COMET LA

COmmunity-based Management of
EnviromenTal challenges in Latin America

SEVENTH FRAMEWORK PROGRAMME

D1.1: "Locally-adapted tools for the Characterization of Social-Ecological-Systems"

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Executive summary

COMET-LA is a research project for the benefit of the Civil Society Organizations (CSOs) aiming to identify sustainable governance models for the management of environmental challenges. The COMET-LA project emerges as a result of the collaboration of 11 partners and several local and regional stakeholders. The working method is based on the use of participatory techniques and a learning arena where scientific and local knowledge are shared and integrated. This way, it not only fosters the participation, but also the involvement of the local communities in the project, which leads to a higher level of appropriateness of the outcomes to their needs.

The project is developed around 3 Case Studies (CSs) in Colombia, Mexico and Argentina, each one analyzing environmental challenges in specific Social-Ecological Systems (SESs); water and biodiversity management is analyzed in 2 Communitarian Councils of Black Communities in the Colombian Pacific, forest management in a community of the Mexican Sierra of Oaxaca, and marine and coastal area management in the Argentinean Bahia Blanca Estuary.

A comprehensive characterization of the SESs is a key stage to identify sustainable governance models. This report summarizes the results of Task 1.1: Adaptation of Social-Ecological System Characterization Frameworks to the local conditions (included in COMET-LA WP1) and presents the work developed to deliver a locally-adapted methodological framework for the characterization of SESs applicable on different scales.

The framework proposed by COMET-LA, is adapted from Elinor Ostrom´s, and based on her 8 core sub-systems and 53 variables (considered as second-level variables) to characterize SESs (Ostrom, 2009). However, the Ostrom framework is analytical, not methodological, so adaptations were necessary for improving the framework's applicability.

A good definition of all second tier variables and the expansion of some of them in third tier variables can be mentioned as key changes to the Ostrom framework for improving the practical applicability.

The report also includes guidelines for gathering the information needed to define the third level variables being among others the level on which the data should be found (local, regional or (inter)national), where and how the information can be obtained and in which format it should be delivered (numerical, descriptive, geographical or analytical).

Additionally, some of the problems raised while gathering the data related to the level on which the data should be looked for, the quality of the data, the difficulty in understanding the concept expressed by the variables, or the subjectivity of the information, have been listed. Therefore, future applications of the adapted framework can be prepared taking these issues into account.

The whole process of adapting and applying the Ostrom framework at a local level has set in motion an interesting methodological learning process involving researchers and local

stakeholders. The adapted framework came about through collaboration among COMET-LA partners and local stakeholders during and throughout SES characterization workshops. This use of participatory techniques and the building of the COMET-LA learning arena as a communication and knowledge platform in the CSs, has opened a space for interaction between scientists and civil society, and for debate on the main issues at stake in each of the SES.

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List of abbreviations

CBNRM	Community-Based Natural Resources Management
COMET-LA	COmmunity-based Management of EnviromenTal challenges in Latin America
CPR	Common Pool Resources
CS	Case Study
CSO	Civil Society Organization
DB	Database(s)
IADO	Instituto Argentino de Oceanografía
NGO	Non-Governmental Organization
PUJ	Pontificia Universidad Javeriana (Colombia)
SES	Social-Ecological System
SGM	Sagremarisco-Viveiros de Marisco Lda.
UCO	University of Cordoba (Spain)

1 Introduction

COMET-LA is a research project for the benefit of the Civil Society Organizations (CSOs). The call the project answers to the proposition that "*given access to and control of their own resources, local community members can create and enforce original rules that lead to successful and sustainable economic governance models*". Thus, it calls for "*partnerships between civil society and research organizations with a view to identify and analyze locally owned and developed solutions put in place to prevent and resolve tensions arising from a necessary new repartition and use of natural resources, including ecosystem services, due to environmental and climate changes*".

The expected impact is described as "*enhancing the understanding and knowledge of local sustainable economic governance models of natural resources, and supporting the identification and implementation of means of resolving local tensions arising from new repartition and use of natural resources*".

In this scenario, COMET-LA's overall objective is "*to identify sustainable governance models for the management of environmental challenges*", using participatory techniques and building a learning arena where scientific and local knowledge are shared and integrated. This working method fosters not only the participation, but the involvement of the local communities in the project and the appropriateness of the outcomes to their needs.

Environmental problems are acknowledged to be complex situations because they bottle up the high dynamic interactions between natural systems and social systems. Natural resource governance is challenging due to the need to understand the 'complex systems' involved in it (social conditions, diverse stakeholders, economic interests, diverse perceptions, individual beliefs and the natural resources themselves).

A Social-Ecological System (SES) is a complex, adaptive system or assemblage of a bio-geophysical unit and its associated social actors and institutions (Berkes and others, 2003; Glaser and others, 2012). The concept "social-ecological systems" is well accepted nowadays and it is used to emphasize that stressing the delineation between social and ecological systems is artificial and can only respond to an arbitrary object study selection (Berkes and others, 2000). A social-ecological system is a complex adaptive system (Holland, 1992) in which different sub-systems (either ecological or social) interact in a strong linked performance. Thus, once their units are integrated, their structures and mechanisms interact in an interdependent fashion. Similarly, SESs can be described as sets of actors (representing not only individuals, but also historical processes, economical forces and institutional perspectives) (Norberg and others, 2008) who share a space or structure (a geographical space, an ecosystem, a social network, a market, etc.) (Hahn and others, 2008), are interdependent (Berkes and Folke, 1998; Gunderson and Holling, 2001) and their relations cannot be linearly described.

To reach the abovementioned objective, different work phases are proposed. The first one is the characterization of the SESs present in the 3 COMET-LA Case Studies (CSs). The environmental challenges present in each of these CSs are considered to be representative of

some of the main current environmental challenges. Namely, the management of water and biodiversity is analyzed in 2 Councils of Black Communities in the Colombian Pacific, the management of forest in a community of the Mexican Sierra of Oaxaca and the management of marine and coastal areas in the Argentinean Bahia Blanca Estuary. Each CS aims to identify sustainable governance models focused on these challenges.

This report summarizes the results of Task 1.1: *Adaptation of Social-Ecological System Characterization Frameworks to the local conditions* and presents the work developed during the first 16 months of the project to deliver a locally-adapted methodology for the characterization of SESs in 5 sections. The different tools and methodological approaches proposed, developed and adapted have been tested in the CSs and the problems found, the necessary adaptations and the learnt lessons shared among the different partners.

The results of each SES characterization are part of deliverables D2.2 (Stakeholder vision on problems and drivers related to environmental challenges in Colombia Case Study), D3.2 (Stakeholder vision on problems and drivers related to environmental challenges in Mexico Case Study) and D4.2 (Stakeholder vision on problems and drivers related to environmental challenges in Argentina Case Study) elaborated respectively by the Colombian, Mexican and Argentinean teams and available at COMET-LA website. D1.1 includes the framework proposed and the methodological learning derived from the discussion of different frameworks, tools and techniques and their application in the 3 CSs, highlighting the advantages and the difficulties found in the process and proposing some guidelines to overcome them.

The first step to embark upon the characterization of SES has been a review of the conceptual basis of COMET-LA to better understand the underlying principles. Through a thorough literature review, the foundations, shortfalls, and latest developments in Community-Based Natural Resources Management (CBNRM), SES and the creation of participatory learning arenas have been described. This review has provided an understanding of the problems affecting these approaches and the main points and techniques to focus on when defining a locally-adapted working method for the characterization of SESs. Section 2 provides a summary of the results.

The second step has been a review of different frameworks characterizing SES and evaluating SES sustainability. In the accepted project proposal, the framework designed by Elinor Ostrom (2009) to analyze SESs was proposed as central part of the methodology. However, an introduction to other frameworks and methodologies has been done to confirm that Ostrom's framework is the most adapted to COMET-LA objectives and to strengthen its potential weaknesses with inputs (indicators, variables and factors) from other methods. The results of this analysis are presented in section 3.

Thereafter, Section 4 presents the main contribution of this task: adapting Ostrom's framework for use at local level. Ostrom proposed a framework based on 8 core sub-systems and 53 variables (considered as second-level variables). She left open the option to chose other second tier variables or add a deeper level of variables according to the particularities of the analyzed SES (Ostrom, 2009).

However, the Ostrom framework is an analytical one, not a methodological one. When applying the framework to COMET-LA's CSs, the second tier variables were rather broad and diffuse. So these variables should be defined and many of them should be expanded in a set of deeper level variables (named third tier variables) to allow a better comprehension and characterization of the analyzed SES. Hence, the main contribution of this report is to present the adaptations undertaken to deliver a methodological framework for the characterization of SESs useful at a local level and applicable at different scales.

Section 5 compiles some guidelines to facilitate the descriptions of the third tier variables like the expected type of information, the level to analyze each variable, the information sources and the research tools that can be used. The main problems found when searching for this information at local level, have also been underlined.

The necessary developments and decisions taken to adapt the framework to the local level, after testing it in the three CSs are documented throughout sections 4 & 5. The encountered problems, the necessary adaptations and the solutions put into practice are an essential contribution of this report and are summarized in the Conclusion Section.

Finally, Annex I assembles the variables and tools for characterizing SESs at local level. The Annexes II, III, IV and V summarize other tools developed by COMET-LA valuable for characterizing SESs at local level, like stakeholder mapping, participatory and gender approaches, and tools for measuring climate variability.

2 Conceptual basis of COMET-LA

COMET-LA is founded on the community-based management of environmental challenges in different Social-Ecological Systems[1] (SESs), using a participatory learning arena. A literature review of these approaches for extracting information and lessons of interest for the characterization of SES is presented in this Section.

2.1 Community-Based Natural Resource Management

The natural resources analyzed by COMET-LA are either open access or common-pool resources (CPR). Both types of resources can be referred as "commons". This term is informally used to refer to public goods, CPR, or any area with uncertain property rights (McGinnis, 2011). Commons share two characteristics: *excludability* (the control of access of potential users is difficult) and *subtractability* (each user is capable of subtracting from the welfare of others). The study of the "commons" has been a flourishing research topic over the last decades, not only because of the importance of common resources like land, water or biodiversity for society but also because of the challenges that the management of commons imply for many research disciplines.

Hardin formulated in 1968 his well-known *tragedy of the commons*: whenever a group of people depend on a resource that everybody uses but nobody owns, and where one person's

[1] More information about the theoretical foundation of Social-Ecological Systems (SESs) will be given in the next section.

use affects another person's ability to use the resource, either the population fails to contribute to the resource or overconsumes and/or fails to replenish it. They never invest time and energy to manage sustainably the resources using collective action.

However, Ostrom (2009) found that even if until recently, accepted theory assumed that resource users would never self-organize to maintain their common resources and therefore governments must impose solutions, empirical research concluded that some government policies accelerated resource destruction, whereas some resource users have invested their time and energy to achieve sustainability. When local community members have access to, and control of, their resources, they often create and enforce rules that lead to successful and sustainable economic governance models. However, the sustainable governance of commons requires institutional arrangements and adaptive governance systems recognized across scales (Dietz and others, 2003).

Community-Based Natural Resource Management approach has been often considered as a suitable approach to govern commons. The approach evolved over the past two decades as an alternative approach to top-down strategies in Natural Resource Management. There is no single definition of CBNRM, but Western and Wright (1994:7) provided the following seminal definition of community-based conservation: "it includes natural resources or biodiversity protection by, for, and with the local community".

The central idea in the concept is "the coexistence of people and nature, as distinct from protectionism and the segregation of people and nature" (Western and Wright, 1994:8). Its major components are: (1) local stakeholder involvement, (2) public participation and (3) inter-organizational collaboration. These principles will allow local communities to overcome the inherent biases and limitations in the traditional environmental planning model through incorporating the ideas, knowledge, energy, and assistance of local people (Berkes, 2007).

The approach seeks to encourage better resource management outcomes with the full participation of communities and resource users in decision-making activities, and the incorporation of local institutions, customary practices, and knowledge systems in management, regulatory, and enforcement processes (Pomeroy, 1996; Borrini-Feyerband, 1996; Barrett and others, 2001, quoted in Armitage, 2005). CBNRM efforts are based on assumptions that communities and community-based organizations closely connected to natural resources are most likely to foster sustainable resource use and possess the knowledge required to do so (Blaikie, 2006). It assumes that place-based and contextualized analyses are required to build a better understanding of the socio-institutional conditions, risks, and interdependencies that shape prospects for adaptation and sustainable management (Armitage, 2005).

CBNRM seeks to establish a direct linkage between conservation and local benefits. Involving local communities in conservation is often used as a means of making conservation measures less likely to meet local resistance. Conversely, protecting the productivity of a resource may be used as a means to enhance local livelihoods and development options. Thus, it emphasizes collaborative, deliberate, programmatic, decentralized, democratic, inter-disciplinary, and adaptive, dynamic decision processes (Lane and McDonald, 2005; Lurie and Hibbard, 2008).

These approaches are appealing because they link the concerns of conservationists, traditional rights advocates, and political reformers, including social equity, traditional resource access and use rights, local economic development and livelihoods, alternative forms of state–community relationships, and the promise of environmental conservation (Brosius and others, 1998; Kellert and others, 2000; Barrett and others, 2001 quoted in Armitage, 2005).

However, today many authors illustrate that CBNRM approach is not a panacea (Berkes, 2007). It is possible to find examples of effective and equitable outcomes of community-based conservation initiatives (e.g. Matzke and Nabane, 1996), but also unsuccessful results (e.g. Lund and Treue, 2008). Some examples of the main problems CBNRM faces:

- *Tendency to strategic simplifications* (Li, 2002; Agrawal and Gibson, 1999). Some usual simplifications are: considering "communities" as homogenous units with shared goals and values and to not recognize the nuances of ownership and access to different types of resources (and even elements within a particular resource) at different times of the year in the local property rights view.
- *Idealized notions of traditional resource use systems and livelihood strategies accepted as inherently sustainable* (McCay and Jentoft, 1998; Brosius and others, 1998; Kellert and others, 2000; Barrett and others, 2001). Indigenous or community management is not intrinsically sustainable. Resource-based rural communities, especially indigenous ones, have always challenged the claims of the state over their resources. But can communities conserve? Does community-based conservation work? "Are indigenous people conservationists?" (Berkes, 2004).
- *Partnership is more than participation* as used in most conservation projects of the past. The application of CBNRM principles does not simply lead to an active participation process and to effective responses for local environmental conservation planning. Many times, participants in the CBNRM are still passive recipients of environmental conservation projects (Tang and Zhao, 2011). Tang and Brody (2009) pointed out that public participation itself does not automatically lead to good planning results. Moreover, the concept of collaborative planning is "quite difficult to translate into reality" because it actually takes time and experience. Ineffective communication and insufficient trust among stakeholders can be important barriers to effective CBNRM decisions (Ryan and Klug, 2005).
- *Conflicts of interests*: Not clearly bounded social or geographic units in the SES are likely to have conflicting interests. Different users and stakeholders can take advantages of fuzzy boundaries about time, procedures, norms and scales on natural resources and privately benefit from them. The complexity of decision-making processes integrating environmental and social spheres makes the SESs arenas open to conflict (Galaz, 2005; Waylen *et al.*, 2013).
- *External recognition and respect of community rules*: Commons institutions face the challenge of functioning across levels and deal with trade-offs. Very

often these institutions are not recognized by higher governmental levels nor respected by external actors. Thus, communities have few options to control and sanction the actions of externals.

- *Linking development and conservation*: Despite being one of the bases of CBNRM, one of the main concerns is to ensure how local people reap the benefit of their own management actions so that conservation incentives can be maintained.
- *External pressures to community-based management*. Increasing commodification, privatization, and the extension of capitalist systems of production in even the most remote of regions generate changing patterns of resource use and access rights. These changes and the uncertainties they create affect performance because they influence the social processes and institutional forms that shape the collective action and the capacity for communities and community based organizations to adapt (Armitage, 2005). Furthermore, there are community members who are increasingly external to formal community-based management processes and who have different interests regarding the use and commercialization of resources. They bring changing norms, values, and world views about property rights that increase the potential problems and sources of conflict within formerly subsistence-based communities (Dahl, 2000, quoted in Armitage, 2005).

Despite these critics, CBNRM is an increasingly used approach and several research contributions to provide the basis for its effective use can be found in the literature. There is a need for more evidence on how to maximize the chances for success. COMET-LA expects to contribute to this debate.

Research states that more attention should be given to local socio-economic characteristics as well as to broader socio-political influences (e.g. Brechin and others, 2002), and to more insight from both the natural and social sciences (Adams, 2007). The engagement with the local cultural and institutional context, local participation and capacity building has been proven important (Waylen and others, 2010). Social factors external to communities (such as market links) have been shown also to affect social and conservation outcomes (Brooks and others, 2006). A focus on adaptive capacity can help to establish where certain tasks should be undertaken by extra-local authorities and where community-based organizations should play a lead role. Finally, important variables influencing CBNRM effectiveness are group size and homogeneity, benefit and cost distribution mechanisms, land tenure, partnerships, traditional leadership, ecological status of resources and the existence of monitoring systems (Armitage, 2005).

In summary, all the criticisms and recommendations for improving CBNMR implicitly suggest that a systems approach is needed. Ostrom's framework, through the use of Social-Ecological systems (SESs), is such a systems approach that facilitates interconnecting the multiple, exogenous and endogenous factors affecting successful CBNRM strategies. These factors and their interactions have been considered when choosing the different variables included in the SES characterization framework proposed by COMET-LA. How they affect the performance of the SES has been analyzed in each case study (CS).

2.2 Social-Ecological Systems approach

Berkes and Folke (1998) introduced the concept of social-ecological systems (SES) to describe the need of linking social and ecological systems for building resilience. Indeed, successful Natural Resource Management requires recognition that it is impossible to understand nature without society, and vice versa. Both are part of complex and highly dynamic SES that evolves, often in unexpected or non-linear ways, according to the human and natural interventions they undergo (Nelson and others, 2007).

However, this system approach is not necessarily innovative or new. The need to couple society and environment has a long tradition among scholars and the SES concept can be considered as an evolution of other definitions such as "human-environmental systems" or "ecosocial systems" (Berkes and Folke, 1998; Berkes and others, 2000; Gunderson and Holling, 2001; Glaser and others, 2012; Stokols and others, 2013).

More recently Glaser and others (2012) have provided a working definition of SESs: "A social-ecological system consists of a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive, and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context." SESs are understood to be concrete units in the real world of spatial-temporal phenomena. It is also possible to understand SESs as models of knowledge about real-world phenomena.

Social and ecological systems are dynamic and change over time, but are inextricably linked forming integrated SESs. As linked social and ecological systems co-evolve they display characteristics of what have been described as complex adaptive systems (Berkes and others, 2003). Complex adaptive systems are systems in which lower level components interact in ways that result in emergent patterns at higher levels during one period. These emergent higher-level patterns then feed back to influence future lower level interactions for the next round of interactions. Other characteristics of these systems are high levels of uncertainty, nonlinearity, multiple equilibria and cross scale interactions (Berkes and others, 2003).

The concept "social-ecological systems" is now widely accepted and used in the analysis of natural resources management. An interesting definition of SESs for COMET-LA is proposed by Janssen and Anderies (2007): A SES can be described as a structure composed of a common-pool resource (CPR), its users and an associated governance system. This definition emphasizes that the separation between social and ecological systems is artificial and can only respond to arbitrary object study selection (Folke and others, 2005).

