALAC (2010), Willows and Connell (2003)

Defining and analyzing drivers of policy issues as clearly and concretely as possible (e.g. number of people affected, economic losses, and future trends) can yield major budgetary savings, while improving adequacy of response, and reducing further disagreements amongst stakeholders (Guess and Farnham, 2000; UNEP, 2009). Gathering facts, evidences, and arguments to document and communicate the issue precisely, is therefore essential (UNEP, 2009). In this context, special focus should be given on clearly distinguishing between the symptoms of the problem and the problem itself. In fact, policy responses typically concentrate on reducing pressures – *the short-term effects* instead of thinking about tackling drivers – *the causes* (UNEP, 2012). The reconstruction and mitigation projects undertaken in Honduras in the aftermath of hurricane Mitch are good examples of the latter (Winograd, 2007, see Case study 3).

### 3.2 Policy formulation and decision making

During policy formulation (i.e. establishing policy-making criteria, risk assessment, identifying and appraising options), policy-makers set objectives that will be translated into operational criteria - this is to say key factors and “higher level drivers” that could affect policy performance (Swanson and Bhadwal, 2009). These can be related to legislation and regulation, existing infrastructure, geographic and topographic specificities, and socioeconomic particularities. Criteria should be measurable (through indicators or proxies) and standardized. Because policy-making is also influenced by societal values, the weight of each factor or criteria could depend on value, beliefs, and/or cultural settings (Harding et al., 2009). In this regard, spatially-explicit decision systems including sensor imagery are useful for integrating different factors that must inform prudent investment decisions in disaster risk reduction (see Case study 2).

Assessing the degree of uncertainty for policy options and comparing sources of risk are also part of the policy formulation stage. This can be done through risk assessment; in that context, remote sensing could provide reference points and thresholds, which could be surveyed, demarcated and approved. Furthermore, processes and rates of events (e.g. sea-rise level, floods frequency and spatial extent of affected areas, and droughts) could be measured, producing important baselines and model simulations to enable first-order estimates of possible responses (Metternicht et al., 2005). By overlaying different hazard maps and impact layers using spatial and non-spatial data, GIS supports multi-hazards analysis (e.g. cyclone, floods, drought, rains, thunderstorm) and enables the identification of most vulnerable areas using vulnerability profile mapping from census data, the Human Development Index (HDI) and economic surveys), as shown in case study 2. Combining probabilistic risk evaluation of hazards with data on vulnerability (e.g. infrastructure at risk, population density, socio-economic situation) enables assessing risk of loss and damage (e.g. crops, properties, people).

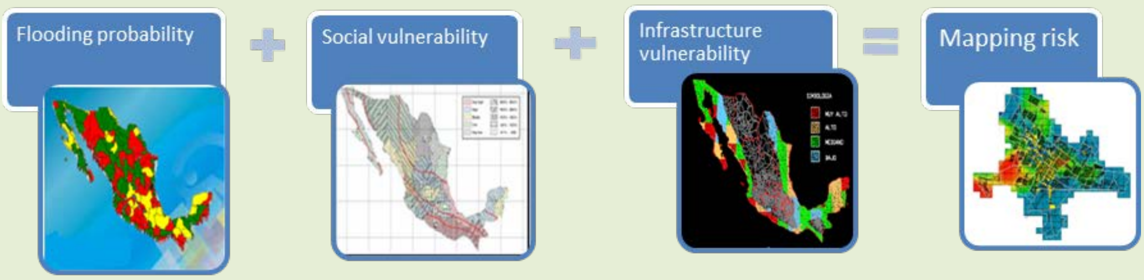
**Case study 2: spatial information in support of policy formulation**

Mapping risks locally can support policy-makers in their decision to clear development and relocate people away from at-risk areas, and therefore limit causalities. Over large geographic regions, risk maps can assist policy decisions about development options. The Mexican National Atlas of Risks (*Atlas Nacional de Riesgos*) offers a good example of risk assessment and mapping. Aiming to support policy-makers establishing effective measures for prevention and mitigation, the Atlas main objectives are to answer some essential policy formulation questions:

- What are the expected risk-related economic losses and possible impacts on human population?
- In order to reduce risk, which policies can be carried out?
- Where are shelters and evacuation routes located, and what is their capacity?

To this end, the Atlas makes use of geospatial information in order to develop risk assessment and mapping. In general terms, three elements are combined so as to create effective mapping of risks:

- Hazard: Flood, drough, hurricane, etc.
- Disaster: Casualities, property losses, resource and ecological losses, etc.
- Risk: Vulnerability, resilience, adaptation, etc.



