Chapter 1
Monitoring and Evaluation of Climate Change Adaptation in Coastal Zones: Overview of the Indicators in Use

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Abstract Recently, the number of public policies initiated within the framework of CCA has increased in several western countries. On the other hand, the evaluation and measurement of CCA progress remain embryonic and inadequately charted by indicators quantifying the changes and impacts attributable to these policies that engender new stakes and concepts that are difficult to measure and do not always produce a consensus.

Our paper presents the results of a scoping review examining the extent, scope and nature of the literature dealing with CCA indicators and metrics. Using scoping-review protocol, bibliographic databases were examined (for the years 2005–2015), using key words, in both English and French, dealing with the measurement of progress in public CCA efforts in coastal areas. In all, 165 documents were selected and analyzed and more than 200 indicators were looked at.

Our analyses point out that the conceptual framework for CCA remains fragmented given the different scientific approaches and disciplines. The lack of consensus about CCA and about the indicators designed to assess CCA initiatives is a major limitation in coastal zone management. One way is to harmonize the practices for analyzing human and environmental systems respectively, both in the fields of the social and the natural sciences. In terms of governance, network management appears to be the most effective method in the context of social and environmental change. In terms of indicators, the WorldRiskIndex provides a useful estimate of the vulnerability of countries with respect to the effects of climate change in a context of rapid urbanization. In a regional context or a smaller geographical area, GIS stands out for being able to incorporate a lot of data, and to ensure their continuous update. Moreover, the ICZM is an effective approach at the national level that nevertheless takes into account the regional differences in coastal zones. The studies included in this analysis also demonstrate that the

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W.L. Filho et al. (eds.), *Climate Change Adaptation, Resilience and Hazards*, Climate Change Management, DOI 10.1007/978-3-319-39880-8_1

process of adopting CCA measures must be transparent and participatory since they aim for both short-term and long-term objectives.

Keywords Climate change adaptation • Monitoring and evaluation • Coastal zone • Indicators • Scoping review

Introduction

Since and throughout the last decade, efforts to mobilize collective action to advance climate change adaptation (CCA) have proliferated, as reflected in public policies and in activities and initiatives undertaken at various levels of government (Cooper and Pile 2014). These efforts, which can be quite costly and complex, involve a multitude of fields of intervention and stakeholders who are affected by the many facets and consequences of climate change.

In Canada, like in all Western countries, governments must support and structure their efforts in CCA, particularly in coastal areas, where shores are increasingly exposed to erosion as well as other phenomena associated with climate change. The need for collective action with regard to CCA is especially important and urgent in coastal zones and in wetland, river and sea ecosystems. In these ecosystems, climate change-related disturbances and unpredictabilities manifest primarily in rising sea levels, an increased frequency of storms, coastal erosion and loss of cliffs, the recurrence of devastating floods, the salinization of fresh water sources, and other phenomena that put densely populated coastal zones to the test. All of these phenomena greatly affect critical infrastructures (energy, transport, etc.) and even critical decision-making centers for governments and communities (IPCC 2014a).

As Governments are getting more aware of the risks associated with climate change, they are in the forefront of the development and implementation of innovative adaptation strategies. Indeed, several OECD countries have come up CCA initiatives and programs (OECD 2014; Mullan et al. 2013). At the same time, and considering the innovative nature of the actions to implement, governments and collective action as a whole must distinguish between effective actions from those that are not. In this context, reliable indicators are required to measure progress in CCA and support decision making. Significant amounts are often involved and policymakers and taxpayers want to ensure that the budgets allocated and the defined regulations give conclusive results, for example in reducing communities' vulnerability to extreme climate events. Several OECD countries have come up CCA initiatives and programs (OECD 2014; Mullan et al. 2013). Indeed, some governments and communities have also developed indicators to measure progress in CCA to support coastal management (Torresan et al. 2008; Harvey and Woodroffe 2008; Hanak and Moreno 2012).

Yet, despite the importance of the issues, concerns and actions involved, and the proliferation of research on initiatives and programs pertaining to CCA, we still know very little about the progress and results of the policies and initiatives

implemented to advance CCA. Because no systematic approach to monitoring and evaluating CCA has emerged, the capacity to conduct assessments and to incorporate them in adaptation policies is limited. Consequently, although adaptation is occasionally subject to critical examination, the evaluation of CCA is still far from being an institutionalized practice (Preston et al. 2011). This is an important limitation especially for public administrators who cannot rely on a set of and validated indicators to support decision-making in adaptation.