Berkes and Folke (1998) proposed to use the ecosystem perspective including explicitly humans, or the so-called "social system" and avoiding the barriers imposed for traditional disciplines to understand human-environmental interactions. All humanly used resources are embedded in complex SESs that are composed of multiple subsystems and internal variables within these subsystems at multiple levels analogous to organisms composed of organs, organs of tissues, tissues of cells, cells of proteins, etc. In a complex SES, subsystems are relatively separable but interact to produce outcomes at the SES level, which in turn feed back to affect these subsystems and their components, as well other larger or smaller SES (Ostrom, 2009).

This complexity makes it difficult to understand the functioning of SESs. Environment and natural resources condition and simultaneously are conditioned by the actions exerted by the population (Anderies and others, 2004). Simplistic and mono-dimensional approaches based on methodologies from individual disciplines fail to comprehend the complexity of SESs.

Understanding and predicting appropriate management responses is made more difficult by an incomplete knowledge of these complex and variable SESs, by limited information availability (or accessibility being prohibitively expensive or time consuming), and by uncertainties in modeling and in the response of ecosystems to both natural and human interventions.

The abovementioned supports the need of a good SES characterization framework to have a clear understanding of the factors present in it and of the interactions and outcomes derived from it. This phase is essential to identify sustainable governance models for the management of natural resources.

2.3 Developing a learning arena

The lack of a communication platform and the resulting absence of fluid communication between researchers, civil society organizations and policymakers is often one of the causes of governance problems in natural resource management. In order for such a platform to function fully, some basic conditions have to be met, like the use of participatory, bottom-up approaches, of a common language, etc. In this part, a scientific brainstorming takes place on how to organize such a platform, a learning arena.

Participatory approaches involving all stakeholders ensure higher quality decisions (Reed, 2008). However, developing a good level of understanding and comfort is very time and effort consuming. Some main criticisms to public participation are: i) the costs are not justified by the benefits; ii) the participants can be ill-equipped to deal with the complex nature of analysis, and iii) the participation processes seldom achieve equity in the process (Dietz and Stern, 2008).

As different authors discussed, the interaction of researchers with local people is not an easy task due to differences of thinking, lack of mutual trust, different styles of conversation and discussion, differences in views and power or relevance of the outputs for each part (Huntington and others, 2002; Davidson-Hunt and O'Flaherty, 2007; Reed, 2008, Gray and others, 2012; Burford and others, 2013).

The integration of knowledge is also a controversial issue. The advantages of knowledge integration are highlighted by different authors (Agrawal, 1995, 2002; Sillitoe, 1998; Nygren, 1999; Bruckmeier and Tovey, 2008, 2009 quoted in Raymond and others, 2010). Nevertheless, it also has important costs like the increasing complexity that complicate the interpretation of knowledge (Gray and others, 2012) or the difficulty to do not privilege one of these knowledge over the other.

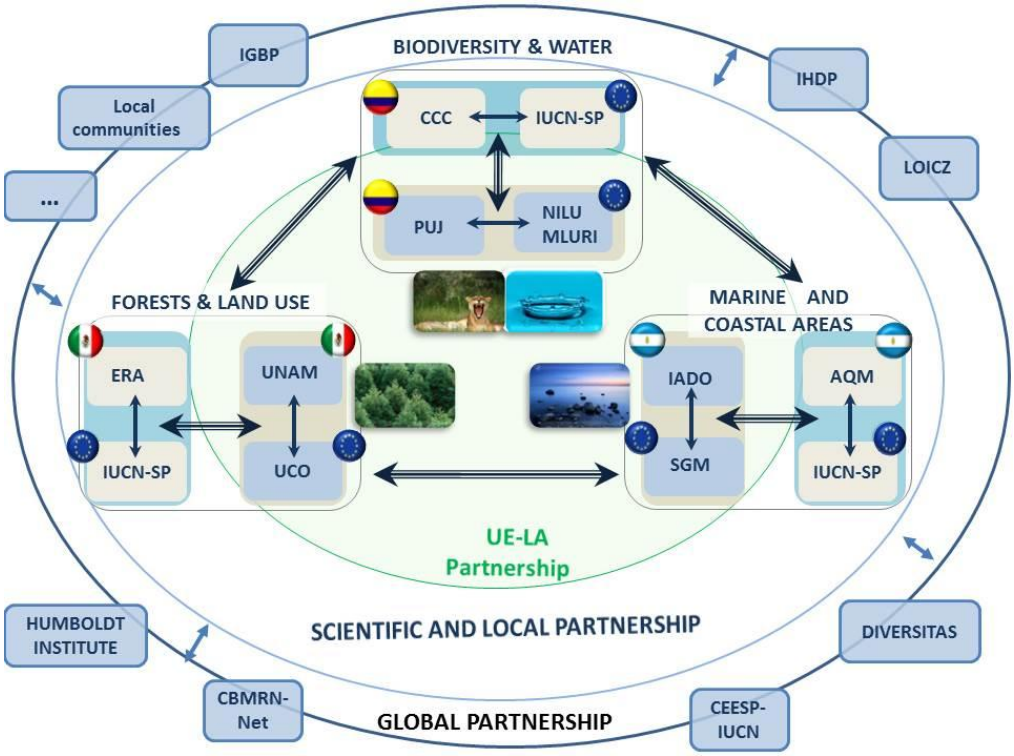
COMET-LA aims to rethink and innovate the methods for sharing and applying knowledge. It proposes the creation of a participatory learning arena where civil society and research organizations, stakeholders and policymakers can interact and share knowledge to analyze

and discuss the situation of the SES and to identify CBNRM practices and lessons of mutual interest. Bottom-up and participatory approaches are thus necessary to ensure the full engagement and representation of local people. The so-called learning arena is conceived as a space where to identify good CBMNR practices and to enable sustainable adaptation and governance of SESs.

The goals for the COMET-LA's learning arena are: i) to provide a space for participation and interaction between researchers, local communities and policymakers, and ii) to create a partnership that integrates scientific and local knowledge in Natural Resource Management, but also involves policymakers and decision-takers. As a result, scientists can support management by targeting their research and provide managers and local communities with understandable and useful information to take decisions. Likewise, the sustainable community-based models and local perceptions can also be integrated in the management of environmental and climate changes.

However, the settling of the learning arena faced important challenges. Literature has been reviewed to explore aspects such as participatory methods, methodologies to foster local-scientific interactions, to integrate social and scientific knowledge, and to link knowledge to action. The results of this work and of its applications at local level in the three CSs will be presented in a future deliverable. However, some notions of interest to locally characterize SESs are included in this report (see Annexes III and IV).

Figure 1. The structure of COMET-LA's learning arena.



Source: Own elaboration.

The learning arena should be built as a cross-cultural setting for interaction, in which the important stakeholders at different levels are included (see Annex II), where time and effort is

given to create mutual trust and where participatory methods are carefully selected to allow optimal integration of all participants and to include all views and perceptions in a way that does not privilege any at another one's expense.

Different participatory methods and approaches have been reviewed and used in the CSs. Pontificia Universidad Javeriana (PUJ) has an acknowledged background and expertise on these issues and has supported the learning arena with information and documents to enhance the use of these methods (see Annex III). The participatory methods mostly used to work with local stakeholders in the characterization of SESs have been workshops, focus groups and interviews, however other methods like life stories, transects, field visits, matrix of norms and rules … have also been applied. Capacity building meetings in Bahia Blanca (August, 2012 and July 2013) and Cordoba (February, 2013) were delivered to strengthen team awareness of using properly the participatory research tools.

The above presented theoretical and methodological discussions have been of high interest to prepare the following guidelines that could ensure the good functioning of the COMET-LA learning arena:

- The knowledge shared in the learning arena must be salient, credible and legitimate to foster actions (Cash and others, 2002).
- The working method and the strategies to develop the learning arena have to be well-planned and the facilitators have to be well-trained (Raymond and others, 2010).
- The basis of common work includes the creation of trust and of a common language among the participants and needs a lot of time and efforts (Huntington and others, 2002).
- The rationale of participation must be focused on empowerment, equity, trust and learning opportunities for all the participants.
- The objectives and outcomes of local-scientific interactions must be clearly established and agreed by both parts, in advance.
- The participants have to know the expected outcomes of their participation and false expectations cannot be created.
- The initiatives as co-researchers' training can empower the communities.
- The different collectives (women, young people) need to be included.
- The results have to be devolved and the community's views and perceptions on them discussed.
- The process of decision-making has to be ethical, democratic and representative of the different participant visions.
- The learning arena has to be a space to build capacities and to open opportunities.
- Different methods and sources need to be used to avoid biased representation of the facts.
- The use of sophisticated scientific methodologies can prevent local stakeholders' participation, but they can be adapted to local level and results can be really satisfactory.

- Some values facilitating success are *empowerment, capacity building, trust, integrity, fairness, care and respect for communities' lifestyle and values* and *inclusiveness and non-discrimination* for all stakeholders (Burford and others, 2013).

3 Introduction to the frameworks for SES characterization

COMET-LA proposed to offer a common, classificatory framework to facilitate multidisciplinary efforts toward a better understanding of complex SESs. In order to do it, a first step has been a review and understanding of different frameworks used for this purpose. As mentioned, SESs are complex systems, thus comparing and learning from different guiding frameworks used by other scholars and research groups is a necessary exercise. The objectives of this section are:

- To offer a review of different guiding frameworks used for understand, analyze or characterize SESs
- To highlight the main attributes and analytical variables of them and their possible contribution to COMET-LA's goals.
- To explain and support why the Ostrom's framework was selected for COMET-LA.

SES characterization requires transdisciplinary and integrative approaches to keep focus on the multi-layered and complex relations among systems and sub-systems. However, understanding a complex whole requires also knowledge about specific variables and how their component parts are related (Levin, 1992, quoted in Ostrom, 2009). The aim is to dissect and harness complexity, rather than eliminate it from such systems (Axelrod and Cohen, 2001).

This process is complicated, however, because entirely different frameworks, theories, and models are used by different disciplines to analyze their parts of the complex multilevel whole. The task involves a carefully defined and explained process to define borders, variables, conditions and mechanisms. The relations cannot be described as simple cause-effect connections, but as the result of complex interactions.

The SESs approach analysis has settled two key ideas for COMET-LA objectives: 1) the need of finding solutions, strategies and proposals towards sustainability and 2) the need of governance systems for sustainable management.

According to Tretter and Halliday (2012:61) the detailed information required for understanding and defining management strategies in SESs is:

- The state of the nature and the characteristics and validity of the data used to measure it.
- The nature´s response to human disturbance (in scale and in time).
- The feedback mechanisms, enabling social systems to adapt to environmental problems.

- The nature of the response and the mechanisms involved or the specific response and adaptation processes in sub-system scales.

Over the last years, different theoretical and conceptual frameworks have been designed to guide researchers in the process of understanding linked social and ecological systems. After a deep review of different frameworks, this report presents the characteristics of the six considered as more interesting to give answer to COMET-LA goals.

1. Analytical framework to study SESs (Berkes and Folke, 1998)
2. Framework for analyzing the social-ecological resilience (Walker and others, 2002)
3. Framework to analyze the robustness of SESs (Anderies and others, 2004)
4. Framework for analyzing sustainability of SESs (Ostrom, 2009)
5. Framework for linking functional diversity to society (Diaz and others, 2011)
6. Understanding SESs as epistemic objects (Becker, 2012)

In addition to these frameworks, the options and possibilities introduced by other frameworks not specifically developed for SESs, but dealing directly or indirectly with them and with its sustainable management have been explored, namely: i) the Drivers-Pressures-State-Impact-Responses framework initially introduced by the European Environmental Agency (1999); ii) the System Approach Framework (Hopkins and others, 2011; Hopkins and others, 2012) and iii) the Sustainable Livelihood approach (Chambers, 1992). However, COMET-LA Erasmus Mundus PhD candidates will develop their usefulness and application to the CSs in their PhD thesis. The results will be part of the general synthesis of D1.4 (Policy Brief on sustainable management and governance models).

Finally, the review of other frameworks and approaches containing systems of indicators (like the Society at a Glance Indicators (OECD, 2011), the UN Sustainable Development Indicators (UN, 2007) and The Economics of Ecosystems and Biodiversity (TEEB, 2010)) have been useful to develop the third tier variables.

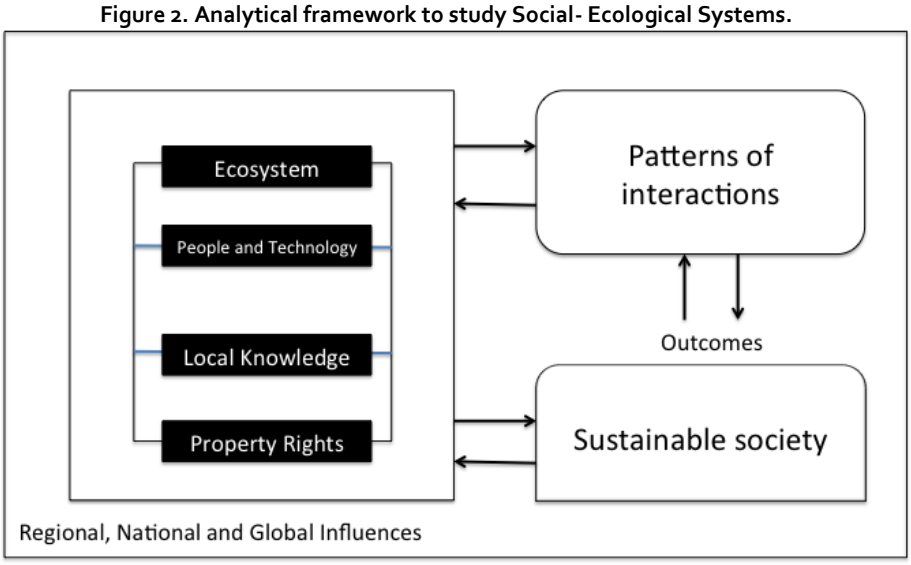
3.1 A framework for analysing the link between social and ecological systems for resilience and sustainability

In their analytical framework to study SESs, Berkes and Folke (1998) offered some of the initial steps to understand those systems. This analytical framework gathers some of the principal features used by Ostrom (1990) and Oakerson (1992) to analyze common property resources and institutional frameworks for their management (Berkes and Folke, 1998). The framework starts with four sets of elements:

- Ecosystems (freshwater, terrestrial or ocean),
- People and technology (users and the way they access and extract units from the resources),
- Local knowledge (traditional or scientific) and
- Property rights institutions (also institutional arrangements to use the natural resources).

The principal conditions to analyze the different characteristics of the SESs are the relations or patterns of interactions. They provide information about the interactive adaptive process. These adaptive processes are recognized as outcomes, and they are the principal condition to determine whether some practices and natural resources management strategies are effective for sustainability. Each set can be analyzed and explored using different types of research tools and approaches, and the result is the analysis of interactions or feedbacks.

Figure 2. Analytical framework to study Social- Ecological Systems.



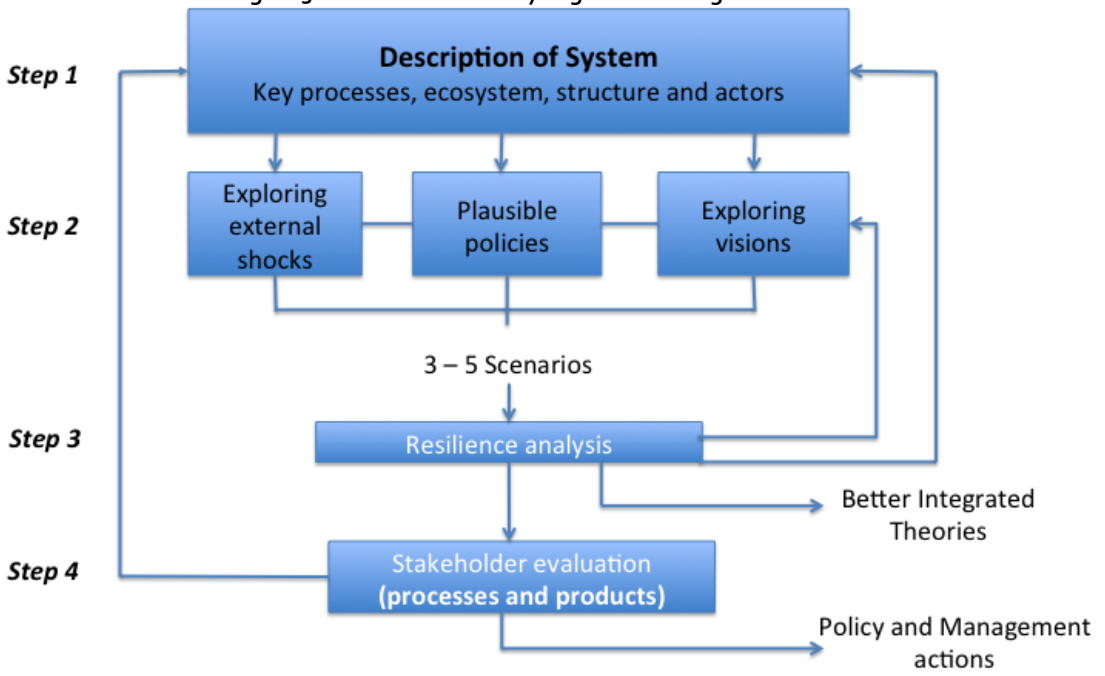
Source: Berkes and Folke 1998:15.

This framework puts the emphasis on recognizing the effects that the outcomes from the system interaction have on the sustainable management strategies. Some other scholars have proposed similar analytical frameworks but designed or adapted to analyze specific conditions or characteristics in SESs, as for instance, resilience and robustness (Folke, 2006).

3.2 Framework for analyzing social-ecological resilience

Walker and others (2002) proposed some further steps to analyze resilience in SESs. Besides analyzing the principal four features proposed by Berkes and Folke (1998) their framework proposed the design of 3 to 5 scenarios to specifically analyze the resilience of the systems and the interaction patterns among theoretical descriptions, policy needs and management strategies.

Figure 3. Framework for analyzing social-ecological resilience.



Source: Walker, and others 2002:5.

This framework emphasizes the need to involve different stakeholders in the whole process of understanding, conceptualizing and defining the SES management strategies. Also, the authors point out that it is impossible to expect that a clear boundary definition would diminish the large complexity and high uncertainty in SESs. Therefore the authors decided to focus on learning to live within systems rather than controlling them.

The resilience-centred approach to SES management makes the following assumptions:

- SESs may contain thresholds and hysteretic effects that should be assumed in managing them.
- It is necessary to find the way to determine management strategies affecting a big number of highly uncertain variables
- It is important to recognize that SES decision makers have bounded rationality and that perfect strategies to managing SESs do not exist.
- Market-oriented management and valuations are problematic in understanding SESs
- Well-defined property rights systems are not present in many important ecological goods and services.

The steps proposed in this framework are:

Step 1. Description of System: This step defines a model of the SES and is strongly based on stakeholder inputs. The conceptual model must include all the possible variables, borders and mechanisms used by different stakeholders in understanding the SESs. As an integrative model, it will help to connect different perceptions about the same SESs and to enrich possible descriptions.

The authors suggest the following questions to guide this step:

- What are the spatial boundaries of the SES?
- What are the key ecosystem services used by, and of concern to people in the SES? What do they value?
- Who are the stakeholders?
- What is the nature of the key SES components?
- What is the historical profile of the system?
- What are the principal variables of the system?
- How does the current institutional framework work?