Main elements of risk assessment. Source: Armonia (2007), INEGI & CentroGeo (2010),

In order to improve future outcomes and limit possible policy conflicts, policy-makers often prefer to produce a range of possible scenarios (Metternicht and Suhaedi, 2003) and compare results rather than generating a single, optimal option. Scenario analysis to test policy performance under a range of anticipated conditions is an effective option to increase the robustness of policy formulation (Swanson and Bhadwal, 2009). UNEP's Fourth Global Environment Outlook (GEO-4) presented four types of future scenarios: markets first, policy first, security first and sustainability first (UNEP, 2009); some components of these scenarios relay on spatial information (e.g. the IMAGE model used for land use projections). Along the same line, the "*What if*" methodology used by the European Environment Agency (EEA) apply a scenario analysis tool to appraise the effects of different policy options at defined spatial and temporal scales (Winograd et al., 2004), and offers the framework and spatial analysis tools that could be adapted to evaluate what-if scenario options related to climate change and hydrometeorological disasters.

Using the information gathered throughout previous phases, policy-makers choose amongst potential alternatives the best option possible to answer the identified problem. Few policies arise from a clear "preferred" option; the complexity of the situation, the interconnection between systems, the number of stakeholders, and uncertainties about future outcomes of climatic events increase the difficulty of environmental decision-making. Beyond existing tools, the ultimate decision is also affected by priorities, beliefs, values and other subjective factors (e.g. politics) (Dovers and Hussey, 2013).

### 3.3 Policy Implementation

Policy implementation usually aims to change the behavior of a target population to ameliorate some environmental public problem (Theodoulou and Kofinis, 2004). In general terms, policy responses to climate change impacts can either be directed at reducing the human-caused net emissions of greenhouse gases (i.e. mitigation) or at assisting adaptation to impacts (UNEP, 2011). Table 1 presents some policy instruments and highlights those where spatial information could assist in their design and implementation.

Spatial data can support the policy implementation phase; one example is the common use of mapping and GIS technologies in the implementation of planning and zoning codes. In addition, spatial data are highly beneficial to monitor advances in policy implementation; for instance, spatial information can be used to ensure the equitable coverage of the chosen policy, in other words to ensure all citizens have access to services *when* and *where* they are required.

**Table 1: Policy instruments for climate change adaptation and the role of spatial information**

| Policy instrument | Definition | Example | Contribution of spatial information |
|---|---|---|---|
| Regulatory | laws or regulations influencing the behavior of stakeholders: citizens, government, private sector, international organizations, etc. | • Planning and zoning code, building codes, regulation on water distribution;<br>• Bills on preventive measures against landslides and other natural disasters;<br>• Standards, etc. | • Planning and zoning |
| *Financial or economic* | Measures that directly influence the price that a producer or consumer pays for a product, a behavior or an activity (UNEP, 2009); it does include subsidies, taxation, and credits | • Financial incentives include credit access and interest rate regulations for landowners that engage in conservation practices (e.g. conservation of forest which could help prevent landslides in times of hazards) or climate proof infrastructure.<br>• Subsidies for production activities that lead to environmental protection (e.g. mangroves production) | • Cadastral maps<br>• Land cover /land use data |
| *Direct expenditure* | Aims to change social behavior by direct expenses. Contrary to financial and economic instruments, direct expenditures are generally made through programmes, facilities, services. | • Environmental education programme;<br>• Safety net (e.g. labor market programme). | • Census maps |
| *Institutional instruments* | Are generally directed at reshaping government's structures in order to promote changes. This can be done by creating institutions, procedures or by means of internal education, etc. | • Emergency management agencies, National Disaster Risk Reduction and Management Councils, climate change commissions, etc.;<br>• Tightening the policy-making architecture in case of disaster, defining an institutional network with participation of local, regional, and national entities;<br>• Formulation of Natural disaster emergency plans;<br>• Integrated watershed management and disaster risk management; | • Disaster emergency maps<br>• Watershed management maps |

### 3.4 Monitoring and evaluation

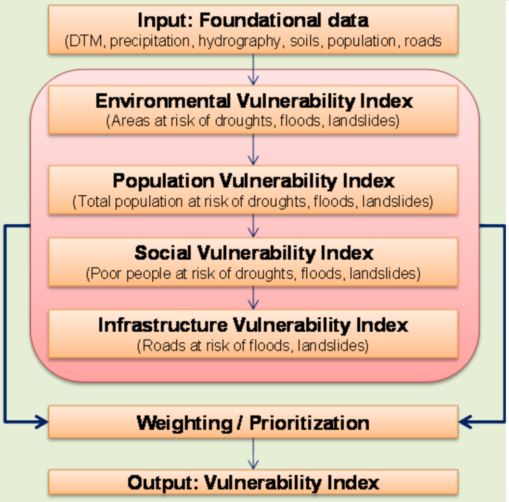
By examining the means employed, the objectives served, and the effects of the implemented policy, the monitoring process can help with appraising effectiveness and performance in addition to tracking matters of concern. Monitoring can also be directed to ensure the consistency of management decisions with scientific information (case study 3). This in turn could lead to additional policies or to adjusting existing ones (e.g. adaptive policy design) (UNEP, 2009). The use of spatial data and geo-technologies to monitor policies can serve different purposes and use various methods. It could be chosen to monitor the policy process itself by mapping out, for instance, the flow of every implementation stages. Time series of satellite imagery (e.g. confirming that the number of built up areas slowed down after government policy implementation to reduce residential expansion in flood prone area) and remote sensing for the comparison of two development pathways can be used to ensure policy objectives are met.