On the one hand, this limitation could be attributed to the scarcity of research on the measurement and evaluation (M&E) of CCA efforts (Lemmen et al. 2008; MMM 2005; de Bruin et al. 2009). Most studies undertaken in the context of climate change also have a limited scope, their focus being more on documenting and measuring the efforts to mitigate climate change and less on analyzing and measuring the effects of CCA measures (Dupuis and Biesbroek 2013). M&E of CCA is also an emerging field of practice, albeit still riddled with a number of complicating factors. Existing assessment frameworks often focus on different and varied aspects of planning, making it difficult to identify an appropriate planning process, as well as generic indicators (Brooks et al. 2011; Hedger et al. 2008).

But the real challenge with M&E of CCA lies in its embryonic nature, insufficiently marked by indicators quantifying the changes and impacts due to different adaptation strategies and measures. Furthermore, adaptation refers to new issues and concepts which are not easily measurable and not always without controversies. The resulting confusion complicates the measurement of progress in CCA achieved through collective action on climate change (Ostrom 2010; Magnan 2009) and calls for improvements in M&E (Preston et al. 2011).

"Measuring" is understood as the systematic process of assigning a value to a phenomenon (and therefore something that can be observed) (Hinkel 2011). Because the different concepts and variables associated with a phenomena can take on different values, measuring will consist in establishing their state, in order to quantify and compare. Thus, the design and selection of indicators will be understood as the effort to operationalize a concept of a theoretical nature, meaning that the quality of an indicator can be assessed on the basis of ontological criterias. The quality of an indicator is also dependent on many methodological prerequisites. The most cited writings emphasize three types of attributes: reliability, accessibility and relevance of the data and measures used. To be reliable, an indicator must reflect in a relevant and robust way what the evaluator, the researcher or planner actually want to measure and observe.

Like any emerging area of research, the scientific literature on CCA in coastal zones is not mature, even if it is continually progressing to better define its theoretical contours and empirical indicators (Magnan 2009). Adaptation is a polysemic neologism which is theoretically hard to apprehend. The very nature of what constitutes adaptation is not constant (Hedger et al. 2008; OECD 2006) which complicates the determination of generic indicators. Is it a series of specific activities or decisions, or rather a set of processes evolving concurrently (Brooks and Frankel-Reed 2008; UNDP 2005) or a result to be achieved (UKCIP 2003)? The lack of consensus on what constitutes "good" adaptation or "maladaptation" is

also a source of difficulty, preventing the application of universal criteria and standards to appreciate an adaptation response (Hedger et al. 2008).

Vague concepts and their various corollaries, which in some cases refer to undefined concepts, are also a source of difficulties. For a central concept such as vulnerability, Thywissen (2006) identified as many as 35 definitions, plus related terms referring to similar ideas (risk, sensitivity, fragility) or conversely similar (resilience, adaptability, adaptive capacity, stability) (Brooks 2003). This lack of consensus make it difficult to establish metrics on concepts whose definitions are shared by a large number of actors (Hinkel 2011). Furthermore, the inherent normative dimension in the appreciation of various concepts (adverse effect; significant climate variation) adds to the complexity to the operationalization of key CCA concepts. For one, a concept such as vulnerability do not refer to a single observable phenomenon (Moss et al. 2001; Patt et al. 2009) but rather to a theoretical concept, contingent to a given system, place or context, which can be measured on multiple spatial and temporal scales. Vulnerability will be perceived differently in different geographic region and will depend on various scenarios regarding climate change and socio-economic changes. It will also varies between sectors and social groups (Dunford et al. 2015), leading to very little certainty about the object around which to develop indicators (Cutter et al. 2003).

The numerous categories of CCA measures are pursuing various and ambitious goals (reduce vulnerability, develop adaptive capacity, reduce climate risk, address climate change, etc.). Several of these interventions have intangible nature, which complicates their evaluation in the light of a single paradigm or theory. Coming with indicators measuring the "invisible" and reliably quantifying all the benefits from a CCA measure are hard to come by. Indicators mostly account for the "visible part of the iceberg", but lose in relevance when one whishes to learn more on the underlying dynamics, currents, mechanisms, etc. by which the impacts associated with CCA interventions are happening.

The design and implementation of CCA measures are also associated with the intertwined of numerous interrelated and complementary initiatives. In many cases, indicators are struggling to "sort out" the various interventions and to isolate the impacts associated to each intervention. Frequent shifts (temporal and intergenerational) between the moment a CCA measure is implemented and its impacts become visible limit the relevance of certain indicators, as well as complicate the use of analytical methods and the definition of indicators, too oftently developed under static and ad hoc approaches. The emergence of certain impacts often depends on interactions between results and economic and social context, and this reality is hard to capture with a set of generic indicators.