The outcome of this first step is the information about the local situation and about the major issues of concern to stakeholders.

Step 2. Visions and scenarios: This step analyzes external disturbances (policy drivers, visions and external shocks made by stakeholders' actions) and how they could be modified, changed or eliminated in different scenarios. It generates information about how the system would respond to drivers of change.

Step 3. Resilience analysis: This step consists in integrating the information generated at the previous two steps and to explore the interaction between them. The aim is to identify possible driving variables and barriers in governing the system.

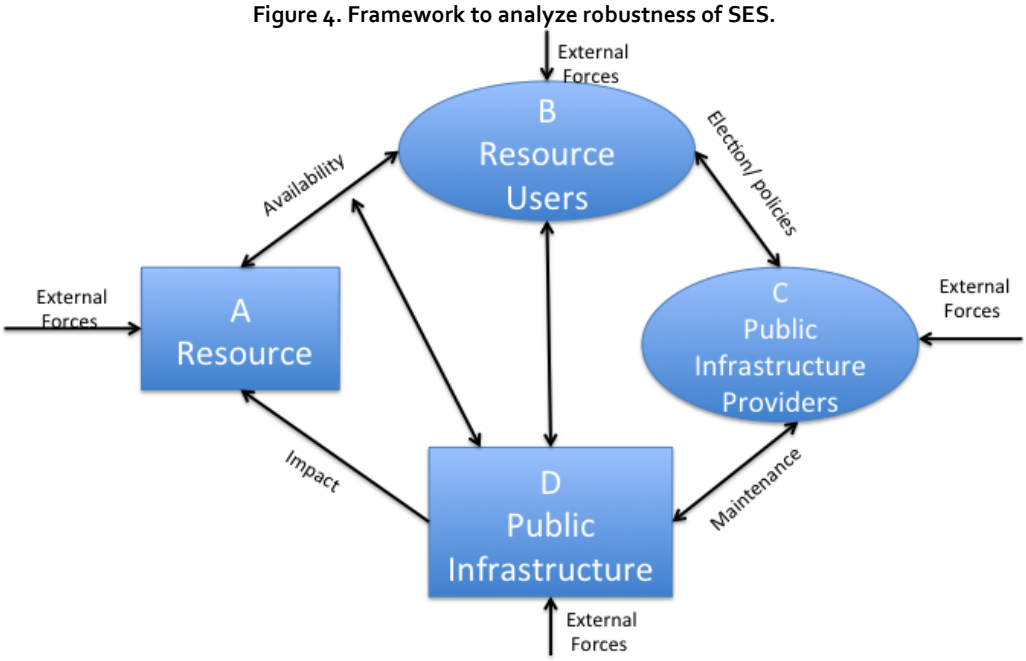
Step 4. Resilience management (evaluation and implications): This step involves an evaluation of the process by the stakeholders and the definition of management strategies.

This framework desired outcome is to define a set of targets for policy and management strategies to achieve sustainability based on the knowledge about the behavior and response of both the biophysical and social systems (Walker and others, 2002).

3.3 Framework to analyze the robustness of SES

Anderies, Janssen and Ostrom (2004) proposed a framework to analyze the robustness of SESs with a special accent on how infrastructure and infrastructure providers influence the SES's behavior. They share the basic characteristics proposed by Berkes and Folke, but their design includes a specific view about the link between resource users and infrastructure providers.

Figure 4. Framework to analyze robustness of SES.



Source: Anderies, and others 2004:3.

In this framework, authors restrict their attention to those SESs where the cooperative aspects of the social system are key. They recognize these cooperative aspects using as a selection key, the existence of any sort of physical or institutional infrastructure to cope with different disturbances. The framework includes as a first step the design principles formulated by Ostrom (2000) to analyze the sustainability of common-pool resources.

The framework is composed by six entities or main components: resource, resource users, public infrastructure providers, public infrastructure, institutional rules and external environment. The principal aspect of this framework is to analyze the links between the operational level and the collective choice level, understanding the links between:

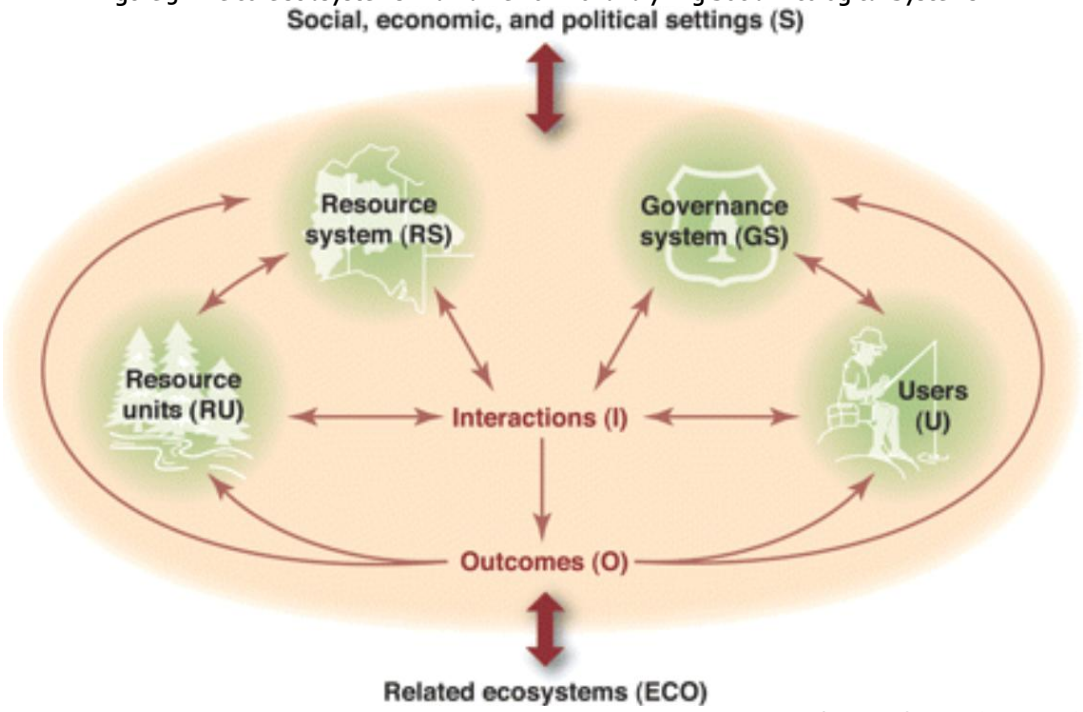
- Resource and resource users.
- Users and public infrastructure providers.
- Public infrastructure providers and public infrastructure.
- Public infrastructure and resource dynamics.
- Resource users and public infrastructure.
- External forces on resource and infrastructure.
- External forces on social actors.

Therefore, the authors suggested that a SES is robust when the social system can prevent changes to the ecological system so that it can no longer support the human population (Anderies and others, 2004). The principal outcome of this framework is the proposal to understand how institutional agreements affect SESs robustness and how they can be changed, strengthened or replaced.

3.4 Framework for analyzing the sustainability of SESs

This general framework proposed by Ostrom (2009) is a multilayered and nested framework in which a multidisciplinary approach is the condition to characterize and study SESs. It defines graphically the relations and interactions (Interactions (I)) between four multi-linked subsystems (Resource Units (RU), Resource System (RS), Governance System (GS) and Users (U)). The relational process then delivers outcomes (O) interacting either with the social, economic and political settings (S) and with the related ecosystems (ECO).

Figure 5. The core subsystems in a framework for analyzing Social-Ecological Systems.



Source: *Ostrom (2009:420)*

Based on extensive field research, Ostrom proposed a set of sub-variables (or second level variables) to synthesize the main features of each subsystem in different SESs (see Table 1). As suggested by her, those variables are not a unique set of possible variables, and they need to be adjusted for particular local conditions, but they can serve as a common ground for researchers.

Table 1. Example of second-level variables under first-level core.

Social, Economic, and Political Settings (S)	
S1- Economic development. S2- Demographic trends. S3- Political stability. S4- Government resource policies. S5- Market incentives. S6- Media organization.	
Resource Systems (RS)	**Governance Systems (GS)**
RS1- Sector (e.g., water, forests, pasture, fish) RS2- Clarity of system boundaries RS3- Size of resource system RS4- Human-constructed facilities RS5- Productivity of system RS6- Equilibrium properties RS7- Predictability of system dynamics RS8- Storage characteristics RS9- Location	GS1- Government organizations GS2- Nongovernment organizations GS3- Network structure GS4- Property-rights systems GS5- Operational rules GS6- Collective-choice rules GS7- Constitutional rules GS8- Monitoring and sanctioning processes
Resource Units (RU)	**Users (U)**
RU1- Resource unit mobility RU2- Growth or replacement rate RU3- Interaction among resource units RU4- Economic value RU5- Number of units RU6- Distinctive markings RU7- Spatial and temporal distribution	U1- Number of actors U2- Socioeconomic attributes of actors U3- History of use U4- Location U5- Leadership/entrepreneurship U6- Norms/social capital U7- Knowledge of SES/mental models U8- Importance of resource U9- Technology used
Action situations [Interactions (I) → Outcomes (O)]	
I1- Harvesting levels of diverse actors I2- Information sharing among actors I3- Deliberation processes I4- Conflicts among actors I5- Investment activities I6- Lobbying activities I7- Self-organizing activities I8- Networking activities	O1- Social performance measures (e.g. efficiency, equity, accountability, sustainability) O2- Ecological performance measures (e.g. overharvested, resilience, biodiversity, sustainability) O3- Externalities to other SESs
Related Ecosystems (ECO)	
ECO1- Climate patterns. ECO2- Pollution patterns. ECO3- Flows into and out of focal SES.	

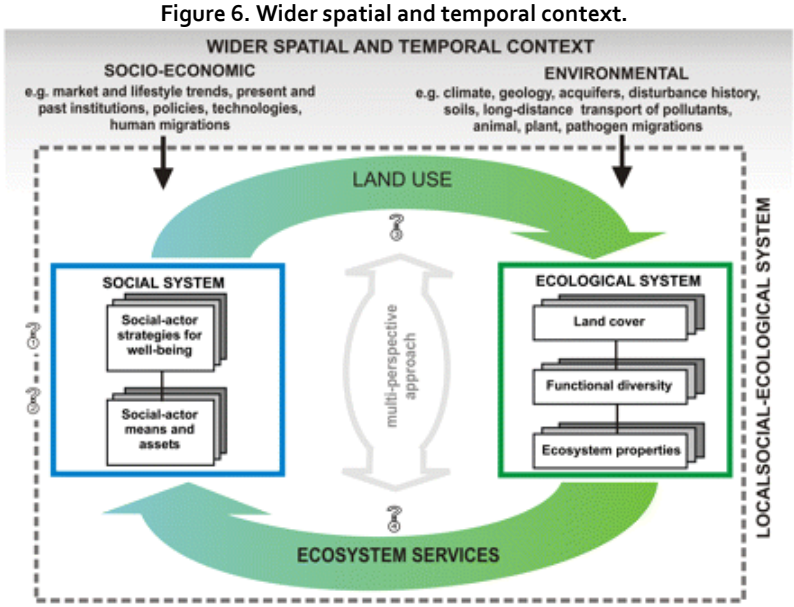
Source: *Ostrom, 2009:421.*

This framework provides a common set of potentially relevant variables and their subcomponents to use in the design of data collection instruments, the conduct of fieldwork and the analysis of findings about the sustainability of complex SESs. It combines the use of qualitative and quantitative data to study the SESs. It has also immersed the challenge to make social and natural sciences interact without defining clear borders or constructing pure natural or social empiric research objects. It is also important to emphasize the flexibility this framework exhibits, allowing researchers with a particular focus (either biological or social) to have a board to integrate different data into an extensive and comprehensive analysis. Finally, it helps identify factors that may affect the likelihood of particular policies enhancing sustainability and include the analysis of the governance systems implemented by users to increase the likelihood of sustaining the SES.

3.5 Framework for linking functional diversity to society

Diaz and others (2011) designed an analytical framework in which the relevant point to understand SESs is the analysis of the links between the social systems and biological systems based on the ecological services availability and the management strategies for land use. Therefore, this proposal has biodiversity as the principal axis and the social interactions are determined by the availability of natural resources. The social sphere then is highly influenced by the ecosystem services provided by the ecological communities.

Figure 6. Wider spatial and temporal context.



Source: Diaz and others, 2011.

In this approach the principal characteristic is the effect of ecosystem services availability on social decisions and regulation systems to management and to decide how to use land and how to protect it. The approach pays attention to the multilayered connections between social and ecological systems but giving special attention to the complexity inherent to the ecological system and to the diversity of perceptions of the communities involved in their characterization. The differences between this framework and the latter are summarized by the authors in two points:

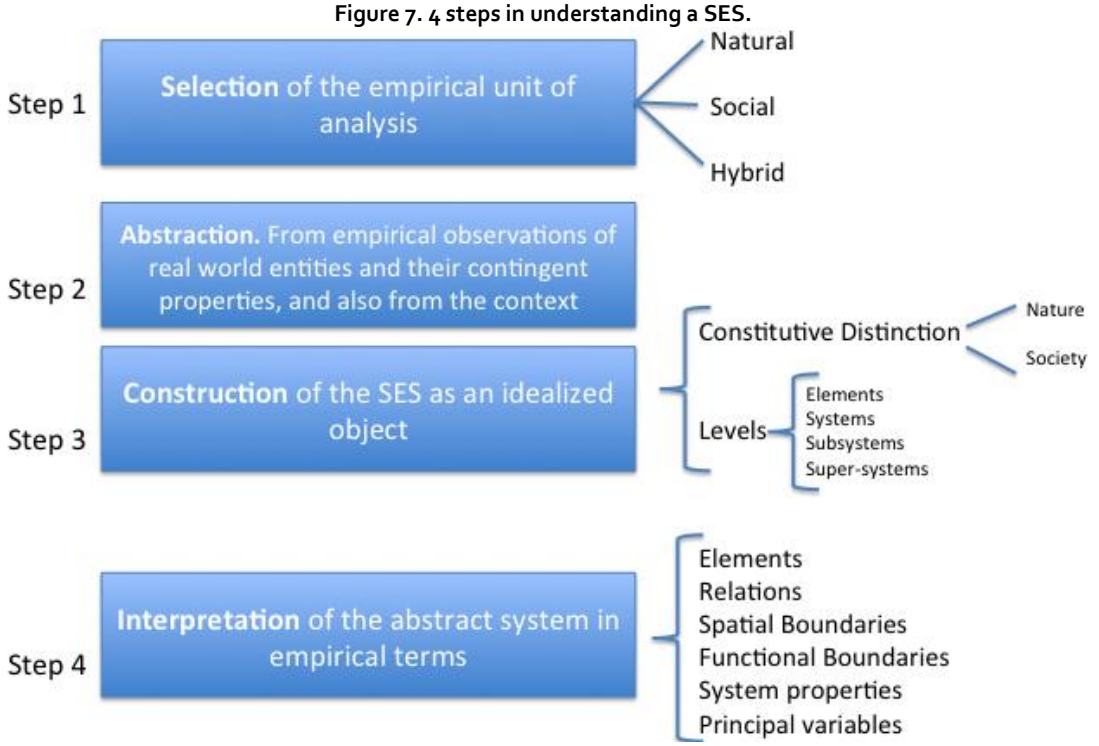
- This framework emphasizes the importance of recognizing the different connections between stakeholders and biodiversity use. It also calls for including different social actors in the process of knowledge generation.
- It stresses the importance of biotic components in analyzing the systems and determining that the evaluation of the biodiversity does not rely only on terms of economic value.

3.6 Understanding SESs as epistemic objects

The last framework presented in this report, is the one recently proposed by Becker (2012) as a response to some of the criticisms made by Brand and Jax (2007) about resilience and complex systems. It supports the understanding of the concept of SES from an epistemological perspective introducing a method to define SESs as research objects. Becker

highlights the need to place SES as: boundary objects situated in different scientific fields, as epistemic objects and as real objects represented by models and idealizations. Then, the process to analyze a SES starts by selecting the empirical unit of analysis to distinguish if it is natural, social or hybrid. It follows a process of abstraction to define the SES principal variables. The third step is the construction of the SES as an idealized object, generating the constitutive distinctions among the natural and social systems, the elements, the sub-system and the super system. Finally, the abstract system is interpreted in empirical units and terms, identifying the elements, relations, spatial boundaries, functional boundaries, system properties, etc.

Figure 7. 4 steps in understanding a SES.



Source: Becker, 2012.

This approach proposes "networks" as objects of study to understand and analyze SES (social, natural, hybrid). The emphasis on networks helps researchers to make the abstraction process to select the units of analysis. To conclude his proposal, the author suggested three objects of study in analyzing SESs based on the expected outcomes. When the intention is to define management strategies, the natural network should be the object of study. When the intention is to analyze supply systems and societal metabolism, the hybrid networks is the best object of study. Finally, when the emphasis is on sustainable development, the best object of study is the social network in SESs.

3.7 Choosing the right framework

All these frameworks share some characteristics that fit to COMET-LA goals, namely:

- They are evolutions or adaptations of models designed to understand natural resources sustainability, particularly in common pools resource management.

- They have as theoretical ground the need to understand SESs as complex and adaptive systems.
- They put an emphasis on combining qualitative and quantitative information.
- They pay special attention to the process of construction of the units of analysis based on research questions and recognizing the limitations generated by complexity and uncertainty.
- They recognize that the differences of scale (human constructions, human institutions, ecosystems, etc.) are one of the biggest challenges in understanding SESs.
- They call for creativity to understand the highly complex dynamics embedded in different systems or sub-systems interactions.
- They all emphasize that a better understanding of the SESs dynamics will provide better ways to take policy decisions, but the policy intention can no longer dominate the systems.

The main differences are:

- They have different scales of analysis: frameworks 1, 2, 3, 4 and 5 propose the local level and framework 6 a general level
- The stakeholder's participation is defined as a condition in the description process in frameworks 2 to 5.
- Frameworks 3, 4 and 5 offer second level variables; the others offer only principal general variables.
- Framework 5 specifically requests the generation of biological data and analysis.
- Frameworks 1 and 2 are specifically oriented for analyzing resilience, framework 3 to analyze robustness and in SESs, and framework 4 to analyze sustainability.

The six frameworks are directly or indirectly related to Ostrom's contributions, present interesting features for COMET-LA and are useful in different contexts or research objectives. COMET-LA CSs deals with complex Social and Ecological Systems presenting different environmental challenges and conflicts in the management of natural resources. Hence, a common framework useful for all of them, but also with potential to be used on other SESs should fulfilled at least the following features:

- To be a general framework, but with the flexibility to adapt the process to the local conditions.
- To be a multilevel, nested framework that analyses subsystems and interactions.
- To understand SES as embedded in settings that influence and are influenced.
- To integrate different information to present a multidisciplinary and holistic view.
- To propose a broad and flexible spectrum of sub-variables offering space for adaptation to different SES conditions and to focus in or out of the SES and its context.

- To put an emphasis on the governance rules to manage natural resources and on the local stakeholder role.
- To be a framework designed to analyze the impacts of users' self-organization rules on sustainability.
- To give the possibility of comparing different case studies.
- To deliver useful results for policy planning and for knowledge creation.