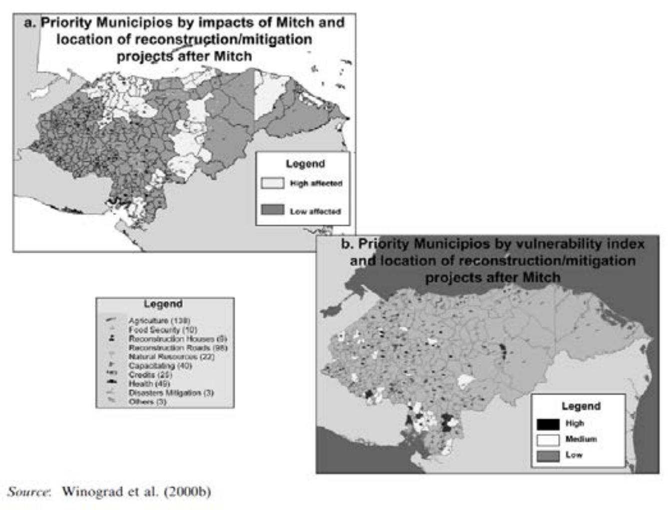
## 4. CONCLUDING REMARKS

Integrating spatial data and scientific information into the policy-making process remains a challenge; while some of these challenges are related to the broken bridges between science and policy, particularly the integration of scientific uncertainty, others are directly linked to access and use; the importance of timely access to accurate, reliable and consistent spatial data has long been established as a critical requirement for well-invested resources, services improvement and sound policy-making (UN, 2006; National Research Council, 2007). Reinforced by increased investments in Research and Development and progresses in communication technologies, quality and availability of data remain a central preoccupation for the effective integration of space-based data in the policy-making process. Various countries count with regular data collection programmes and/or agencies with dedicated mandates for data and information production and analysis (e.g. national meteorological and hydrological services and national mapping agencies); however, disasters continue occurring in areas where with paucity of up-to-date information.

**Case study 3: Monitoring responses and actions at national level – lessons learned from Hurricane Mitch (Honduras)**
One of the most destructive natural disasters to hit Central America in the last century, Hurricane Mitch killed between 11,000 and 19,000 across Central America and Mexico, predominantly from rain-induced flooding. In addition to human losses, Hurricane Mitch led to significant economic damages. In Honduras only (the most affected country), Hurricane Mitch caused US$3.8 billion (66% of GDP) of damages: 70-80% of transportation infrastructure was destroyed, 70,000 houses were damaged, over 25 small villages were swept away and the city of Morolica, completely devastated. Furthermore, 70% of the country's crops were ravaged. In fact, Honduran officials estimated at 50 the number of years of economic development destroyed by Hurricane Mitch. The reconstruction process of Honduras was evaluated under the scope of sustainable development and vulnerability criteria; to do so, the location of reconstruction and mitigation projects was mapped and coupled with impacted and most vulnerable areas (figures a. and b).

The monitoring process made use of the vulnerability assessments developed during the policy formulation stage. Using a set of indices and indicators to assess environmental, social, infrastructure and human vulnerability (e.g. climatic risk index, human development index, poverty, welfare access, forests surfaces, actual land use, household structure, and economic loss by natural disasters), the project created and mapped a vulnerability Index. The spatial representation of vulnerable areas made it easier to literally "see" areas in need of additional assistance.





*Source:* Winograd et al. (2000b)

The monitoring process can help appraise effectiveness and performance in addition to track matter of contentions. In the case of the Post-Mitch evaluation process, it was observed that less than 40% of the reconstruction and mitigation projects were located in highly affected area, while less than 10% of the reconstruction and mitigation projects were in highly vulnerable areas. This is saying that programs and projects that resulted from the decision-making process failed to address the underlying causes of impacts. Winograd (2007) concluded that the urgency and the lack of appropriate information was the main reason behind the fact that highly vulnerable areas weren't more targeted by reconstruction/mitigation projects. This conclusion highlights the need of timely and accurate information for policy-making.

Source: modified from Winograd et al. (2000), and US Geological Survey (2002), Winograd (2007), De la Torre (2009), UNEP and CATHALAC (2010).

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