There is also an equity dimension in CCA, and if the efficiency of a measure can be easily assess from the perspective of its beneficiaries, this demonstration is much more difficult when we adopt the perspective of the whole society bearing all the costs associated with the investment required by an adaptation measure. Very often, indicators address the beneficiaries of public intervention but fail to reflect all the costs that are diffuse and unevenly borne by taxpayers. From a methodological perspective, this distinction between the economic impacts and the social impacts

of a CCA measure is not always easy to operate. The strong interdependence between social and economic factors makes it difficult to assess all the benefits for the society and so is their quantification as indicators.

Understanding the complexity in the course of designing M&E indicators can thus be realized in two directions: (i) according to the dimensions of the performance of an intervention (i.e., the elements of the logic model: inputs, processes, outputs, effects, impacts); (ii) whether this complexity is solely related to methodological issues, or is also weighted down by ontological difficulties. So, the more the purpose for performance monitoring concerns those responsible for implementing an intervention, or their direct beneficiaries, the lower the level of complexity. In this situation, chances are that indicators will refer to simple metrics, and that their collection will not present significant methodological challenges. As we move along in the chain of results, the identification process might become trickier, as it will require the analyst to reflect on specific outcomes and impacts theoretically associated to the intervention. Indicators will also have to be time and context specific, which reduces the potential use of generic indicators. Furthermore, as we adopt a societal perspective, more robust methods will be required to assess the benefits and costs collectively supported for one intervention. But the conceptualization of the concepts covered by the measure will be the real challenge, as M&E will still present different levels of complexity from a methodological standpoint, as well as ontological problems. Before even thinking for a method to gather data in order to assess the level of vulnerability of a community, one has to state what the concepts even means and how it can be apprehended if it is not directly observable.

With all the aforementioned difficulties associated with CCA indicators said, one can postulate the following hypothesis: Unlike with mitigation to climate change, where establish metrics are identified and used without controversies, existing CCA indicators are more controversial than mitigation indicators, and CCA indicators in coastal zone are even more complex. Our contribution aims to innovate on that subject, as these hypothesis have not been adequately treated in the literature. It also aims to reduce the knowledge gap on indicators to measure progress in CCA. It develops an analytical portrait of the indicators currently used to measure various dimensions relating to CCA in coastal zones. This portrait is built on a synthesis of knowledge (scoping review) from the scientific literature and from the most cited official documents in the context of the OECD countries. It revolves around three sub-questions that can be formulated as follows:

- What are the CCA indicators used in the coastal zones of the most affected OECD countries?
- How are CCA indicators designed and measured to assist in decision-making?
- What are the most common indicators and how are they valued in the development or implementation of a system of indicators?

The article is divided into four sections. In the first section, we present the methodological guidelines established as part of this scoping review. In the second section, we discuss the conceptual framework for CCA as well as indicators for

measuring progress in CCA in coastal zones. In the third section, the results of this portrait are highlighted with a view to developing a set of indicators that are useful and usable in decision-making. This section also puts into perspective the impact of CCA monitoring indicators on decision-making. The fourth and final section discusses the governance of indicators for measuring CCA.

Methodology

This article adopts an investigative approach inspired by a method for synthesizing knowledge known as the scoping review method. Our investigations aim to generate empirical results from different types of research in order to draw valuable and useful findings for decision-making in matters concerning the monitoring and evaluation of CCA in coastal zones (Anderson et al. 2008). A scoping review is a method that is particularly relevant in a context where the research domain under study is relatively recent or in which the scientific writings are compartmentalized, contradictory or controversial. It allows to take stock of and better organize complex and relatively new issues (Levac et al. 2010; Davis et al. 2009). Unlike for a systematic review, the protocol of the scoping review does not lead to identify and consult systematically all the literature on a subject but rather to identify publications that meet certain criteria. This is a limitation to the study, as one might think of some other documents that would have been relevant to consult.

The literature mobilized for our scoping review includes documents from the OECD context, with a particular focus on Australia, the United States, France, New Zealand, the Netherlands and the United Kingdom—all countries that have made, to varying degrees, interesting experiences and initiatives in CCA in coastal zones. This is another limitation to the study, as other countries might have been interesting cases, but for time considerations, we had to focus on these countries. Two types of documentary sources are used: articles published in scientific journals with evaluation procedures that are rigorous and based on anonymity and official reports from government agencies or international organizations active in the field of CCA in coastal zones. The selected texts have been published during the last decade (2006–2015) and were written in either English or French.

This research used relevant databases from the social sciences as well as from multidisciplinary and environment-oriented fields. Eleven databases were consulted: (1) Arts & Humanities Citation Index, (2) Érudit, (3) JSTOR, (4) Sage, (5) Science Citation Index Expanded, (6) ScienceDirect (Elsevier), (7) Social Sciences Citation Index, (8) International Bibliography of the Social Sciences (IBSS), (9) Web of Science Core Collection, (10) Wiley, and (11) WorldWide Political Science Abstract.