Even though all of the presented frameworks are more or less suitable for the purpose of COMET-LA, and all of them are related and share the principal analytical variables, Ostrom's provides the most appropriate approach for attaining the objectives of COMET-LA. Thus, it is the one that has been adapted to the local level. However, relevant aspects and concepts of the other frameworks have been included in this adaptation.

4 COMET-LA adaptations to the Ostrom framework

The literature review (see previous chapters) led to a better understanding of the mechanisms and latest developments in the conceptual basis of COMET-LA. The Ostrom framework came out of the analysis as the most applicable for COMET-LA's objectives. Indeed, the 8 core sub-systems, or first tier variables, defined by 53 second tier variables (as shown in Table 1 and discussed in section 3.4 on page 17), compose a good general model for a SES, but a proper characterization of a particular SES needs a framework with a high level of applicability.

The framework has been tested through application in COMET-LA's 3 CSs. In the process, the second tier variables have been evaluated and, although all of them were considered as useful, even if some are more relevant than others in specific CSs, their definition has proven to be very broad and diffuse. Many of the narratives elaborated for each CS revealed different and sometimes even wrong understandings of the concepts.

So, further development was considered necessary. The first step to improve the applicability of the framework was to define properly all the second tier variables. Some definitions were found in the literature and others defined according to COMET-LA's goals and priorities. One particularly important possibility for improving the practical applicability of the framework was already mentioned by Ostrom (2009): the option to choose other second or deeper tier variables according to the particularities of the analysed SES.

The second step was the development of a set of third tier variables to allow a better comprehension of the analysed SESs. According to COMET-LA's objectives, the drivers to propose these variables were the analysis of the sustainability of the SES and the analysis of the governance and management rules. The aforementioned literature review was useful for identifying the variables to include in the third tier, and also to give examples that could show which aspects should be analysed.

UCO's team initially proposed 155 third tier variables, but after the testing in the CSs, and the subsequent feedback and discussions with the other partners, these variables were reduced to 132. However, it is worth mentioning that some of these variables are SES-specific.

This framework was initially presented as if the SES involved only one set of users, inhabiting one overarching governance system, who were dependent on a particular type of resource unit, which were in turn extracted from a particular resource system. However, in some of the COMET-LA CSs coexist multiple instances of each of the top-tier components (more than one resource system, or more than one relevant resource unit, as well as multiple user groups), thus following McGinnis and Ostrom (2012), the possibility of multiple components in the subsystem has been introduced in the proposed framework.

The following section presents the third tier variables proposed for each of the core-subsystems characterize, are described.

4.1 Social, Economic, and Political Settings

This core subsystem aims to describe how all SES may affect and be affected by the larger socioeconomic, political, and ecological settings in which they are embedded.

An important point when applying the framework is to clearly outline the SES to be analysed and its external settings. In practice, COMET-LA partners and stakeholders tended to merge both and to not clearly distinguish the features belonging to each one. Some information can be similar, but also there can be important differences between the SES and its settings. The boundaries are not always clear or may be associated only to some features; hence this distinction is very important.

Ostrom proposed 2 variables to describe the economic setting (economic development and market incentives), 2 for the social setting (demographic trends and media organization) and 2 for the political setting (political stability and government resource policy).

All these variables are considered too broad and for each of them a set of third tier variables has been proposed. The economic development and the market incentives in the setting are key variables to give information on the pressures on the SES resources. To understand the **economic development**, information about the *economic sectors* in the area, the *income per capita* and the *income dispersion*, the *employment per sector* (mentioning not only the percentages, but the trends), the *subsistence and non-paid activities*, the *specialization of stakeholders* in one or more activities, and the *time allocation* to the different activities are considered necessary. The last two variables provide valuable information about the dependence on natural resources management of the stakeholders.

The **market incentive** is another key variable to understand how environmental challenges are managed, but also difficult to understand if not further developed. That is why it has been split into different variables: the type of *markets* (global or local) in the area and the *influence* they have in the area's dynamic; the *type of products* marketed distinguishing between commodities and non-commodities; the facilities of *access to markets*, the *demand for the natural resources* in the SES and the existence of *market incentives for natural resource conservation*, like extra added-value for sustainable products or ecosystem service payments.

The **demographic trends** affect social sustainability of the SES. Information on issues like the *number of inhabitants*, the *population density*, the *gender ratio*, the *demographic structure*, the *population growth rate*, the *migration trends*, the *ethnical diversity* and the *settlement patterns*

can give a more precise overview of the demographic situation in the area and the threats it can face.

Nowadays, media play a very important role in society. Their interest and implication on environmental issues can be very relevant for the SES sustainability. To understand the **media organization** in the setting the three following variables are proposed: *existence of communication networks*, *media deterrence capability* and *interest of the media in socio-environmental issues*.

The **political stability** affects the institutional sustainability in the area. It can be explained by the *existence and respect of a core legal framework*, by the *level of norm compliance* and its capacity of reinforcement, by the *type of conflicts* and its influence in the SES, by the rating of the area in *security indices* (the existence of important conflicts in the Colombian CS has led to the inclusion of this variable) and by the *respect for democratic values*.

Finally, the variables that can better define the **government resource policies** are the *governmental regulatory framework for the management and use of natural resources*, the *environmental policies* at different levels and their level of implementation and the *compliance of environmental regulatory and policy frameworks.*

Table 2 gives the description of the second tier variables and the different third tier variables proposed for describing the Social, Economic, and Political Settings core subsystem.

Table 2. Second and third tier variables for describing the 'Social, Economic, and Political Settings' subsystem.

	Second tier	Third tier	
Social, Economic and Political Setting (S)	S1	**Economic development** - Sustained, concerted actions of communities and policymakers improving the standard of living and economic health of a specific area / the quantitative and qualitative changes in an existing economy	S1a Economic sectors in the study area
			S1b Income per capita
			S1c Employment per sector (% and trends)
			S1d Subsistence activities
			S1e Non-paid activities (related to land management)
			S1f Income dispersion
			S1g Time allocation to the different economic activities carried out by the stakeholders
			S1h Specialization of stakeholders (in one of different economic activities)
	S2	**Demographic trends** - Development, changes and status of the human population	S2a Number of inhabitants
			S2b Population density
			S2c Gender ratio
			S2d Demographic structure
			S2e Population growth rate
			S2f Migration trends
			S2g Ethnical diversity (in % per group)
			S2h Settlement patterns
	S3	**Political stability** - Eventual existence of a core regulatory framework for the country or area / eventual existence of defined laws / the regularity of the democratic processes	S3a Core legal framework (national constitution and core laws)
			S3b Level of norm compliance (norm stability, capacity of reinforcement, knowledge of norms)
			S3c Type of conflicts
			S3d Security indexes (e.g. the UN Security Risk Rating Index)
			S3e Respect for democratic values (e.g. human rights, corruption)
	S4	**Government resource policies** - Type of resource policies adopted by the national, regional and local governments (top-down approach)	S4a Governmental regulatory framework for natural resources management and use
			S4b Environmental policies at national, regional and local levels and the implementation level (including climate change mitigation strategies)
			S4c Environmental regulatory and policy frameworks compliance
	S5	**Market incentives** - Market functioning for natural resource management and conservation	S5a Influence of global/local markets in the area (e.g. levels of dependency of external markets, price definition)
			S5b Type of products (e.g. commodities, certified products, other kind of labelling)
			S5c Access to markets (distance, commercialisation channels and networks, marketing)
			S5d Demand for natural resources from local, regional, national and international markets
			S5e Market incentives for natural resource conservation (e.g. existence of taxes, fees and charges, tradable permits, eco-labelling, financial mechanisms, liability and compensation schemes)
	S6	**Media organization** - Number, diversity, freedom ... of private and public media	S6a Existence of communication networks
			S6b Media deterrence capability
			S6c Interest of media in socio-environmental issues

Source: *Own elaboration*.

4.2 Resource System

Once the external settings to a SES are defined, the Ostrom framework proposes 4 core subsystems that define the SES itself: the Resource System, the Resource Units, the Governance System and the Users. The Resource System describes the environment where the resource is produced/found.

Ostrom proposed 9 second tier variables to describe the SES Resource System. Five of them are descriptive, namely the **sector** or sectors in the SES, the **clarity of the system boundaries**, the **size**, the **human constructed facilities** and the **location**. For these variables, few additions are proposed, since they are well specified themselves.

The only one needing further definition is the **clarity of system boundaries**. That is a key variable to understand a SES. Well-defined boundaries around a community of users and boundaries around the resource system seem to be more effective for sustainability. The positive and negative externalities produced by participants, and the costs of appropriation and the benefits of resource provision can all be better demarcated with well-defined limits. When boundaries are fuzzy and users and actors don't have well defined limits they lack instruments to achieve benefits and to control and prevent negative processes from happening in the territory. However, the SES boundaries can be defined naturally or by man and that is why a division is proposed for *natural boundaries* and *anthropogenic boundaries*. A further variable has been proposed on the *boundaries to extraction access and property*.

The other four variables requiring more extensive definitions are: productivity of the system, equilibrium properties, predictability of the system dynamics and storage characteristics. To analyse the **productivity of the system**, three variables are proposed: the *productivity of the resource system,* the *resource regeneration period* and the *resource extraction period.* The first variable data is not always available at local level. To overcome it a qualitative approach (high, medium, low) can be used if necessary, since it is not so relevant to know exactly how many kg, m3 or litters are produced but how productive is the SES resource system in relation to its setting or to other similar productive systems. The other two variables are added because the sustainability of the SES is highly dependent on the regeneration periods and on the management of extraction periods.

To the initial **equilibrium properties'** variable defined by Ostrom, two more have been added, the *history of natural hazards occurrence* and the *evidence of impacts in sub-systems and its effects*. Both are considered to contribute to the understanding of the SES functioning and on the impacts that affect the equilibrium properties.

For the last two variables in this subsystem, **predictability of the system dynamics** and **storage characteristics**, no more variables are proposed.

Table 3 gives the description of the second tier variables and the different third tier variables proposed for describing the Resource System core subsystem.

Table 3. Second and third tier variables for describing the 'Resource System' subsystem.

	Second tier		Third tier	
Resource Systems (RS)	RS1	**Sector(s) (**e.g. water, forest, pasture, fish) - Different biological production systems	RS1	Sectors
	RS2	**Clarity of system boundaries** - Clarity of the system's geographical, social and legal boundaries, describing if the boundaries of the studied resource system are clear, fuzzy or undefined	RS2a	Natural boundaries (e.g. rivers, mountains, specific vegetation)
			RS2b	Anthropogenic boundaries (e.g. land use distribution, conservation areas)
			RS2c	Extraction access and property boundaries
	RS3	**Size of resource system** - Size of each type of resource (private, club, open access or common pool resources)	RS3	Size
	RS4	**Human constructed facilities** - Anthropogenic structures facilitating resource management (e.g. boundaries, access ways, storage or transformation facilities)	RS4	Constructed facilities (e.g. roads, enclosures, field systems, boundary banks and ditches, ponds, parks and woods, wind and water mills, manor houses, moats and churches)
	RS5	**Productivity of system** - General estimation of the resource system productivity	RS5a	Productivity of the resource system (high, medium, low, exhausted)
			RS5b	Resource regeneration period
			RS5c	Resource extraction period
	RS6	**Equilibrium properties** - Influences (positive and negative) on the equilibrium of the resource system (interaction between species, in social systems, or between biological and anthropological systems)	RS6a	Equilibrium properties
			RS6b	Natural hazards occurrence (frequency and magnitude): e.g. flooding, fires, drought
			RS6c	History, evidence of impacts in sub-systems and its effects
	RS7	**Predictability of system dynamics** - Capacity to estimate the evolution and dynamics of the resource system and the impact of interventions or external influences on them	RS7	Predictability of system dynamics
	RS8	**Storage characteristics** - Retention of information about the system dynamics	RS8	Storage (memory) of the effects of disturbances on a system or sub-systems
	RS9	**Location** - Geographic location	RS9	Geographical location, distribution and distribution patterns

Source: *Own elaboration*.

4.3 Resource Units

The Resource Units describe the natural resource units generated by the resource system (e.g. fish, water, fodder).

The Resource Units in the SES are described by seven second level variables: the **resource unit mobility**, the **growth or replacement rate**, the **interaction among resource units**, the **economic value**, the **number of units**, the **distinctive markings** and the **spatial and temporal distribution** of the resource units. Most of these variables are clearly understood. Additional variables are proposed only for the variable economic value.

The concept of **economic value** is associated to monetary value, but a complete understanding of the resource value should include the *market value* (to know the price associated to the resources), the *environmental value* (even if it is not recognised by the market) and *the strategic value* that can be linked to economics, social, geopolitical, cultural or even symbolic considerations.

Table 4 gives the description of the second tier variables and the different third tier variables proposed for describing the Resource Unit core subsystem.

Table 4. Second and third tier variables for describing the 'Resource Units' subsystem.

	Second tier		Third tier	
Resource Units (RU)	RU1	**Resource unit mobility** - E.g. fish are mobile, while molluscs are static	RU1	Resource unit mobility
	RU2	**Growth or replacement rate** - Based upon the resource unit's life cycle (e.g. reproductive age, harvesting age, growth rate)	RU2	Growth or replacement rate
	RU3	**Interaction among resource units** - E.g. competition, collaboration	RU3	Interaction among resource units
	RU4	**Economic value** - Economic value of the resources	RU4a	Market value
			RU4b	Environmental value
			RU4c	Strategic value (e.g. economic, social, geopolitical, cultural, symbolic)
	RU5	**Number of units** - Total volume or amount of resource (e.g. wood volume, agriculture production volume, number of fish)	RU5	Number of resource units / amount of resource
	RU6	**Distinctive markings** - Natural or artificial markings to distinguish categories in the resource	RU6	Distinctive markings
	RU7	**Spatial and temporal distribution** - Availability of the resource in space and time	RU7	Spatial and temporal distribution

Source: *Own elaboration*.

4.4 Users

This subsystem describes the users of the resource system under consideration.

Ostrom initially proposed the term 'users', however in the adaptations to the framework proposed by her and McGinnis users was replaced by actors (McGinnis and Ostrom, 2012). This allows an expansion to the potential range of application of the framework. For example the situation in which the set of direct participants in the processes of resource extraction was

not identical to the set of participants consuming the product of their labours. However, for COMET-LA CSs this change in terminology has not been considered necessary and 'users' has been kept.

Nine second level variables describe the users of the SES: the number of users, the socio-economic attributes of users, the history of use, the location, the leadership/entrepreneurship, the norms/social capital, the knowledge of SES/mental models, the importance of resources and the technology used. The **number of users**, the **history of use**, the **location**, the **importance of resources** and the **technology used** can be directly measured.

However, the other four were found too broad. The **socio-economic attributes of users** have been split into a number of variables. To analyse the economic aspects, the *sources of income*, the *consumption patterns*, the *poverty*, the *sanitation*, the *access to drinking water*, the *access to electricity* and the *home gadgets* are proposed. To describe the social aspects, the proposed ones are the *women rights* and the *cultural identities.* Three other third level variables with social and economic implications are the *vulnerability,* the *access to health* and the *access to education.*

Leadership/entrepreneurship is a variable with strong effects on management decisions. Two variables are considered to better describe the aspects included in this variable: the *leadership/entrepreneurship patterns* to explain the type of leadership, the entrepreneurial skills, the level of acceptance and respect of leaders and the leaders' *attitudes toward conservation* to indicate if it is based on entrepreneurship, maintenance or sustainable use considerations.

The **norms/social capital** variable is also differentiated into two third tier variables: the *social capital* in the SES and the *traditional forms of collaboration among users* including norms, habits, traditions and customs.

Finally, several variables are considered necessary to a good understanding of the second level variable **knowledge of SES/mental models**: the *local knowledge on SES*, the *knowledge of the effect of over-harvesting,* the *knowledge of the effect of social attitudes toward resource management on the SES*, the *knowledge of the effect of biological shocks on the SES* and the *mental models related to SES management* (e.g. conservation, exploitation, human-nature relationships).

Table 5 gives the description of the second tier variables and the different third tier variables proposed for describing the Users core subsystem.

Table 5. Second and third tier variables describing the 'Users' subsystem.

	Second tier		Third tier	
Users (U)	U1	**Number of users** - Number of the direct users of the SES	U1	Number of users
	U2	**Socio-economic attributes of users** - Socio-economic characteristic of the resource system users	U2a	Sources of income (linked or not with the resource)
			U2b	Consumption patterns (e.g. local resources, local/imported food, shopping)
			U2c	Women rights (e.g. land tenure, empowerment, gender equity, private-public roles, health, education)
			U2d	Access to health
			U2e	Access to education
			U2f	Poverty (e.g. income, life cost, access to food)
			U2g	Vulnerability (e.g. social, economic, institutional, environmental)
			U2h	Cultural identities (e.g. language, food, celebrations, traditions)
			U2i	Sanitation
			U2j	Access to drinking water
			U2k	Access to electricity
			U2l	Home gadgets (e.g. TV, washing machine, computer, telephone)
	U3	**History of use** - Chronological description of resource extracting methods	U3	History of use
	U4	**Location** - Geographical location of users of the resource system (e.g. settlements, villages, dispersion)	U4	Location/dispersion patterns
	U5	**Leadership/entrepreneurship** - Existence of, and attitude towards leadership and entrepreneurship among users	U5a	Leadership patterns (e.g. level of acceptance, prominence, leadership models)
			U5b	Attitudes toward conservation (e.g. entrepreneurship, maintenance, sustainable use)
	U6	**Norms/social capital** - Levels of social interaction, reciprocity and trust among users	U6a	Social capital
			U6b	Traditional forms of collaboration among users (e.g. norms, habits, traditions, customs)
	U7	**Knowledge of SES/mental models** - Level of knowledge among the users of the SES conditions, perturbance patterns and possible effects	U7a	Local knowledge on SES (based on traditional or scientific knowledge)
			U7b	Knowledge of the effect of over-harvesting
			U7c	Knowledge of the effect of social attitudes toward resource management on the SES
			U7d	Knowledge of the effect of biological shocks on the SES
			U7e	Mental models related to SES management (e.g. conservation, exploitation, human-nature relationships)
	U8	**Importance of resources** - Users dependence on resources for livelihood	U8	Importance of resources for livelihood
	U9	**Technology used** - Type of technology used to extract, harvest and manage the resource, as well as differences in access among users based on access to different technologies	U9	Type of technologies used on the SES

Source: *Own elaboration*.

4.5 Governance System

This subsystem describes the governance system affecting and affected by the SES.

The original framework proposed eight variables to describe it, including top-down and bottom-up institutions (the government organizations and the NGOs), the interaction structure (network structure), and the SES internal rules and instruments to control and sanction its accomplishment (the property-rights systems, the operational rules, the collective-choice rules, the constitutional rules and the monitoring and sanctioning processes).

For external organizations, like **government organizations** and **NGOs**, no additional variable is suggested. To have a good definition of the **network structure**, a distinction between the most important networks affecting the SES is proposed: *social networks*, *environmental networks* and *market networks.*

As most of the analysed SESs are commons, to better describe the **systems of property rights**, an analysis of the two characteristics that affects commons have been introduced, the *excludability* options and the *subtractability* properties of the system.

For the rest of the initial second level variables (**operational rules, collective-choice rules, constitutional rules** and **monitoring and sanctioning processes**) no additional variables have been included.

Table 6 gives the description of the second tier variables and the different third tier variables proposed for describing the Governance System core subsystem.

Table 6. Second and third tier variables describing the 'Governance System' subsystem.

	Second tier		Third tier	
Governance Systems (GS)	GS1	**Government organizations** - Permanent or semi-permanent organizations (or systems of rules) controlled by national, regional and local regulation institutions	GS1	Government Organizations
	GS2	**NGOs** - Different types of NGOs (e.g. social, environmental, technical organizations) interacting with the analyzed SES	GS2	NGOs
	GS3	**Network structure** - Networks existing in the socio-ecological system and with direct or indirect influence on the management and use of resources	GS3a	Social networks
			GS3b	Environmental networks
			GS3c	Market networks
	GS4	**Property-rights systems** - Presence or absence of formal property right systems for the resources (e.g. land property, exclusive fishing rights)	GS4a	System of property right
			GS4b	Excludability (i.e., possibility to exclude potential users from using the resource)
			GS4c	Subtractability (i.e. whether resource appropriation by one user reduce availability to others)
	GS5	**Operational rules** - Community rules established for the extraction, management, access and use of natural resources	GS5	Operational rules (local rules for defining Who, How, Where, When, and Why have access to local natural resources)
	GS6	**Collective-choice rules** - Used to change the day-to-day operational rules related to the resource management	GS6	Collective-choice Rules
	GS7	**Constitutional rules** - The background rules set at the beginning of the common use of resource organization (e.g. the constitutional or core rules of the community)	GS7	Constitutional rules
	GS8	**Monitoring and sanctioning processes** - Set of methods to monitor and enforce the operational rules	GS8a	Monitoring processes
			GS8b	Sanctioning processes

Source: *Own elaboration*.

4.6 Interactions

Once the four core subsystems existing in the SES are defined, Ostrom proposes a new subsystem to categorize the interactions among them.

These interactions are described by eight types of second level variables: the harvesting levels of diverse users, the information sharing among users, the deliberation processes, the conflicts among users, the investment activities, the lobbying activities, the self-organizing activities and the networking activities.

The **harvesting levels of diverse users** should be complemented by *harvesting level and its effects on the SES*, but also it is important to underline *free-riding* activities, if any. The **information sharing among users** should be more specifically related to the SES, this is proposed by describing the *knowledge dissemination on the SES* and by the mechanisms for *information/know-how sharing about the SES variations* used by the users.

The **deliberation processes** can be better understood if the *knowledge about participation mechanisms and rights* among the users is added. Finally, the variables proposed for a better characterization of the **networking activities** are: the *internal networks* of the users, the *external networks*, their *partnership and cooperation* activities and the *external cooperation channels* they can use.

The other four variables (**conflicts among users, investment activities, lobbying activities** and **self-organizing activities**) are considered to be sufficiently explicit. Hence, no third level variables are proposed, just some examples or additional information have been added.

Table 7 gives the description of the second tier variables and the different third tier variables proposed for describing Interactions core subsystem.

Table 7. Second and third tier variables describing the 'Interactions' subsystem.

	Second tier		Third tier	
Interactions (I)	I1	**Harvesting levels of diverse users** - Quantity of the resource(s) harvested by different users	I1a	Harvesting level and effects on SES
			I1b	Free-riding
	I2	**Information sharing among users** - Methods of information sharing among users	I2a	Knowledge dissemination on the SES
			I2b	Information/knowhow sharing about the SES variations
	I3	**Deliberation processes** - Deliberation process used among users	I3a	Deliberation processes among users
			I3b	Knowledge about participation mechanisms and rights
	I4	**Conflicts among users** - Existing conflicts among users	I4	Type of conflict (e.g. conflict based on greed, grievance, scarcity, technology, access, power, information)
	I5	**Investment activities** - Investments for improving and managing the resources (investor, amount invested and destination of investment)	I5	Investments activities (investor, amount invested and destination of investment)
	I6	**Lobbying activities** - Internal, external and influence capacity	I6	Lobbying activities (actors involved, expected outcomes)
	I7	**Self-organizing activities** - Self-organization activities among users for extracting resources	I7	Self-organizing activities (include description of any solidarity activities)
	I8	**Networking activities** - Networking activities of the users within and outside the community	I8a	Internal networks
			I8b	External networks
			I8c	Partnership and cooperation
			I8d	External communication channels

Source: *Own elaboration*.

4.7 Outcomes

As a result of the Interactions' subsystem, Ostrom proposes the Outcomes' subsystem to describe the results of the interactions among the different aforementioned variables.

Three very broad variables describe all these outcomes: the social performance measures, the ecological performance measures and the externalities to other SES. All of them are considered as needing additional variables to capture the richness of outcomes and nuances in a SES.

The **social performance measures** should be better named as socio-economic performance measures, since they include social and economic processes. For this variable, seven third level variables are proposed: the *efficiency*, the *equity*, the *socio-economic sustainability*, the *accountability*, the *effects of deliberation processes on the SES*, the *empowerment* (including a gender analysis on empowerment) and the *adaptation strategies to climate change.*

The outcomes linked to **ecological performance measures** can be better distinguished if specifications on the following third level variables are introduced: the *environmental sustainability*; the *pressures on the resources,* identifying aspects like the increasing demand of resources; the presence of new actors and uses of resources, the overharvesting, etc.; the situation of the *natural habitat* including information on biodiversity indexes, species richness, connectivity, the situation of the habitat (conserved / degraded / fragmented); the *effects of SES management on natural hazards* describing if changes in type, frequency or patterns are happening; the *structure and function of the resources,* analysing the changes, the interactions among the resource units, the situation of the trophic chains, etc.; the status of the *soil* identifying erosion, degradation or improvement patterns; the conditions of the *water*

including information on its quality and availability; the conditions of the *air (e.g. quality)*; the occurrence of *pollution* including its causes and frequency; the *resilience* of the SES and its *vulnerability* status. The two last variables are not easy to measure, but a qualitative approach has been selected to understand the views of stakeholders on them.

Finally the **externalities to other SESs** have been differentiated in *positive externalities* and *negative externalities.*

Table 8 gives the description of the second tier variables and the different third tier variables proposed for describing Outcomes core subsystem.

Table 8. Second and third tier variables describing the 'Outcomes' subsystem.

	Second tier	Third tier	
Outcomes (O)	O1 **Social performance measures (e.g. efficiency, equity, accountability, sustainability)** - Impact of different activities on social performance	O1a	Efficiency
		O1b	Equity (distribution of benefits between SES users)
		O1c	Socio-economic sustainability
		O1d	Accountability
		O1e	Effects of deliberation processes on the SES
		O1f	Empowerment (including gender analysis)
		O1g	Adaptation strategies to climate change
	O2 **Ecological performance measures (e.g. overharvesting, resilience, biodiversity, sustainability)** - Impact of different activities on ecological performance	O2a	Environmental sustainability
		O2b	Pressure on resources (e.g. increasing demand, new actors, overharvesting)
		O2c	Natural habitat (e.g. biodiversity indexes, species richness, connectivity, habitat conservation/degradation/fragmentation)
		O2d	Effect of SES management on natural hazards (e.g. changes in type, frequency, pattern)
		O2e	Structure and function of resources (e.g. changes, interactions among resource units, trophic chains)
		O2f	Soil (e.g. erosion, degradation, improvement)
		O2g	Water (e.g. quality, availability)
		O2h	Air (e.g. quality)
		O2i	Pollution (e.g. waste generation, frequency of occurrence)
		O2j	Resilience
		O2k	Vulnerability
	O3 **Externalities to other SESs** - Positive or negative impacts on other SESs without previous agreement or request	O3a	Positive externalities (e.g. CO_2 capture, water protection, biodiversity conservation)
		O3b	Negative externalities (e.g. CO_2 emissions, pollution)

Source: *Own elaboration*.

4.8 Related Ecosystems

The last core subsystem describes the connection of the considered SES with the surrounding SESs.

For this subsystem no additional variable is proposed, the local SESs analysed by COMET-LA have limited capacity to influence these parameters. Whether they could influence, a description of these three variables is considered sufficient.

Table 9 gives the description of the second tier variables and the different third tier variables proposed for describing the Related Ecosystems core subsystem.

Table 9. Second and third tier variables describing the 'Related Ecosystems' subsystem.

	Second tier		Third tier	
Related Ecosystems (ECO)	ECO1	**Climate patterns** - Climate patterns affecting the considered SES	ECO1	Climate patterns (e.g. precipitation, temperature, sea level, extreme events, seasonal changes)
	ECO2	**Pollution patterns (water, waste, soil, air, other)** - Pollution patterns affecting the considered SES (e.g. water, waste, soil, air)	ECO2	Pollution patterns (e.g. water, waste, soil, air)
	ECO3	**Flows into and out of focal SES** - Flows from other SESs affecting the considered SES and vice versa	ECO3	Flows from other SESs affecting the considered SES and vice versa (economic pressures, environmental effects and social effects)

Source: *Own elaboration*.

5 Applying the adapted Ostrom framework

Within the previous section, the application and improvement of the Ostrom framework has been described. The core subsystems that make up a SES have been developed into well described second tier variables, and third tier variables have been designed for helping a proper characterisation of those second tier variables.

Once the applicable adapted Ostrom framework was ready, additional work was done to facilitate its use. Many of the problems encountered when gathering information for the framework were analyzed for identifying possible solutions, so guidelines can be formulated for the application of the adapted framework.

The additional parameters were used to gather the following information:

1. The analysis level (from local to international);
2. The expected type of data, including numerical, descriptive, geographical (e.g. maps, satellite images) and analytical data;
3. The information sources (for secondary information);
4. The research tools (for primary information); and
5. The most frequently encountered problems.

The categories identified for each of these aspects are shown in Table 10 and Table 11, which both can be of great help when applying the adapted Ostrom framework in future CSs.

Table 10. Parameters for guiding the application of the adapted Ostrom framework.

Analysis Level	Data type	Information sources	Research tools
International	Numerical	Environmental databases	Workshops
National	Descriptive	Socio-economic databases	Interviews
Regional	Geographical	Geospatial databases	Surveys
Local	Analytical	Legal databases	Life stories
		International databases	Observation
			Media

Source: *Own elaboration*.

The problem category is the category with the widest possibilities. The main and more common problems encountered when finding the information for describing the third tier variables of the adapted Ostrom framework in the 3 CSs have been abstracted to the categories listed in Table 11.

Most of these problems were linked with the lack of information at local level; the difficulties to access, measure and collect data; the lack of formal records for a good number of variables; the low reliability of statistics at local level and the fuzziness of some categories. Nevertheless, other qualitative problems were also identified like the subjectivity of some information which was highly dependent on the opinion of the informants; the unstable character of the demanded data and its variability over time; and the difficulties to understand some concepts (several of the Ostrom´s concepts are novelties or complex for non-specialists). These categories are not necessarily exclusive, but they try to include the most frequently found problems in COMET-LA CSs.

Table 11. Problems encountered when applying the adapted Ostrom framework.

Problems
Complex measurement
Concept definition hard to understand
Difficult to access and collect data
Difficult to measure
Difficult to measure at local level
Frequent measurements hard to organize
Fuzziness of limits
Information subjective and dynamic over time
Lack of data at local level
No formal register of this data
Subjective information
Uncertain reliability of statistics
Unclear definition of categories

Source: *Own elaboration*.

The following sections present the logic used in the process of defining the third tier variables and the problems encountered when finding their description for a certain SES. The emphasis is on clarification of the encountered problems, since the rest of the parameters do not need further explanations. This exercise has been done for the first 5 subsystems of the framework. As Interactions (I), Outcomes (O) and Related ecosystems (ECO) are described using the information from the other variables.

These experiences expect to serve as helpful guidelines when applying the adapted Ostrom framework in future CSs.

5.1 Social, Economic, and Political Settings

For each variable in this subsystem, a detailed analysis has been done to define the categories in the different parameters that can help to characterise the different SESs in future applications of the adapted Ostrom framework.

Table 12 shows the different categories for each variable in this subsystem that can help in their characterization. The main problems found at local level for the third level variables included in this subsystem are:

- The lack of statistical data at local level on economic issues such as income per capita, employment per sector, income dispersion, time allocation, main economic activities; and on social issues like population growth rate, migration trends or conflicts.
- The difficulties to access and gather information related to environmental policy frameworks at different levels and the compliance of norms and regulatory frameworks.
- The lack of formal records at local level for different economic issues (due to the informal situation of many people with no formal jobs and salaries) and social issues (demographic trends, conflicts and media related variables).
- The change over time of the situations as it happens in the subsistence and non-paid activities.
- The subjectivity of the information in aspects like the type of conflicts and the respect of democratic values.
- The difficulties to measure variables like the time allocation of stakeholders to different activities.
- The definition of concepts like communication networks, media deterrence capability and interest of media in socio-environmental issues have been found as concepts more difficult to understand at local level.

Table 12. Application of the Social, Economic, and Political Settings.

	Third tier		Level	Research tools	Data sources	Data type	Problems
Economic development (S1)	S1a	Economic sectors in the study area	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
	S1b	Income per capita	Regional - Local		Socio-economic DB	Numerical	Lack of data at local level; No formal register of this data
	S1c	Employment per sector (% and trends)	Regional - Local		Socio-economic DB	Numerical	Lack of data at local level; No formal register of this data
	S1d	Subsistence activities	Regional - Local	Interviews; Life stories; Surveys; Workshops	Socio-economic DB	Descriptive	Information subjective and dynamic over time; No formal register of this data
	S1e	Non-paid activities (related to land management)	Regional - Local	Interviews; Life stories; Surveys; Workshops	Socio-economic DB	Descriptive	Information subjective and dynamic over time; No formal register of this data
	S1f	Income dispersión	Regional - Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Lack of data at local level
	S1g	Time allocation to the different economic activities carried out by the stakeholders	Regional - Local	Interviews; Surveys; Workshops		Descriptive; Numerical	Complex measurement; Lack of data at local level
	S1h	Specialization of stakeholders (in one of different economic activities)	Regional - Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Lack of data at local level
Demographic trends (S2)	S2a	Number of inhabitants	Local		Socio-economic DB	Numerical	
	S2b	Population density	Local		Socio-economic DB	Numerical	
	S2c	Gender ratio	Local		Socio-economic DB	Numerical	
	S2d	Demographic structure	Local		Socio-economic DB	Numerical	
	S2e	Population growth rate	Local		Socio-economic DB	Descriptive; Numerical	Lack of data at local level
	S2f	Migration trends	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Lack of data at local level
	S2g	Ethnical diversity (in % per group)	Regional - Local		Socio-economic DB	Numerical	
	S2h	Settlement patterns	Local		Geospatial DB	Descriptive	
Political stability (S3)	S3a	Core legal framework (national constitution and core laws)	National		Legal DB	Descriptive	
	S3b	Level of norm compliance (norm stability, capacity of reinforcement, knowledge of norms)	Regional - Local	Interviews; Life stories; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Difficult to access and collect data
	S3c	Type of conflicts	National - Local	Interviews; Life stories; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Subjective information; No formal register of this data; Lack of data at local level
	S3d	Security indexes (e.g. the UN Security Risk Rating Index)	National		International DB	Numerical	
	S3e	Respect for democratic values (e.g. human rights, corruption)	Regional - Local	Interviews; Life stories; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Subjective information; No formal register of this data

	Third tier		Level	Research tools	Data sources	Data type	Problems
Government resource policies (S4)	S4a	Governmental regulatory framework for natural resources management and use	National - Regional		Legal DB	Descriptive	
	S4b	Environmental policies at national, regional and local levels and the implementation level (including climate change mitigation strategies)	National - Local	Interviews; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Difficult to access and collect data
	S4c	Environmental regulatory and policy frameworks compliance	National - Regional	Interviews; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Difficult to access and collect data
Market incentives (S5)	S5a	Influence of global/local markets in the area (e.g. levels of dependency of external markets, price definition)	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
	S5b	Type of products (e.g. commodities, certified products, other kind of labelling)	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
	S5c	Access to markets (distance, commercialisation channels and networks, marketing)	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
	S5d	Demand for natural resources from local, regional, national and international markets	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
	S5e	Market incentives for natural resource conservation (e.g. existence of taxes, fees and charges, tradable permits, eco-labelling, financial mechanisms, liability and compensation schemes)	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
Media organization (S6)	S6a	Existence of communication networks	National - Local	Interviews; Media; Observation; Workshops		Descriptive	Unclear or abstract concept for local stakeholders; No formal register of this data
	S6b	Media deterrence capability	International - Local	Interviews; Media; Observation; Workshops		Descriptive	Unclear or abstract concept for local stakeholders; No formal register of this data
	S6c	Interest of media in socio-environmental issues	National - Local	Interviews; Media; Observation; Workshops		Descriptive	Unclear or abstract concept for local stakeholders; No formal register of this data

Source: *Own elaboration*.

5.2 Resource system

For each variable in this subsystem, a detailed analysis has been done to define the categories in the different parameters that can help to characterise the different SESs.

Table 13 shows for each variable in this subsystem the different categories that can help in their characterization. The main problems found at local level for the third level variables included in this subsystem are:

- The lack of statistical data at local level, in variables like the productivity of the resource (for this variable the difficulty can also be how to access and collect this information), the resources' regeneration and extraction periods, the history and evidence of impacts in the resource system and the SES storage capacity.
- The fuzziness of limits in variables like the natural and socio-economic boundaries (the latter also can present an unclear definition of categories).
- The difficulties in understanding concepts such as size and the equilibrium properties of the SES.

Table 13. Application of the Resource system.

	Third tier		Level	Research tools	Data sources	Data type	Problems
Sector(s) (RS1)	RS1	Sectors	Regional - Local	Interviews; Observation; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive; Numerical	
Clarity of system boundaries (RS2)	RS2a	Natural boundaries (e.g. rivers, mountains, specific vegetation)	Regional - Local	Observation; Surveys; Workshops	Environmental and Geospatial DB	Descriptive; Geographical	Fuzziness of limits
	RS2b	Anthropogenic boundaries (e.g. land use distribution, conservation areas)	Regional - Local	Interviews; Observation; Surveys; Workshops	Geospatial and Socio-economic DB	Descriptive; Geographical	Fuzziness of limits; Unclear definition of categories
	RS2c	Extraction access and property boundaries	Local	Interviews; Surveys; Workshops	Geospatial and Socio-economic DB	Descriptive; Numerical	
Size (RS3)	RS3	Size or resource system	Local		Environmental, Geospatial and Socio-economic DB	Numerical	Unclear or abstract concept for local stakeholders
Human constructed facilities (RS4)	RS4	Constructed facilities (e.g. roads, enclosures, field systems, boundary banks and ditches, ponds, parks and woods, wind and water mills, manor houses, moats and churches)	Local	Interviews; Observation; Surveys; Workshops	Environmental, Geospatial and Socio-economic DB	Descriptive	
Productivity of system	RS5a	Productivity of the resource system (high, medium, low, exhausted)	Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive; Numerical	Lack of data at local level; Difficult to access and collect data
	RS5b	Resource regeneration period	Local	Interviews; Observation; Surveys; Workshops	Environmental DB	Descriptive; Numerical	Lack of data at local level No formal register of this data

	Third tier		Level	Research tools	Data sources	Data type	Problems
	RS5c	Resource extraction period	Local	Interviews; Observation; Surveys; Workshops	Legal and Socio-economic DB	Descriptive; Numerical	Lack of data at local level
Equilibrium properties (RS6)	RS6a	Equilibrium properties	Regional - Local	Interviews; Observation; Surveys; Workshops		Descriptive	Unclear or abstract concept for local stakeholders
	RS6b	Natural hazards occurrence (frequency and magnitude): e.g. flooding, fires, drought	Regional - Local	Interviews; Surveys; Workshops	Environmental DB	Descriptive	
	RS6c	History, evidence of impacts in sub-systems and its effects	Regional - Local	Interviews; Media; Surveys; Workshops	Environmental DB	Descriptive	Lack of data at local level
Predictability (RS7)	RS7	Predictability of system dynamics	Regional - Local				
Storage characteristics (RS8)	RS8	Storage (memory) of the effects of disturbances on a system or sub-systems	Regional - Local	Interviews; Life stories; Surveys; Workshops	Environmental and Legal DB	Descriptive	Lack of data at local level
Location (RS9)	RS9	Geographical location, distribution and distribution patterns	Local		Geospatial DB	Geographical	

Source: *Own elaboration*.