The keywords were identified using the thesaurus of the databases presented above and by performing a preliminary documentary research. Thus, the term “climate change adaptation” was combined with synonyms of: coastal zone; indicators, or indexes; monitoring and evaluation; and governance, decision-making,

management, public policy or institution. This allowed to identified 165 articles. After a first screening stage, based on the titles and abstracts, 50 articles were retained for a more comprehensive and detailed reading. Subsequently, eight of the 50 studies were excluded for non-compliance with the inclusion criteria established beforehand. Moreover, another four studies were rejected in a final validation because their methodology and results were insufficiently described and explained. This resulted in a total of 38 articles to proceed with. Detailed information on the methodology used is provided upon request by the authors.

A Conceptual Framework for CCA Issues

Despite the consensus on the need for CCA in the international arena, the term has many definitions. Cooper and Pile (2014: 91) presented a compilation of early definitions of CCA: "[t]he process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides" (Burton 1992); "any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change," (Stakhiv 1993), and "all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system" (Smith 1996).

In parallel, in the United Nations Framework Convention on Climate Change (UNFCCC), CCA is defined as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change." According to the Organization for Economic Cooperation and Development (OECD), "various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation." In addition, the European Commission considers that CCA "aims at reducing the risk and damage from current and future harmful impacts cost-effectively or exploiting potential benefits [. . .] Adaptation can encompass national or regional strategies as well as practical steps taken at community level or by individuals" (Cooper and Pile 2014: 91).

Some of the above-mentioned definitions show commonalities and differences in their understanding of CCA. Some emphasize the anthropogenic causes of climate change, thereby highlighting the importance of human behavior in CCA, whereas other definitions focus on the natural and physical determinants, in which case collective action implicitly becomes somewhat exogenous. These nuances reflect the various levels of responsibility assumed by social actors in their efforts to advance CCA. In addition, social actors defend divergent interests, due to which their support of government actions and policies in CCA is not always unanimous (Cooper and Pile 2014).

Coastal areas have the particularity of being densely populated, holding the bulk of productive infrastructure and economic wealth. At the same time, coastal areas are also zones where the impacts of climate change are especially strong, as has been demonstrated over the last 20 years [rising sea levels; the extinction or migration of species, which has a significant impact on the fishing industry; coastal erosion, acidification of the oceans; changes in the distribution of marine species; changes in precipitation; and the recurrence of storms, ocean temperatures and marine winds and currents—all of which can cause extensive flooding and damages (McClatchey et al. 2014: 14)]. Adaptation measures can take many forms, whereby a dichotomy exists between interventions modifying the environment and those concerning human behavior. In the end, CCA measures undertaken in coastal zones are highly dependent on anticipated risks as well as on the public opinion regarding climate change-related risks and harms. Cooper and Pile (2014) highlight that CCA measures in these areas tend to focus on the short term and the search for cost-effective results allowing to solve immediate problems.

The scientific literature on CCA clearly identifies the need to monitor and evaluate adaptation efforts with a view to determining the effectiveness and the success of interventions. OECD outlines the contours of monitoring by giving it the status of a "continuing function that uses systematic collection of data on specified indicators to provide management and the main stakeholders of an ongoing development intervention with indications of the extent of progress and achievement of objectives and progress in the use of allocated funds." (OECD 2010: 27). On the other hand, evaluation is conceived as the "systematic and objective assessment of an on-going or completed project, programme or policy, its design, implementation and results. The aim is to determine the relevance and fulfillment of objectives, development efficiency, effectiveness, impact and sustainability" (OECD 2010: 21). Ultimately, "successful adaptation will be measured by how well different measures contribute to effectively reducing vulnerability and building resilience. Lessons learned, good practices, gaps and needs identified during the monitoring and evaluation of ongoing and completed projects, policies and programmes will inform future measures, creating an iterative and evolutionary adaptation process" (Sanahuja 2011: 15).

Because the scientific literature on these different concepts remains vastly fragmented, the recognized impacts of climate change and the adaptation measures and vulnerability indicators for the regions studied are not usually presented in a quantitative and systematic manner. This situation is not without generating a lack of empirical evidence to support the information and indicators presented (Hofmann et al. 2011; Nicholls et al. 2008). Sanahuja (2011) argues that the concept of CCA is polysemous and difficult to measure since it encompasses a multitude of disparate elements from sectors, disciplines, stakeholders, processes, diverse ecosystems and often divergent interests. As a result, the conceptual organization and structure surrounding the definition of CCA are fluid, which puts great stress on M&E efforts in adaptation. Given that the CCA challenge is marked by great complexity and requires a multidisciplinary analysis, Hofmann et al. (2011) recommend that we examine our notion of CCA more rigorously and resolve the

confusion surrounding the terminology relating to CCA. This brings us to the concept of CCA indicators.

CCA Indicators for Coastal Zones

Our review of the literature confirms the absence of a standardized and consensual acceptance of notions dealing with metrics, measures or indicators in CCA. This absence also explains the overlaps, confusion and knowledge gaps on the subject. The IPCC (IPCC 2014a, b) defines measure as the quantity or degree of development of an observed object, in view of its supposed present condition; metrics as a group of values that, taken together, gives a broader indication of the state or the degree of progress towards the desired state; and indicator as a sign or estimate of the state of something, and often of the evolution of an observed object or phenomenon (IPCC 2014b).

Assessing the vulnerability or scope of an adaptation action cannot be done without the use of metrics or indicators to describe these components. The IPCC determines three types of use of indicators: an instrumental use, to determine the static state of a need to adapt (the measure of vulnerability); a dynamic use, to measure the dynamics and monitor the implementation of adaptation actions; and finally, an evaluative use, to measure the effectiveness or efficiency of a CCA initiative (IPCC 2014b).

The Organisation for Economic Cooperation and Development (OECD) defines an indicator as a "quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention, or to help assess the performance of a development actor." (OECD 2010). As part of CCA, the indicators aim to "simplify, quantify, standardize and communicate complex and often disparate data and information." In addition, appropriate indicators allow building a solid foundation for evaluating the effectiveness and output of CCA measures undertaken (Sanahuja 2011).

At present, the measure of vulnerability to climate change in coastal zones is the most commonly used indicator at the international level. The IPCC defines vulnerability according to three central themes: "the magnitude and rate of climate variations to which a system is exposed (i.e., exposure); the degree to which a system could be affected by climate-related stimuli (i.e., sensitivity); the ability of a system to adjust or to cope with climate-change consequences (i.e., adaptive capacity)" (Torresan et al. 2008). Thus, contrary to the notion of sensitivity, vulnerability refers to a number of biophysical, socio-economic, institutional and political concepts.

The objective behind the design of vulnerability indicators is to assist in the decision-making, problem-solving and evaluation of business strategic performance measures in CCA. Yet, according to Hinkel (2011), in terms of public policy, the way in which such indicators are used remains unclear. An analysis of official documents produced by the UN and the European Union showed that public

entities do not clearly state how these indicators should be taken into account. An analysis of the scientific literature showed that a large number of case studies do not state how vulnerability is estimated. According to Hinkel, the conceptual literature provides some answers by highlighting that vulnerability indicators serve to expose the needs with regard to CCA; to identify populations and the most vulnerable sectors; to alert the public and decision-makers about climate change; to assign resources to combat climate change to the most vulnerable areas; and to assess the performance of CCA initiatives.

Tibbetts and van Proosdij (2013) argue that CCA indicators are effective tools that shed light on policy design for both the short term and the long term. According to them, these tools can be made available to managers and persons in charge of CCA action, allowing these to identify the populations and areas exposed to higher levels of risk and to allocate CCA resources more efficiently (Tibbetts and van Proosdij 2013).

Romieu et al. (2010) examined the literature on the evaluation of the vulnerability of coastal zones, dividing these writings into two categories: one deals with risks associated with climate change, and the other concerns natural hazards at large (floods, storms, rising sea levels). They found that the studies focused on climate change have more of a long-term vision when analyzing vulnerability. Dupuis and Biesbroek (2013) conducted a comparative study of writings on CCA and the evaluation of CCA measures. The conclusions suggest that the methods used to evaluate the effectiveness and effects of CCA initiatives using valid indicators are inconsistent in the literature and face conceptual limitations. They therefore argue that the measurement of the effect of CCA measures should not be limited only to ex post evaluations, since adaptation measures are also designed to prevent future risks, which is complex to evaluate when the anticipated negative impacts have not yet manifested. In this context, the authors suggest viewing ex post analyses in conjunction with ex ante analyses, and to compare countries or regions with similar characteristics to highlight the most effective policies (Dupuis and Biesbroek 2013).

Because of the inherent methodological difficulties in evaluating CCA measures, several studies point to the need to analyze the processes in which policies are developed, including their goals and success factors. However, these studies hardly mention the design of indicators for this type of analysis.