5.3 Governance System

The variables in this subsystem presented fewer problems. However, for each variable in, a detailed analysis has been done to define the categories in the different parameters that can help to characterise the different SESs.

Table 14 shows for each variable in this subsystem the different categories that can help in their characterization. The main problems found at local level for the third level variables included in this subsystem are:

- The subjectivity of the information in aspects such as the social, environmental and market networks (with no formal registers of this data), and the excludability possibilities.
- For these variables, the lack of formal data records at local level has also been identified as a problem.

Table 14. Application of the Governance Systems.

	Third tier		Level	Research tools	Data sources	Data type	Problems
Government organizations (GS1)	GS1	Government Organizations	National - Local	Interviews; Life stories; Surveys; Workshops	Legal and Socio-economic DB	Descriptive	
NGOs (GS2)	GS2	NGOs	National - Local	Interviews; Life stories; Surveys; Workshops	Legal and Socio-economic DB	Descriptive	No formal register of this data
Network structure (GS3)	GS3a	Social networks	Regional - Local	Interviews; Life stories; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data
	GS3b	Environmental networks	Regional - Local	Interviews; Life stories; Media; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data
	GS3c	Market networks	National - Local	Interviews; Life stories; Media; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data
Property-rights systems (GS4)	GS4a	System of property right	Regional - Local	Interviews; Observation; Surveys; Workshops	Legal and Socio-economic DB	Descriptive	
	GS4b	Excludability (i.e., possibility to exclude potential users from using the resource)	Local	Interviews; Observation; Surveys; Workshops		Descriptive	Subjective information
	GS4c	Subtractability (i.e. whether resource appropriation by one user reduce availability to others)	Local	Interviews; Observation; Surveys; Workshops		Descriptive	
Operational rules (GS5)	GS5	Operational rules (local rules for defining Who, How, Where, When, and Why have access to local natural resources)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
Collective-choice rules (GS6)	GS6	Collective-choice Rules	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	

	Third tier		Level	Research tools	Data sources	Data type	Problems
Constitutional rules (GS7)	GS7	Constitutional rules	National - Local	Interviews; Observation; Surveys; Workshops	Legal DB	Descriptive	
Monitoring and sanctioning processes (GS8)	GS8a	Monitoring processes	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
	GS8b	Sanctioning processes	Local	Interviews; Observation; Workshops	Socio-economic DB	Descriptive	

Source: *Own elaboration*.

5.4 Resource Units

For each variable in this subsystem, a detailed analysis has been done to define the categories in the different parameters that can help to characterise the different SESs.

Table 15 shows for each variable in this subsystem the different categories that can help in their characterization. The main problems found at local level for the third level variables included in this subsystem are:

- The lack of statistical data at local level at aspects such as the growth or replacement rate and the number of resource units.
- The difficulties to measure the environmental and strategic value of the resource units at local level. The latter being also subjective information for each stakeholder.
- The lack of formal records at local level of the market value of resources. This information can also be subjective and dynamic over time.
- The difficulties to understand concepts such as the interactions among resource units.
- The need to do frequent measurements to know the spatial and temporal distribution of the resources.

Table 15. Application of the Resource Units.

	Third tier		Level	Research tools	Data sources	Data type	Problems
Resource unit mobility (RU1)	RU1	Resource unit mobility	Regional - Local	Interviews; Surveys; Workshops	Environmental DB	Descriptive	
Growth or replacement rate (RU2)	RU2	Growth or replacement rate	Local	Interviews; Workshops	Environmental DB	Descriptive; Numerical	Lack of data at local level
Interaction among resource units (RU3)	RU3	Interaction among resource units	Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive; Numerical	Unclear or abstract concept for local stakeholders
Economic value (RU4)	RU4a	Market value	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Information subjective and dynamic over time; No formal register of this data
	RU4b	Environmental value	International - Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive	Difficult to measure at local level
	RU4c	Strategic value (e.g. economic, social, geopolitical, cultural, symbolic)	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Difficult to measure; Subjective information
Number of units (RU5)	RU5	Number of resource units / amount of resource	Local	Interviews; Surveys	Environmental DB	Numerical	Lack of data at local level; Difficult to measure
Distinctive markings (RU6)	RU6	Distinctive markings	Regional - Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive	

	Third tier		Level	Research tools	Data sources	Data type	Problems
Spatial and temporal distribution (RU7)	RU7	Spatial and temporal distribution	Regional - Local	Interviews; Surveys; Workshops	Environmental and Geospatial DB	Descriptive; Geographical Numerical	Frequent measurements hard to organize

Source: *Own elaboration*.

5.5 Users

For each variable in this subsystem, a detailed analysis has been done to define the categories in the different parameters that can help to characterise the different SESs.

Table 16 shows the different categories that can help in the characterization for each variable in this subsystem. The main problems found at local level for the third level variables included in this subsystem are:

- The difficulties to access and gather information related to sources of incomes and women rights (this information is also subjective).
- The change over time of the information related to leadership patterns and level of collaboration among users. This information is also subjective.
- The subjectivity of the information in aspects like the history of use, the level of collaboration between users (concept that also can have different nuances and be difficult to understand), the local knowledge on SES and the accuracy of SES mental models.
- The difficulties to understand/measure concepts such as poverty, vulnerability and accuracy of mental models.

Table 16. Application of the Users.

	Third tier		Level	Research tools	Data sources	Data type	Problems
Number of users (U1)	U1	Number of users	Local	Surveys; Workshops	Socio-economic DB	Numerical	Information subjective and dynamic over time; Lack of data at local level
Socio-economic attributes of users (u2)	U2a	Sources of income (linked or not with the resource)	Local	Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Difficult to access and collect data
	U2b	Consumption patterns (e.g. local resources, local/imported food, shopping)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Subjective information
	U2c	Women rights (e.g. land tenure, empowerment, gender equity, private-public roles, health, education)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Difficult to access and collect data; Lack of data at local level; Subjective information
	U2d	Access to health	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	Lack of data at local level
	U2e	Access to education	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
	U2f	Poverty (e.g. income, life cost, access to food)	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	Unclear or abstract concept for local stakeholders
	U2g	Vulnerability (e.g. social, economic, institutional, environmental)	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	Unclear or abstract concept for local stakeholders
	U2h	Cultural identities (e.g. language, food, celebrations, traditions)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
	U2i	Sanitation	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
	U2j	Access to drinking water	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
	U2k	Access to electricity	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
	U2l	Home gadgets (e.g. TV, washing machine, computer, telephone)	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	No formal register of this data
History of use (U3)	U3	History of use	Regional - Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
Location (U4)	U4	Location/dispersion patterns	Local	Interviews; Surveys; Workshops	Geospatial and Socio-economic DB	Descriptive; Geographical	

	Third tier		Level	Research tools	Data sources	Data type	Problems
Leadership/entrepreneurship (U5)	U5a	Leadership patterns (e.g. level of acceptance, prominence, leadership models)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Information subjective and dynamic over time
	U5b	Attitudes toward conservation (e.g. entrepreneurship, maintenance, sustainable use)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
Norms/social capital (U6)	U6a	Social capital	Local	Interviews; Life stories; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Information subjective and dynamic over time; Unclear or abstract concept for local stakeholders
	U6b	Traditional forms of collaboration among users (e.g. norms, habits, traditions, customs)	Local	Interviews; Life stories; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Subjective information
Knowledge of SES/mental models (U7)	U7a	Local knowledge on SES (based on traditional or scientific knowledge)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
	U7b	Knowledge of the effect of over-harvesting	Local				Subjective information
	U7c	Knowledge of the effect of social attitudes toward resource management on the SES	Local				Subjective information
	U7d	Knowledge of the effect of biological shocks on the SES	Local				Subjective information
	U7e	Mental models related to SES management (e.g. conservation, exploitation, human-nature relationships)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information; Unclear or abstract concept for local stakeholders
Importance of resources (U8)	U8	Importance of resources for livelihood	Local	Interviews; Life stories; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	No formal register of this data
Technology used (U9)	U9	Type of technologies used on the SES	Local	Interviews; Life stories; Observation;Surveys; Workshops	Socio-economic DB	Descriptive	

Source: *Own elaboration*.

6 Conclusions

A comprehensive characterization of social and ecological systems (SESs) is a key stage in identifying sustainable governance models. The delivery of a common framework for this characterization, useful at a local level, proves to be basic for identifying the different natural and social elements present in SESs and the complexity of their interactions and outcomes.

Therefore, the application of this framework should allow recognizing sustainable governance models, either existing or designable, for a particular SES.

In the COMET-LA project proposal, the framework designed by Elinor Ostrom (2009) to analyze the sustainability of SESs was selected as central part of the methodology. The usefulness of this framework for the objectives of COMET-LA was confirmed after an exhaustive literature review and an empirical application in three COMET-LA cases studies, as:

- It is a general framework, but has the flexibility to adapt to local conditions;
- It integrates different information in a holistic integrative model;
- It proposes a broad and flexible set of sub-variables offering space for adaptation to different SES conditions and to zoom in or out on the SES and its context;
- It puts the emphasis on governance and local stakeholders;
- It gives the possibility to compare different case studies (CSs); and
- The results obtained of its application are useful for policy planning and knowledge creation.

However, the Ostrom framework is an analytical one and not directly applicable. Hence, several problems were found when applying the original framework in the 3 CSs. Some adaptations were essential for having a fully functional framework at such a local level:

- The 8 core subsystems and their 52 second tier variables, as proposed by Ostrom, were evaluated as very useful, but the second tier variables were too broad and diffuse to be directly described;
- Some of these variables refer to technical, abstract or novel concepts for the local communities and even for researchers not specialists in the topics; and
- The framework offers a set of variables, but not a methodological, step-by-step approach.

To overcome this difficulty, the first adaptation of the Ostrom framework was the definition of the second level variables for facilitating a better comprehension of the concepts. When available, definitions were extracted from the scientific literature, but some variables were too novel or not totally described – proved scientifically. That is why even though a exhaustive search was made to describe them, it was necessary to reach a common description among COMET-LA partners; these descriptions will be subject to future research.

A second contribution was the expansion into third level variables of those second level variables, for covering the different aspects included in them, and avoiding the omission of relevant information. Hence, 132 third tier variables have been developed for completing the Ostrom framework.

As the final adapted framework is meant for application in different SESs and at different scales, the Ostrom framework has been kept as complete as possible and its applicability has been improved mainly through expanding and concretizing the original variables, even though some variables did not apply to all CSs.

While applying the framework, it was not always obvious which information was requested to describe some of the variables. Guidelines were needed for gathering the information. For that reason, the COMET-LA methodological framework indicates the level on which the data should be found (local, regional or (inter)national), where and how the information can be obtained and in which format it should be delivered (numerical, descriptive, geographical or analytical).

But sometimes problems surfaced while getting the data, be it linked with the level on which the data should be looked for, the quality of the data, the lack of understanding of the concept expressed by the variables, or the subjectivity and dynamism of the information. These problems have been listed so future applications of the adapted framework can be prepared taking these problems into account.

The whole process of adapting and applying the Ostrom framework at a local level has set in motion an interesting methodological learning process involving researchers and local stakeholders. The adapted framework came about through an intense collaboration between the different COMET-LA partners and local stakeholders participating in the workshops for SES characterization. This use of participatory techniques and the building of the COMET-LA learning arena as a communication and knowledge platform in the CSs, have opened a space for interaction between scientists and civil society, and for debate on the main issues at stake in each of the SESs.

The results of testing and applying this adapted framework in the 3 particular COMET-LA CSs are presented in Deliverables D2.2 (Stakeholder vision on problems and drivers related to environmental challenges in Colombia Case Study), D3.2 (Stakeholder vision on problems and drivers related to environmental challenges in Mexico Case Study) and D4.2 (Stakeholder vision on problems and drivers related to environmental challenges in Argentina Case Study) elaborated respectively by the Colombian, Mexican and Argentinean teams, and are available on the COMET-LA website.

Some additional locally-adapted tools delivered by COMET-LA, as a method for stakeholder mapping, a compilation of participatory approaches and techniques, and some tools to measuring climate variability at a local level. These tools have been tested with the local stakeholders for capacity building, in the learning arena, during and after the project lifetime.

Once the SESs are characterized and the procedures for describing them are mastered, the process for modelling their futures with and without intervention will be analyzed. The data from the characterization of the SESs will be an input for the COMET-LA future stages:

1. Prospective Structural Analysis for identifying current and potential problems, and drivers in the evolution of the SES. The methodological outcomes of this phase will be described in deliverable D1.2 (Locally-adapted Prospective Analysis Techniques to Social Ecological Systems) to be delivered by September 2014.
2. Scenario building. The methodological outcomes of this phase will be described in deliverable D1.3 (Locally-adapted Scenario Building Evaluation Methods) to be delivered by January 2015.

7 References

Adams, W.M. (2007). Thinking like a Human: Social science and the two cultures problem. ORYX Volume 41, Issue 3, Pages 275-276.

Agrawal, A. (1995). Dismantling the divide between indigenous and western knowledge. Development and Change 26 (3), 413e439.

Agrawal, A., and Gibson, C. C. (1999). Enchantment and disenchantment: The role of community in natural resource conservation. World development 27:629-649.

Agrawal, A. (2002). Indigenous Knowledge and the Politics of Classification. UNESCO, Oxford, UK

Anderies, J. M., Janssen, M. A. and Ostrom, E. (2004). A framework to analyze the robustness of Social-Ecological Systems form an institutional perspective. Ecology and Society 9(1): 18. [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art18

Armitage, D. 2005. Adaptive capacity and community-based natural resource management. *Environmental Management* 35: 703-715.

Axelrod, R. and Cohen M. D. (2001) Harnessing Complexity. Free Press, New York.

Barrett, C., K. Brandon, C. Gibson, and H. Gjertsen. 2001. Conserving biodiversity amid weak institutions. BioScience 51(6):497–502.

Becker, E. (2012). Social-Ecological Systems (SES) and Complexity. In M. K. Glaser, Gesche. Beate, Ratter and Welp Martin (Ed.), Human-Nature Interactions in the Anthropocene. Potentials of Social-Ecological Systems Analysis (pp. 37 - 59). New York: Routledge.

Berkes, F. (2004). Rethinking Community-Based Conservation. Conservation biology, vol. 18, issue 3, pp 621-630.

Berkes, F. (2007). Community-based conservation in a globalized world. PNAS, September 2007, vol. 104, no. 39, pp. 15188-15193.

Berkes, F., Colding, J. and Folke, C. (2003). Navigating Social-Ecological Systems. Building resilience for complexity and change. Cambridge: Cambridge University Press.

Berkes, F. and Folke, C., eds. 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge: Cambridge University Press.

Berkes F, Colding J, Folke C. 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecol. Appl. 10:1251–62

Blaikie, P (2006). Is small really beautiful? Community-based natural resource management in Malawi and Botswana. World Development, 34(11), 1942– 1957.

Borrini-Feyerband, G. 1996. Collaborative management of protected areas: Tailoring the approach to the context. IUCN, Gland, Switzerland.

Brand, F. S. and Jax, K. (2007). Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object. *Ecology and Society* **12**(1): 23. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art23/

Brechin, S.R., Wilshusen, P.R., Fortwangler, C.L., West, P.C. (2002). Beyond the square wheel: Toward a more comprehensive understanding of biodiversity conservation as social and political process. Society and Natural Resources Volume 15, Issue 1, Pages 41-64.

Brooks, J.S., Franzen, M.A., Holmes, C.M.a, Grote, M.N., Mulder, M.B. (2006). Testing hypotheses for the success of different conservation strategies. Conservation Biology Volume 20, Issue 5, Pages 1528-1538.

Brosius, J., A. Tsing, and C. Zerner. 1998. Representing communities: Histories and politics of community-based resource management. Society and Natural Resources 11:157–168.

Bruckmeier, K., Tovey, H., 2008. Knowledge in sustainable rural development: from forms of knowledge to knowledge processes. Sociologia Ruralis 48 (3), 313e329.

Bruckmeier, K., Tovey, H. (Eds.), 2009. Rural Sustainable Development in the Knowledge Society. Ashgate, UK.

Burford, G., Velasco, I., Janoušková, S., Zahradnik, M., Hak, T., Podger, D., Piggot, G., Harder, M.K. (2013). Field trials of a novel toolkit for evaluating "intangible" values-related dimensions of project. Evaluation and Program Planning 36, 1-14.

Cash, D., Clark, F., Alcock, F., Dickson, N., Eckley, N. and Jager, J. (2002). Salience, credibility, legitimacy and boundaries: Linking research, assessment and decision making. RWP02-046. Kennedy School of Government, Harvard University, Cambridge, MA.

Dahl, J. 2000. Saqqaq: An Inuit hunting community in the modern world. University of Toronto Press, Toronto.

Davidson-Hunt, I. J. and O'Flaherty, R. M. (2007). Researchers, indigenous peoples, and place-based learning communities. Society and Natural Resources, vol. 20, issue 4, pp. 291-305.

Díaz, S., Quétier, F., Cáceres, D.M., Trainor, S.F., Pérez-Harguindeguy, N., Bret-Harte, M.S., Finegan, B., Peña-Claros, M. and Poorter, L. (2011) Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. Proceedings of the National Academy of Sciences of the United States of America, 108 (3), pp. 895-902.

Dietz, T., Ostrom, E., Stern, P. C. 2003. The struggle to govern the commons. Science 12 Dec. 2003: Vol. 302 no. 5652 pp. 1907-1912

Dietz, T. and Stern, P. C. (2008). Public participation in environmental assessment and decision making. Washington, DC, The National Academies Press.

European Environmental Agency. (1999). Environmental indicators: typology and overview. EEA, Copenhagen.

Folke, Carl, Carpenter, S. Elmqvist, T. Gunderson, L. Holling, CS. Walker, B. Bengtsoon, J. Berkes, F. Colding, J. Danell, K. Falkenmark, M. Gordin, L. Kasperson, R. Kautsky, N. Kinzing, A. Levin, S. Mäler, K. Moberg, F. Ohlsson, L. Olsson, P. Ostrom, E. Reid, W. Rockström, J. Savenije, H. Svedin, U. (2006). Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations (Environmental Advisory Council to the Swedish Goverment ed., Vol. Scientific Background Paper on Resilience for the process of The World Summit on Sustainable Develpment). Stockolm.

Folke, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change 16 (2006) 253–267

Folke, C., Hahn, T., Olssen, P. and Norberg, J. (2005). Adaptive governance of Social-Ecological systems. Annual review of environment and resources, vol. 30, pp. 441-473.