Multi-criteria analyses are drawing renewed interest for CCA in coastal zones. Clearly, these analyses require a battery of indicators in order to be able to yield a selection and evaluation of CCA options for coastal zones. de Bruin et al. (2009) use the multi-criteria method to examine a number of options retained to advance CCA efforts in coastal zones, and list five types of criteria based on measurable indicators: (i) the importance of the expected gross impacts; (ii) the urgency associated with the reviewed interventions, (iii) the no-regret features of the options considered (meaning that the options are useful even in the absence of climate risk), (iv) indirect beneficial impacts on other sectors and geographical areas, and (v) effects beneficial to climate change mitigation (e.g., reducing greenhouse gas emissions). Each criterion is supported by a multitude of measurable and often demanding empirical indicators. The process of selecting the options to be applied

to these multi-criteria analyses is, in turn, subject to a review composed of five steps: (1) identification of options on the basis of consultation with stakeholders, (2) qualitative examination of the options; (3) definition by experts of the criteria used to rank the options; (4) creation of scores for the options based on the selected criteria, (5) determination of the relative weights of the criteria and their indicators for classification purposes; and (6) interpretation and classification for decision-making purposes.

Bosello and De Cian (2014) conducted an extensive review of the methods recommended in the literature for CCA indicators in coastal zones. They first identified the exposure and vulnerability indicators, which take into account the elements exposed to risks associated with the negative impacts of climate change. Overall, they identified two main methodological approaches for measuring vulnerability to climate change in coastal zones:

- The Global Vulnerability Assessment (GVA) introduced by the IPCC to assesses the vulnerability of coastal zones to rising sea levels. The indicator takes into account mainly the level of exposure and risk in the study area and vulnerability has three components: exposure, sensitivity and adaptive capacity. It takes into account the population at risk (PaR) on the basis of the frequency of flooding due to climate change in the study area, protection standards in place, and population density. This indicator led to the creation of a global database for calculating the exposure and protection of coastal zones. Nicholls et al. (1999) improved the indicator by creating GVA1, which takes into account the evolution of the population, GDP and its exposure to climate change. In 2014, the authors extended the forecast of this database to the year 2080 (Bosello and De Cian 2014).
- The Dynamic Interactive Vulnerability Assessment (DIVA) measures exposure and vulnerability by adding an algorithm allowing to determine the optimal adaptation on the basis of the cost–benefit ratio. It is based on an extensive database of climate and socio-economic scenarios (Romieu et al. 2010). Hinkel (2010) developed this database that gathers the following types of information on the coastal topography: altitude, type of geomorphology, tidal range, type of terrain; as well as the population, protection status, and wetlands. It allows for the creation of a model structured into modules for performing vulnerability analyses according to different levels of adaptation (Bosello and De Cian 2014). This innovative and interactive database thus allows to integrate knowledge from different disciplines on coastal systems.

DIVA has the advantage of being flexible and including a vast range of data. Nevertheless, it is limited in that it is poorly suited to measuring vulnerability in local or regional contexts. Given its accessibility, DIVA is now among the most used estimation indicators of vulnerability in political, academic and scientific research.

Torresan et al. (2008) examined DIVA and confirmed its limited effectiveness in the analysis at the regional level. For this, they conducted an extensive investigation to identify indicators that are relevant for regional studies or smaller territories. They first identified the indicator *Aera X*, which allows to assess the vulnerability of

coastal zones to flooding and other risks due to rising sea levels. The indicator is particularly useful for identifying the needs for protecting infrastructures in areas at risk. It takes into account the total area of square kilometers of a coastal territory under study. The authors also identified the coastal slope indicator, which measures the topographic slope of an area in degrees. This indicator also aims to estimate the risk of flooding of an area. Furthermore, the indicator of the wetland migratory potential estimates the vulnerability of ecosystems to rising sea levels. It is especially useful for decision-making in the context of urban development and regional coastal management. It includes geographical and geological elements (Torresan et al. 2008).

Leaving GVA and DIVA, Brenner (2008) discussed ways to assess the effectiveness and vulnerability of coastal zones due to climate change in relation to socio-economic variables. The author presents the indicator Geographic Information Systems (GIS) which, given the complexity of coastal regions, takes into account data from the geological, physical, chemical, biological, social, economic and political domains (Brenner et al. 2008).

United Nations University (UNU) published in 2014 the World Risk Report (WRR), which aims to systematically estimate the vulnerability of countries by studying their exposure to risks related to climate change and classifying their sensitivity to natural disasters. The report, which covers 171 countries, built its ranking from many external and internal factors. The WorldRiskIndex is calculated using 28 indicators for which the data are available worldwide and accessible to the public. Overall, this index is constructed from four elements: exposure, susceptibility, coping capacities and adaptive capacities. The WorldRiskIndex is calculated by multiplying the vulnerability index by the susceptibility index, the latter of which takes into account the coping and adaptive capacities.