Galaz, Victor. (2005). Social-Ecological Resilience and Social Conflict: Institutions and Strategic Adaptation in Swedish Water Management. Ambio, 34(7), 567 - 572.

Glaser, Marion. M.W Ratter, B. Krause, G. Welp. M (2012). In M. K. Glaser, Gesche. Beate, Ratter and Welp Martin (Ed.), Human-Nature Interations in the Anthropocene. Potentials of Social-Ecological Systems Analysis (pp. 3 - 12). New York: Routledge.

Gray, S., Chan, A., Clark, D., Jordan, R. (2012). Modeling the integration of stakeholder knowledge in social-ecological decision-making: Benefits and limitations to knowledge diversity. Ecological Modelling 229, pp. 88-96

Gunderson LH, Holling CS. 2001. Panarchy: Understanding Transformation in Human and Natural Systems. Washington, DC: Island

Hardin, G. 1968. The Tragedy of the Commons. Science 162, 1243

Hahn, Thomas; Schultz, Lise; Folke, Carl; Olsson, Per. (2008). Social Networks as a Sources of Resilience. In J. a. C. Norberg, Graeme (Ed.), *Complexity Theory for a Sustainable Future* (pp. 119 - 148). New York: Columbia University Press.

Holland, John, H. (1992). Complex Adaptive Systems. Daedalus, 121(1), 17 - 30

Hopkins, T. S., D. Bailly, and J. G. Støttrup. 2011. A systems approach framework for coastal zones. Ecology and Society 16(4): 25. http://dx.doi.org/10.5751/ES-04553-160425

Hopkins, T. S., D. Bailly, R. Elmgren, G. Glegg, A. Sandberg, and J. G. Støttrup. 2012. A systems approach framework for the transition to sustainable development: potential value based on coastal experiments. Ecology and Society 17(3): 39. http://dx.doi.org/10.5751/ES-05266-170339

Huntington, H. P., Brown-Schwalenberg, P. K., Frost, K. J., Fernandez-Gimenez, M. E., Norton, D. W. and Rosenberg, D. H. (2002). Observations on the workshop as a means of improving communication between holders of tratitional and scientific knowledge. Environmental Management, vol. 30, issue 6, pp. 778-792.

Janssen, M. A. and Anderies, J. M. (2007). Robustness trade-offs in Social-Ecological Systems. International journal of the Commons, vol. I, no. I, October 2007, pp. 43-65.

Kellert, S., J. Mehta, S. Ebbin, and L. Litchtenfeld. 2000. Community natural resource management: promise, rhetoric and reality. Society and Natural Resources 13:705–715.

Lane, M. B., McDonald, G. (2005). Community-based environmental planning: Operational dilemmas, planning principles and possible remedies. Journal of Environmental Planning and Management, Volume 48, Issue 5, pp. 709-731

Levin, S. A. (1992). The problem of pattern and scale in Ecology. Ecology **73 (6)**, 1943-1967

Li, T. (2005). Engaging simplifications: Community-based natural resource management, market processes, and stat agendas in upland Southeast Asia. Chapter 16 of Brosius, J. P., Lowenhaupt Tsing, A., Zerner, C. (2005). Communities and conservation. Altamira Pressa. pp. 427-458

Lund, J. F., Treue, T. Are We Getting There? Evidence of Decentralized Forest Management from the Tanzanian Miombo Woodlands, World Development, Volume 36, Issue 12, December 2008, Pages 2780-2800, ISSN 0305-750X, http://dx.doi.org/10.1016/j.worlddev.2008.01.014.

Lurie, S., Hibbard, M. (2008). Community-Based Natural Resource Management: Ideals and Realities for Oregon Watershed Councils. Society & Natural Resources, vol. 21, issue 5, pp. 430-440.

Matzke, G. E., Nabane, N. (1996). Outcomes of a community controlled wildlife utilization program in a Zambezi Valley Community. Human Ecology 24 (1): 65-85.

McCay, B., and S. Jentoft. 1998. Market or community failure? Critical perspectives on common property research. Human Organization 57(1):21–29.

McGinnis, M. D. (2011). An introduction to IAD and the language of the Ostrom workshop: A simple guide to a complex framework. Policy Studies Journal, Vol. 39, No. 1, pages 169–183.

McGinnis, M. D. and Ostrom, E. (2012). SES framework: initial changes and continuing challenges. Ecology and Society (forthcoming).

Nelson, D.R., Adger, W.N., Brown, K. (2007). Adaptation to environmental change: contributions of a resilience framework. Annual Review of Environment and Resources Volume 32, Pages 395-419.

Norberg, Jon; Wilson, James; Walker, Brian; Ostrom, Elinor. (2008). Diversity and Resilience of Social-Ecological Systems. In J. a. C. Norberg, Graeme (Ed.),*Complexity Theory for a Sustainable Future* (pp. 46 - 80). New York: Columbia University Press.

Nygren, A., 1999. Local knowledge in the environment-development discourse. Critique of Anthropology 19 (3), 267e288.

Oakerson, R. J. (1992). Analyzing the commons: a framework. In D. W. Bromley (ed.). Making the Commons Work: theory, practice and policy, ICS Press, San Francisco, pp. 41-59.

OECD (2011), Society at a Glance 2011: OECD Social Indicators, OECD Publishing. http://dx.doi.org/10.1787/soc_glance-2011-en

Ostrom, E. (1990). Governing the commons. University of Cambridge.

Ostrom, E. (2000). Collective action and the evolution of social norms. The Journal of Economic Perspectives, vol. 14, no. 3, pp. 137-158.

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science 325, 419-422.

Pomeroy, R. S. 1996. Community-based and co-management institutions for sustainable coastal fisheries management in Southeast Asia. Ocean and Coastal Management 27(3):143–162.

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M. and Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. Journal of Environmental Management, vol. 91 (2010), pp. 1766-1777.

Reed, S. M. (2008). Stakeholder participation for environmental management: A literature review. Biological Conservation 141 (2008), pp. 2417-2431.

Ryan, C.M. and Klug, J. (2005). Collaborative watershed planning in Washington state: Implementing the watershed planning act. Journal of Environmental Planning and Management, 48(4), 491–506.

Sillitoe, P., 1998. The development of indigenous knowledge. Current Anthropology 39 (2), 223e252

Stokols, D., Perez Lejano, R. and Hipp, J. (2013). Enhancing the resilience of human–environment systems: a social–ecological perspective. Ecology and Society **18**(1): 7.

Tang, Z and SD Brody (2009). Link planning theories with factors influencing local environmental plan quality. Environment and Planning B: Planning and Design, 36, 522–537

Tang, Z. and Zhao, N. (2011). Assessing the principles of community-based natural resources management in local environmental conservation plans. Journal of Environmental Assessment Policy and Management, vol. 13, no. 3, pp.405-434.

TEEB (2010), The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington

Terborgh, J. (2004). Requiem for Nature. Island Press.

Tretter, F; Halliday, A. (2012). Modelling Social-Ecological Systems: bridging the gap between natural and social sciences. In Glaser, M., Krause, G., Ratter, B. M. W. and Welp, M. (2012). Human-Nature interactions in the Anthropocene. New York, Routledge. Pp. 60-89.

UN. (2007) Indicators of sustainable development: Guidelines and methodologies. Third edition. United Nations, New York.

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G. D. and Pritchard, R. (2002). Resilience management in Social-ecological Systems: a working hypothesis for a participatory approach. Conservation Ecology 6(1): 14. [online] URL: http://www.consecol.org/vol6/iss1/art14

Western, D., and R. M. Wright, eds. 1994. Natural connections: Perspectives in community-based conservation. Washington, DC: Island Press

Waylen, K.A., Fischer, A., Mcgowan, P.J.K., Thirgood, S.J., Milner-Gulland, E.J. (2010). Effect of local cultural context on the success of community-based conservation interventions. Conservation Biology Volume 24, Issue 4, Pages 1119-1129.

Waylen, K.A., Fischer, A., Mcgowan, P.J.K., Thirgood, S.J., Milner-Gulland, E.J. (2013). Deconstructing community for conservation: Why simple assumptions are not sufficient. Human ecology, 41:575-585.

Annexe I: Adapted Ostrom framework

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Social, Economic and Political Setting (S)	Describes how all SES may affect and be affected by the larger socioeconomic, political, and ecological settings in which they are embedded	S1	**Economic development** - Sustained, concerted actions of communities and policymakers improving the standard of living and economic health of a specific area / the quantitative and qualitative changes in an existing economy	S1a	Economic sectors in the study area	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
				S1b	Income per capita	Regional - Local		Socio-economic DB	Numerical	Lack of data at local level; No formal register of this data
				S1c	Employment per sector (% and trends)	Regional - Local		Socio-economic DB	Numerical	Lack of data at local level; No formal register of this data
				S1d	Subsistence activities	Regional - Local	Interviews; Life stories; Surveys; Workshops	Socio-economic DB	Descriptive	Information subjective and dynamic over time; No formal register of this data
				S1e	Non-paid activities (related to land management)	Regional - Local	Interviews; Life stories; Surveys; Workshops	Socio-economic DB	Descriptive	Information subjective and dynamic over time; No formal register of this data
				S1f	Income dispersion	Regional - Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Lack of data at local level
				S1g	Time allocation to the different economic activities carried out by the stakeholders	Regional - Local	Interviews; Surveys; Workshops		Descriptive; Numerical	Complex measurement; Lack of data at local level
				S1h	Specialization of stakeholders (in one of different economic activities)	Regional - Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Lack of data at local level
		S2	**Demographic trends** - Development, changes and status of the human population	S2a	Number of inhabitants	Local		Socio-economic DB	Numerical	
				S2b	Population density	Local		Socio-economic DB	Numerical	
				S2c	Gender ratio	Local		Socio-economic DB	Numerical	
				S2d	Demographic structure	Local		Socio-economic DB	Numerical	
				S2e	Population growth rate	Local		Socio-economic DB	Descriptive; Numerical	Lack of data at local level
				S2f	Migration trends	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Lack of data at local level
				S2g	Ethnical diversity (in % per group)	Regional - Local		Socio-economic DB	Numerical	
				S2h	Settlement patterns	Local		Geospatial DB	Descriptive	
		S3	**Political stability** - Eventual existence of a core regulatory framework for the	S3a	Core legal framework (national constitution and core laws)	National		Legal DB	Descriptive	
				S3b	Level of norm	Regional -	Interviews; Life stories;	Legal DB	Descriptive	Difficult to access and collect data

First tier	Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
		country or area / eventual existence of defined laws / the regularity of the democratic processes		compliance (norm stability, capacity of reinforcement, knowledge of norms)	Local	Media; Observation; Surveys; Workshops			
			S3c	Type of conflicts	National - Local	Interviews; Life stories; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Subjective information; No formal register of this data; Lack of data at local level
			S3d	Security indexes (e.g. the UN Security Risk Rating Index)	National		International DB	Numerical	
			S3e	Respect for democratic values (e.g. human rights, corruption)	Regional - Local	Interviews; Life stories; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Subjective information; No formal register of this data
	S4	**Government resource policies** - Type of resource policies adopted by the national, regional and local governments (top-down approach)	S4a	Governmental regulatory framework for natural resources management and use	National - Regional		Legal DB	Descriptive	
			S4b	Environmental policies at national, regional and local levels and the implementation level (including climate change mitigation strategies)	National - Local	Interviews; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Difficult to access and collect data
			S4c	Environmental regulatory and policy frameworks compliance	National - Regional	Interviews; Media; Observation; Surveys; Workshops	Legal DB	Descriptive	Difficult to access and collect data
	S5	**Market incentives** - Market functioning for natural resource management and conservation	S5a	Influence of global/local markets in the area (e.g. levels of dependency of external markets, price definition)	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
			S5b	Type of products (e.g. commodities, certified products, other kind of labelling)	Regional - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
			S5c	Access to markets	Regional -	Interviews; Surveys;	Socio-economic DB	Descriptive	

First tier	Second tier	Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
			(distance, commercialisation channels and networks, marketing)	Local	Workshops			
		S5d	Demand for natural resources from local, regional, national and international markets	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
		S5e	Market incentives for natural resource conservation (e.g. existence of taxes, fees and charges, tradable permits, eco-labelling, financial mechanisms, liability and compensation schemes)	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	
	S6 **Media organization** - Number, diversity, freedom… of private and public media	S6a	Existence of communication networks	National - Local	Interviews; Media; Observation; Workshops		Descriptive	Unclear or abstract concept for local stakeholders; No formal register of this data
		S6b	Media deterrence capability	International - Local	Interviews; Media; Observation; Workshops		Descriptive	Unclear or abstract concept for local stakeholders; No formal register of this data
		S6c	Interest of media in socio-environmental issues	National - Local	Interviews; Media; Observation; Workshops		Descriptive	Unclear or abstract concept for local stakeholders; No formal register of this data

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Resource Systems (RS)	Comprises the environment where the resource is produced/found	RS1	**Sector(s) (e.g. water, forest, pasture, fish)** - Different biological production systems	RS1	Sectors	Regional - Local	Interviews; Observation; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive; Numerical	
		RS2	**Clarity of system boundaries** - Clarity of the system's geographical, social and legal boundaries, describing if the boundaries of the studied resource system are clear, fuzzy or undefined	RS2a	Natural boundaries (e.g. rivers, mountains, specific vegetation)	Regional - Local	Observation; Surveys; Workshops	Environmental and Geospatial DB	Descriptive; Geographical	Fuzziness of limits
				RS2b	Anthropogenic boundaries (e.g. land use distribution, conservation areas)	Regional - Local	Interviews; Observation; Surveys; Workshops	Geospatial and Socio-economic DB	Descriptive; Geographical	Fuzziness of limits; Unclear definition of categories
				RS2c	Extraction access and property boundaries	Local	Interviews; Surveys; Workshops	Geospatial and Socio-economic DB	Descriptive; Numerical	
		RS3	**Size of resource system** - Size of each type of resource (private, club, open access or common pool resources)	RS3	Size	Local		Environmental, Geospatial and Socio-economic DB	Numerical	Unclear or abstract concept for local stakeholders
		RS4	**Human constructed facilities** - Anthropogenic structures facilitating resource management (e.g. boundaries, access ways, storage or transformation facilities)	RS4	Constructed facilities (e.g. roads, enclosures, field systems, boundary banks and ditches, ponds, parks and woods, wind and water mills, manor houses, moats and churches)	Local	Interviews; Observation; Surveys; Workshops	Environmental, Geospatial and Socio-economic DB	Descriptive	
		RS5	**Productivity of system** - General estimation of the resource system productivity	RS5a	Productivity of the resource system (high, medium, low, exhausted)	Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive; Numerical	Lack of data at local level; Difficult to access and collect data
				RS5b	Resource regeneration period	Local	Interviews; Observation; Surveys; Workshops	Environmental DB	Descriptive; Numerical	Lack of data at local level
				RS5c	Resource extraction period	Local	Interviews; Observation; Surveys; Workshops	Legal and Socio-economic DB	Descriptive; Numerical	Lack of data at local level

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
		RS6	**Equilibrium properties** - Influences (positive and negative) on the equilibrium of the resource system (interaction between species, in social systems, or between biological and anthropological systems)	RS6a	Equilibrium properties	Regional - Local	Interviews; Observation; Surveys; Workshops		Descriptive	Unclear or abstract concept for local stakeholders
				RS6b	Natural hazards occurrence (frequency and magnitude): e.g. flooding, fires, drought	Regional - Local	Interviews; Surveys; Workshops	Environmental DB	Descriptive	
				RS6c	History, evidence of impacts in sub-systems and its effects	Regional - Local	Interviews; Media; Surveys; Workshops	Environmental DB	Descriptive	Lack of data at local level; No formal register of this data
		RS7	**Predictability of system dynamics** - Capacity to estimate the evolution and dynamics of the resource system and the impact of interventions or external influences on them	RS7	Predictability of system dynamics	Regional - Local				
		RS8	**Storage characteristics** - Retention of information about the system dynamics	RS8	Storage (memory) of the effects of disturbances on a system or sub-systems	Regional - Local	Interviews; Life stories; Surveys; Workshops	Environmental and Legal DB	Descriptive	Lack of data at local level
		RS9	**Location** - Geographic location	RS9	Geographical location, distribution and distribution patterns	Local		Geospatial DB	Geographical	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Governance Systems (GS)	Describes the governance system affecting and affected by the SES	GS1	**Government organizations** - Permanent or semi-permanent organizations (or systems of rules) controlled by national, regional and local regulation institutions	GS1	Government Organizations	National - Local	Interviews; Life stories; Surveys; Workshops	Legal and Socio-economic DB	Descriptive	
		GS2	**NGOs** - Different types of NGOs (e.g. social, environmental, technical organizations) interacting with the analyzed SES	GS2	NGOs	National - Local	Interviews; Life stories; Surveys; Workshops	Legal and Socio-economical and	Descriptive	No formal register of this data
		GS3	**Network structure** - Networks existing in the socio-ecological system and with direct or indirect influence on the management and use of resources	GS3a	Social networks	Regional - Local	Interviews; Life stories; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data
				GS3b	Environmental networks	Regional - Local	Interviews; Life stories; Media; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data
				GS3c	Market networks	National - Local	Interviews; Life stories; Media; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data
		GS4	**Property-rights systems** - Presence or absence of formal property right systems for the resources (e.g. land property, exclusive fishing rights)	GS4a	System of property right	Regional - Local	Interviews; Observation; Surveys; Workshops	Legal and Socio-economic DB	Descriptive	
				GS4b	Excludability (i.e., possibility to exclude potential users from using the resource)	Local	Interviews; Observation; Surveys; Workshops		Descriptive	Subjective information; No formal register of this data (ELIMINAR)
				GS4c	Subtractability (i.e. whether resource appropriation by one user reduce availability to others)	Local	Interviews; Observation; Surveys; Workshops		Descriptive	

First tier	Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
	GS5	**Operational rules** - Community rules established for the extraction, management, access and use of natural resources	GS5	Operational rules (local rules for defining Who, How, Where, When, and Why have access to local natural resources)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
	GS6	**Collective-choice rules** - Collective-choice rules used to change the day-to-day operational rules related to the resource management	GS6	Collective-choice Rules	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
	GS7	**Constitutional rules** - The background rules set at the beginning of the common use of resource organization (e.g. the constitutional or core rules of the community)	GS7	Constitutional rules	National - Local	Interviews; Observation; Surveys; Workshops	Legal DB	Descriptive	
	GS8	**Monitoring and sanctioning processes** - Set of methods to monitor and enforce the operational rules	GS8a	Monitoring processes	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
			GS8b	Sanctioning processes	Local	Interviews; Observation; Workshops	Socio-economic DB	Descriptive	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Resource Units (RU)	Describes the natural resource units generated by the resource system (e.g. fish, water, fodder)	RU1	**Resource unit mobility** - E.g. fish are mobile, while trees are static	RU1	Resource unit mobility	Regional - Local	Interviews; Surveys; Workshops	Environmental DB	Descriptive	
		RU2	**Growth or replacement rate** - Based upon the resource unit's life cycle (e.g. reproductive age, harvesting age, growth rate)	RU2	Growth or replacement rate	Local	Interviews; Workshops	Environmental DB	Descriptive; Numerical	Lack of data at local level
		RU3	**Interaction among resource units** - E.g. competition, collaboration	RU3	Interaction among resource units	Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive; Numerical	Unclear or abstract concept for local stakeholders
		RU4	**Economic value** - Economic value of the resources	RU4a	Market value	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Information subjective and dynamic over time; No formal register of this data
				RU4b	Environmental value	International - Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive	Difficult to measure at local level
				RU4c	Strategic value (e.g. economic, social, geopolitical, cultural, symbolic)	International - Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Difficult to measure; Subjective information
		RU5	**Number of units** - Total volume or amount of resource (e.g. wood volume, agriculture production volume, number of fish)	RU5	Number of resource units / amount of resource	Local	Interviews; Surveys	Environmental DB	Numerical	Lack of data at local level; Difficult to measure
		RU6	**Distinctive markings** - Natural or artificial markings to distinguish categories in the resource	RU6	Distinctive markings	Regional - Local	Interviews; Surveys; Workshops	Environmental and Socio-economic DB	Descriptive	
		RU7	**Spatial and temporal**	RU7	Spatial and temporal	Regional -	Interviews; Surveys;	Environmental and	Descriptive;	Frequent measurements hard to organize