Acosta et al. (2013) developed an interesting model for assessing CCA capacity in Europe and exposing the evolution of these adaptive capacities over time. The model is based on the conceptualization of vulnerability of the IPCC and combines forecasts and scenarios of climate change impacts in order to build a quantitative and static index of the vulnerability to climate change of European states. To determine the indicators to be considered in their model, the authors based themselves on the literature on adaptive capacities to climate change and on the socio-economic variables associated with them.

First, their adaptive capacities model by country is based on three levels of aggregation. The first level concerns the determinants of adaptation and has six components: equity, knowledge, technology, infrastructure, flexibility and economic power. The second level concerns the components awareness, ability and action. The third level of aggregation is adaptive capacity. On the basis of these aggregate levels, the authors integrated 12 indicators into their model.

This model of indicators has the advantage of including a wide range of socio-economic data and is therefore a useful tool for identifying the regions that are the most vulnerable to climate change. Thus, the vulnerability index generated by this model allows decision-makers to target the areas and regions that are the most at risk when implementing adaptation measures and channeling resources. By contrast, as the model estimates are based on long-term forecasts, the results generated

do not target specific adaptation measures to be implemented. In sum, these authors emphasize the need to develop a better theoretical understanding of adaptive capacity in a regional context, which would involve conducting empirical research and meta-analyses targeting different regions and economic sectors (Acosta et al. 2013).

Governance and CCA Indicators in Coastal Zones

The fourth part of this analysis focuses on the governance in CCA, and more specifically on the concept of Integrated Coastal Zone Management (ICZM) and the role of stakeholders in this process. ICZM is a process that initially emerged from the 1992 Rio Summit and that was later taken up by the European Commission in a set of policy recommendations and opinions. The integrated management approach aims to take into account the environmental, economic and social aspects of a coastal territory. ICZM is a governance tool allowing coastal territories to deal with climate change and become more oriented towards sustainable development (Tang et al. 2011).

According to Hewett and Fletcher (2010), ICZM is a dominant paradigm for the management of coastal zones internationally. The authors conducted a case study of the United Kingdom, where ICZM actions have been taken since the early 1990s. Overall, the authors demonstrated clear benefits of ICZM, including: its role of consultation between the different sectors and decision-making levels; its ability to promote the participation of stakeholders and citizens; the fact that it promotes information exchange as well as conflict resolution and consensus building; its positive effect on the promotion of adaptation projects and their financing; and the creation of channels for exchanges between local and higher levels of governments (Hewett and Fletcher 2010).

However, several studies show that ICZM, despite its positive effects on partnership-building and decision-making processes, does have a significant limit, namely a fragility and dependence on shorter-term funding, making it vulnerable to contingencies. Indeed, partnerships initiated under ICZM are generally informal and therefore face difficulties in obtaining the necessary resources to remain viable (Hewett and Fletcher 2010).

Tang et al. (2011) also addressed this issue in the context of a larger study of the performance of ICZM strategies at the national and local levels. Their research evaluates the quality and results of 53 counties on the Pacific coast of the United States. The results of this study provide interesting details about the pitfalls of ICZM and also about the factors contributing to the success of this management approach. First, management plans and planning of coastal zones should clearly and consistently identify all the standards concerning this type of environment, allowing to integrate ICZM in a strong legal framework. This plan should also include a review of all the resources and environmentally sensitive areas. In addition, it must take into account the socio-economic context of the zone, and the elements considered essential for citizens, such as infrastructure, economic

development projects and water quality. Finally, it must include extremely rigorous forecasts of the anticipated impacts of climate change (Tang et al. 2011).

Recent research shows that network governance is the approach that has the most success when it comes to CCA. Indeed, network governance promotes an efficient framework in a context like CCA that is characterized by a high level of risk and complexity. This mode of governance allows to manage the constraints brought by a large number of stakeholders at different levels.

In a survey conducted with 138 respondents in charge of CCA plans in the United States, Kettle and Dow (2014) showed that CCA plans adopted at the local and national levels identify potential risks associated with climate change but fail to identify strategies for the implementation and evaluation of the results of the CCA measures. These results confirm the findings of other studies showing that ICZM initiatives have limitations in terms of M&E. This, together with a lack of human and material resources for their implementation, impedes the adoption of adaptation strategies. In addition, entities often find themselves at an impasse due to substantial differences between the levels of government, representing a barrier to adaptation. The authors recommend the adoption of strategies favoring a better synergy between the various government agencies and the stakeholders in order to better allocate resources and risks. Network governance is presented as a possible solution to promote strategies that respect the priorities established at the national level while respecting the needs of different coastal regions. The researchers also call for more leadership from national governments to establish criteria for ranking priorities in each milieu and to accompany the various entities in the design, implementation and evaluation of their CCA initiatives (Kettle and Dow 2014).

Lemieux et al.'s (2013) conclusions, pointing in this same direction, also underline the need for measures to increase the transparency and accountability of agencies or organizations in charge of CCA strategies. This process of adopting such measures should be institutionalized, while also being dynamic, by offering guidelines, strategies and follow-ups in a sporadic manner. Obviously, the effectiveness of adaptation depends on additional factors, such as population density of the affected coastal region, and on the resources available to persons in charge of CCA to develop and implement strategies (Bradley et al. 2015).

Conclusions

This scoping review has highlighted the fact that the conceptual framework for CCA remains fragmented given the different scientific approaches and disciplines. The studies included in this analysis demonstrate that the lack of consensus about CCA and about the indicators designed to assess CCA initiatives is a major limitation in coastal zone management. A number of authors working in this relatively recent area of scientific research have proposed ways to address these limitations.

One way is to harmonize the practices for analyzing human and environmental systems respectively, both in the fields of the social and the natural sciences. The creation of better channels of exchange within the scientific community should also be prioritized, be it with regard to the transfer of data, knowledge or methodological guidelines. As each of these domains are facing complex issues, with anticipated impacts that are uncertain and extended over a long time horizon, they should collaborate to facilitate interaction and synergy. In that sense, vulnerability is a common concept that can serve as a basis for designing better CCA policies through a knowledge transfer process (Romieu et al. 2010).

The meta-analysis conducted by Hofmann et al. (2011) highlights the limits of the scientific literature on CCA, including the question of the quantification of impacts and the design of vulnerability indicators. As CCA initiatives require significant resources, the production of reliable data and recognized indicators is essential to allow for the *ex ante* and *ex post* evaluation of these initiatives.

In terms of governance, it appears that network management is the most effective method in the context of social and environmental change. Woodland and Hutton (2012) have discussed the importance of inter-organizational collaboration and have reiterated its expediency for solving complex public issues such as climate change. Indeed, their work has demonstrated that when an issue is at once political, social and economic, a collaborative approach is more effective. They developed a model outlining the criteria to be taken into account when assessing the action of a network: "(1) Operationalizing the construct of collaboration; (2) Identifying and mapping alliance teams and groups; (3) Monitoring stage/stages of development; (4) Assessing levels of integration; and (5) Assessing cycles of inquiry in high-leverage teams" (Woodland and Hutton 2012: 381). Jørgensen (2006) likewise addressed the importance of fostering partnerships between public, private and non-governmental organizations (NGOs) to address the challenges of climate change, and also assessed the effectiveness of this network collaboration for developing best practices.

In terms of indicators, this study shows that in a national and international context, the WorldRiskIndex provides a useful estimate of the vulnerability of countries with respect to the effects of climate change in a context of rapid urbanization. In addition, the DIVA has the advantage of being accessible and flexible and of including a considerable amount of data. Its integrated model allows to assess the impacts of climate change as well as the costs of adaptation measures. The simulations that can be produced with this tool also have the advantage of including different scenarios and inputs. Together with the fact that it is free of charge and easily accessible, DIVA is thus an essential indicator. The Global Vulnerability Assessment (GVA), introduced by the IPCC, can also be used in a national context to measure the vulnerability of coastal zones with regard to the level of exposure and risk, namely by calculating the exposure, sensitivity and adaptive capacity. The GVA1 developed by Nicholls et al. (1999) moreover allows to take into account the evolution of the population and the GDP.

In a regional context or a smaller geographical area, GIS stands out for being able to incorporate a lot of data, and to ensure the continuous update of that data.

Torresan et al. (2008), for their part, discuss other indicators used exclusively in a regional context. These provide a limited estimate of the vulnerability because they are more oriented towards the evaluation of flood risk or risks associated with the rise of water levels.

Moreover, the ICZM is an effective approach at the national level that nevertheless takes into account the regional differences in coastal zones. The studies included in this analysis also demonstrate that the process of adopting CCA measures must be transparent and participatory since they aim for both short-term and long-term objectives. As short-term risks tend to generate more concern among the public and stakeholders, governments must take swift action to implement CCA initiatives focusing on such risks. Nevertheless, the anticipated effects that extend over the long term should not be ignored either.

Thus, overall this study has shown that the systematic and consensual use of indicators in the scientific community is crucial for advancing the work of the evaluation of CCA initiatives. In a highly complex field such as climate change, the analyses of contributions associated with the realistic evaluation approach (Pawson and Tilley 2004) emerge as a possible solution in the literature. The realistic approach has the advantage of being based on the methodology of the natural sciences and allows to analyze programs in their particular context and according to the mechanisms in place. It provides a coherent framework that takes into account the role of stakeholders in the development of a program all the while maintaining enough flexibility to integrate the diversity of factors that influence the development and implementation of a policy (Pawson and Tilley 2004).

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