First tier		Second tier	Third tier	Level	Research tools	Data sources	Data type	Zooming in/out problems
		distribution - Availability of the resource in space and time	distribution	Local	Workshops	Geospatial DB	Geographical ; Numerical	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Users (U)	Describes users of the resource system under consideration	U1	**Number of users** - Number of the direct users of the SES	U1	Number of users	Local	Surveys; Workshops	Socio-economic DB	Numerical	Lack of data at local level; Information subjective and dynamic over time
		U2	**Socio-economic attributes of users** - Socio-economic characteristic of the resource system users	U2a	Sources of income (linked or not with the resource)	Local	Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	Difficult to access and collect data
				U2b	Consumption patterns (e.g. local resources, local/imported food, shopping)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Subjective information
				U2c	Women rights (e.g. land tenure, empowerment, gender equity, private-public roles, health, education)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Difficult to access and collect data; Subjective information; Lack of data at local level
				U2d	Access to health	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	Lack of data at local level
				U2e	Access to education	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
				U2f	Poverty (e.g. income, life cost, access to food)	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	Unclear or abstract concept for local stakeholders
				U2g	Vulnerability (e.g. social, economic, institutional, environmental)	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive	Unclear or abstract concept for local stakeholders
				U2h	Cultural identities (e.g. language, food, celebrations, traditions)	Local	Interviews; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	
				U2i	Sanitation	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
				U2j	Access to drinking water	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
				U2k	Access to electricity	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	
				U2l	Home gadgets (e.g. TV, washing machine, computer, telephone)	Local	Interviews; Surveys; Workshops	Socio-economic DB	Descriptive; Numerical	No formal register of this data

First tier	Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
	U3	**History of use** - Chronological description of resource extracting methods	U3	History of use	Regional - Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
	U4	**Location** - Geographical location of users of the resource system (e.g. settlements, villages, dispersion)	U4	Location/dispersion patterns	Local	Interviews; Surveys; Workshops	Geospatial and Socio-economic DB	Descriptive; Geographical	
	U5	**Leadership/entrepreneurship** - Existence of, and attitude towards leadership and entrepreneurship among users	U5a	Leadership patterns (e.g. level of acceptance, prominence, leadership models)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Information subjective and dynamic over time
			U5b	Attitudes toward conservation (e.g. entrepreneurship, maintenance, sustainable use)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
	U6	**Norms/social capital** - Levels of social interaction, reciprocity and trust among users	U6a	Social capital	Local	Interviews; Life stories; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Information subjective and dynamic over time; Unclear or abstract concept for local stakeholders
			U6b	Traditional forms of collaboration among users (e.g. norms, habits, traditions, customs)	Local	Interviews; Life stories; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	Subjective information
	U7	**Knowledge of SES/mental models** - Level of knowledge among the users of the SES conditions, perturbance patterns and possible effects	U7a	Local knowledge on SES (based on traditional or scientific knowledge)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
			U7b	Knowledge of the effect of over-harvesting	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
			U7c	Knowledge of the effect of social attitudes toward resource management on the	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information

First tier	Second tier	Third tier	Level	Research tools	Data sources	Data type	Zooming in/out problems
		SES					
		U7d Knowledge of the effect of biological shocks on the SES	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information
		U7e Mental models related to SES management (e.g. conservation, exploitation, human-nature relationships)	Local	Interviews; Life stories; Observation; Surveys; Workshops		Descriptive	Subjective information; Unclear or abstract concept for local stakeholders
	U8 **Importance of resources** - Users dependence on resources for livelihood	U8 Importance of resources for livelihood	Local	Interviews; Life stories; Observation; Surveys; Workshops	Socio-economic DB	Descriptive	No formal register of this data
	U9 **Technology used** - Type of technology used to extract, harvest and manage the resource, as well as differences in access among users based on access to different technologies	U9 Type of technologies used on the SES	Local	Interviews; Life stories; Observation;Surveys; Workshops	Socio-economic DB	Descriptive	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Interactions (I)	Describes interactions among all before mentioned variables	I1	**Harvesting levels of diverse users** - Quantity of the resource(s) harvested by different users	I1a	Harvesting level and effects on SES	Regional - Local			Analytical	
				I1b	Free-riding	Local			Analytical	
		I2	**Information sharing among users** - Methods of information sharing among users	I2a	Knowledge dissemination on the SES	Local			Analytical	
				I2b	Information/knowhow sharing about the SES variations	Local			Analytical	
		I3	**Deliberation processes** - Deliberation process used among users	I3a	Deliberation processes among users	Local			Analytical	
				I3b	Knowledge about participation mechanisms and rights	Local			Analytical	
		I4	**Conflicts among users** - Existing conflicts among users	I4	Type of conflict (e.g. conflict based on greed, grievance, scarcity, technology, access, power, information)	Local			Analytical	
		I5	**Investment activities** - Investments for improving and managing the resources (investor, amount invested and destination of investment)	I5	Investments activities (investor, amount invested and destination of investment)	Local			Analytical	
		I6	**Lobbying activities** - Internal, external and influence capacity	I6	Lobbying activities (actors involved, expected outcomes)	Local			Analytical	
		I7	**Self-organizing activities** - Self-organization activities among users for extracting resources	I7	Self-organizing activities (include description of any solidarity activities)	Local			Analytical	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
		I8	**Networking activities** - Networking activities of the users within and outside the community	I8a	Internal networks	Local			Analytical	
				I8b	External networks	Local			Analytical	
				I8c	Partnership and cooperation	Local			Analytical	
				I8d	External communication channels	Local			Analytical	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Outcomes (O)	Comprises results of the interactions among aforementioned variables	O1	**Social performance measures (e.g. efficiency, equity, accountability, sustainability)** - Impact of different activities on social performance	O1a	Efficiency	Local			Analytical	
				O1b	Equity (distribution of benefits between SES users)	Local			Analytical	
				O1c	Socio-economical sustainability	Local			Analytical	
				O1d	Accountability	Local				
				O1e	Effects of deliberation processes on the SES	Local			Analytical	
				O1f	Empowerment (including gender analysis)	Local				
				O1g	Adaptation strategies to climate change	Local			Analytical	
		O2	**Ecological performance measures (e.g. overharvesting, resilience, biodiversity, sustainability)** - Impact of different activities on ecological performance	O2a	Environmental sustainability	Local			Analytical	
				O2b	Pressure on resources (e.g. increasing demand, new actors, overharvesting)	Local			Analytical	
				O2c	Natural habitat (e.g. biodiversity indexes, species richness, connectivity, habitat conservation/degradation/fragmentation)	Local			Analytical	
				O2d	Effect of SES management on natural hazards (e.g. changes in type, frequency, pattern)	Local			Analytical	
				O2e	Structure and function of resources (e.g. changes, interactions among resource units, trophic chains)	Local			Analytical	

First tier	Second tier	Third tier	Level	Research tools	Data sources	Data type	Zooming in/out problems
		O2f Soil (e.g. erosion, degradation, improvement)	Local				
		O2g Water (e.g. quality, availability)	Local				
		O2h Air (e.g. quality)	Local				
		O2i Pollution (e.g. waste generation, frequency of occurrence)	Local				
		O2j Resilience	Local				
		O2k Vulnerability	Local				
	O3 **Externalities to other SES** - Positive or negative impacts on other SESs without previous agreement or request	O3a Positive externalities (e.g. CO_2 capture, water protection, biodiversity conservation)	Local			Analytical	
		O3b Negative externalities (e.g. CO_2 emissions, pollution)	Local			Analytical	

First tier		Second tier		Third tier		Level	Research tools	Data sources	Data type	Zooming in/out problems
Related Ecosystems (ECO)	Describes the connection of the considered ecosystem with the surrounding ecosystems	ECO1	**Climate patterns** - Climate patterns affecting the considered SES	ECO1	Climate patterns (e.g. precipitation, temperature, sea level, extreme events, seasonal changes)	National - Local			Descriptive; Numerical	
		ECO2	**Pollution patterns** - Pollution patterns affecting the considered SES (e.g. water, waste, soil, air)	ECO2	Pollution patterns (e.g. water, waste, soil, air)	Regional - Local			Descriptive	
		ECO3	**Flows into and out of focal SES** - Flows from other SESs affecting the considered SES and vice versa	ECO3	Flows from other SESs affecting the considered SES and vice versa (economic pressures, environmental effects and social effects)	National - Local			Descriptive	

Annexe II: Stakeholder mapping

1 Stakeholder mapping

Stakeholder analysis techniques were initially developed for businesses and companies as a tool for decision-making. Most of their initial applications are derived from these spheres and are company-centred.

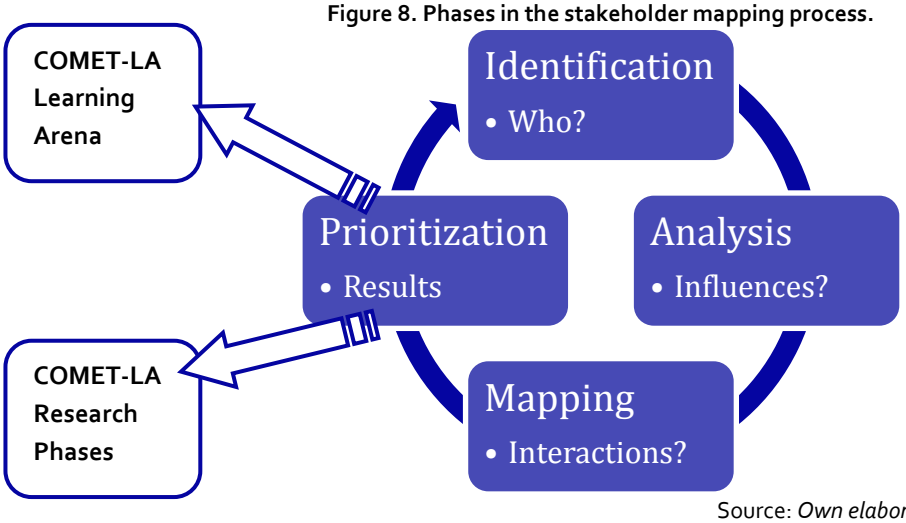
The analysis of actors or the mapping of stakeholders are essential stages in any participatory process aiming to involve key stakeholders, like COMET-LA's learning arena. Hence, stakeholder mapping methods and tools have been adapted for use at local levels and these guidelines delivered and applied in the 3 CSs. This briefing reviews some of the main concepts involved in stakeholder mapping and proposes a method to do it at local level.

The identification and, if possible, the active involvement of all important stakeholders in the project makes its outcomes and impacts more relevant, not only for the project development but also for the SES evolution.

Stakeholder mapping should not be understood as a step, but as a continuous process of identifying individuals or groups that have an impact on or are impacted by the studied SES. The information obtained during this process is also used to assess how the stakeholders should be addressed, how their importance should be evaluated and how they influence or are influenced by the SES.

The process (see Figure 8**Error! Not a valid bookmark self-reference.**) starts with a thorough **identification** of all groups, organizations and persons; next, the stakeholders are **analyzed** for a better understanding of their features; their relationships to the SES and other stakeholders are **mapped**, and the stakeholders are **prioritized** following the different criteria defined by the project. These steps will be discussed in the next paragraphs. Once they are prioritised, all the key stakeholders are invited to participate in the project.

Figure 8. Phases in the stakeholder mapping process.



Source: *Own elaboration.*

1.1 Stakeholder identification

When approaching a SES for stakeholder mapping, stakeholder identification is the first step. A thorough listing of all relevant groups, organizations and persons has to be elaborated. This process is essential and complicated. The risk of forgetting important stakeholders, especially at the initial stages when facilitators are not very familiar with the SES, could undermine the whole effort of stakeholder mapping. So, it is very important to devote the necessary time and effort to this step.

Stakeholder identification starts with a brainstorming by the members of the team. Every person, group or organization that could possibly have an influence on, or be influenced by the SES in question, today or in the future, is listed. When constituting the list of stakeholders, no other criteria than 'influence on or influenced by the SES' is used. There are no geographical limits, no conditions about size or importance, any possible stakeholder is listed. A special effort has to be dedicated to identify 'untraditional' central stakeholders or collectives like women, youngsters, indigenous groups, etc. for including them in the learning arena.

The list can contain, but not exclusively:

- Individual, or associations of, resource users (e.g. farmers, fishermen, forest-users, guilds, unions);
- Individuals, or associations performing economical activities in the SES (e.g. in the next sectors: forest, livestock, agriculture, mining, energy, water, etc.);
- Individual, or associations of, persons with little representation in decision-making organisms (e.g. women, indigenous, black or young people, etc.);
- Local, regional, national and international authorities (e.g. municipalities, regional and national governments, United Nations representations, etc.);
- Local, regional and national institutions and agencies with influence in the SES (e.g. environmental agencies, health and education agencies, etc.);
- International or national civil society organizations (e.g. NGOs, local women's organization, local church organization);
- Opinion makers (e.g. media, civil leaders, preachers, education institutions).

At this stage no analysis is done. The analysis of these stakeholders is the next step and should not be mixed with the identification of the stakeholders.

The identification of stakeholders is a continuous process; during the next phases of stakeholder mapping, it is highly probable that new stakeholders will be found, which should be directly included in the process.

1.2 Analysis of the stakeholders

Once the list is sufficiently complete, a thorough analysis of the listed stakeholders helps in understanding their position and importance within the SES .

For every stakeholder, a list of properties is filled-in. These properties can contain, but are not limited to:

- Contribution (low, medium, high): Does the stakeholder have information, counsel, or expertise in the issue that could be helpful in the SES?
- Legitimacy (low, medium, high): How legitimate is the stakeholder's position for engagement?
- Dependency (low, medium, high): How dependent is the stakeholder on the (sustainability of the) SES?
- Interest (low, medium, high): How interested is the stakeholder in the SES? (Collaboration and Willingness to engage, can also be used)
- Influence (low, medium, high): How much influence does the stakeholder have within the SES? (Define who or what the stakeholder influences) (Power, can also be used)
- Attitude (positive, neutral, negative): Does the stakeholder have an influence towards sustainable management of the SES? (Threat, Alignment and Support, can also be used)
- Necessity of involvement (low, medium, high): Is the stakeholder somebody the SES needs for proper functioning?

A value is attributed to each property of each stakeholder. Biases and misunderstandings are avoided through cross-checking and triangulation when filling these attributes. The produced matrix (see Table 17**Error! Not a valid bookmark self-reference.**) is the basis for the next step.

Table 17. Example of a stakeholder analysis.

	Expertise		Willingness		Value		
Stakeholder	**Contribution**	**Legitimacy**	**Depend-ency**	**Interest**	**Influence**	**Attitude**	**Necessity of involve-ment**
Stakeholder 1 (e.g. Government specialist)	High (Good expertise in management of the resource)	Low (Distance makes engagement low)	Low (Lives independently from SES)	Medium (Willing to contribute from a distance)	High (Influence in legislative power)	Positive (Sustainability is a goal)	Medium (SES functions without him)
Stakeholder 2	Medium	Medium	Low	Low	Low	Neutral	High
Stakeholder 3	High	High	Medium	Medium	Medium	Negative	Low
Stakeholder 4	Low	Medium	High	High	Medium	Positive	Medium
Stakeholder 5	Low	Low	Medium	High	Low	Neutral	Medium

Source: *Adapted from Olson* et al. *2011.*

1.3 Stakeholder mapping

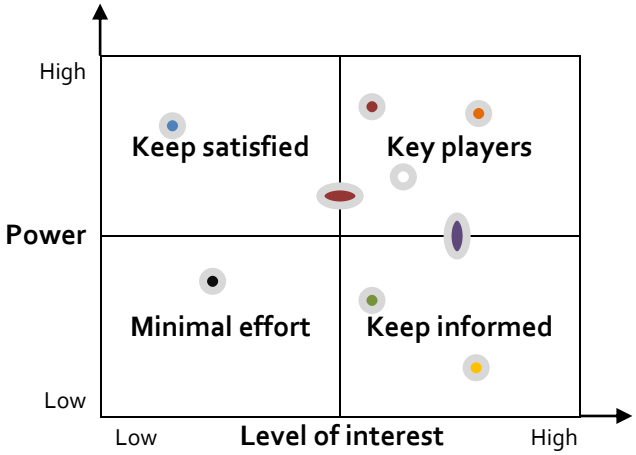
Once the stakeholders and their function within the SES are known, a visual exercise is performed to select the most important stakeholders for the goals of COMET-LA. Stakeholder mapping helps visualizing the data shown in the stakeholder analysis table (see Table 17) according to the selected variables.

Most visualisations are done by ordering the stakeholders around two axis, each representing a property. Sometimes colour and/or size are used for representing one or two extra properties (mostly influence for size and colour for identifying the stakeholder). By ordering the stakeholders, several clusters are created. This gives important information on the necessity to promote stakeholders shifting from one cluster to another.

There are different kinds of stakeholder maps presented in the literature (Mendelow, 1981; Savage et al, 1991; Murray-Webster & Simon, 2006; Mendizabal, 2012). However, only those more adapted or interesting for COMET-LA are presented.

Mendelow's matrix (Mendelow, 1981) classifies stakeholders in a power/interest grid (see Figure 9) delivering four clusters useful for decision-taking.

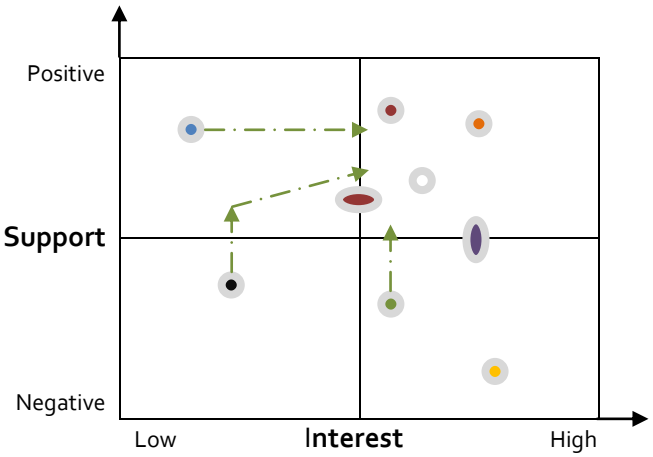
Figure 9. Mendelow's matrix.



Source: *Mendelow, 1981.*

Other methods, like the Alignment, Interest and Influence Matrix (AIIM) includes a general course of action towards the stakeholders (see Figure 10) for moving them from one part of the matrix (or cluster of stakeholders) to a more interesting one for the considered policy influencing action (Mendizabal, 2012).

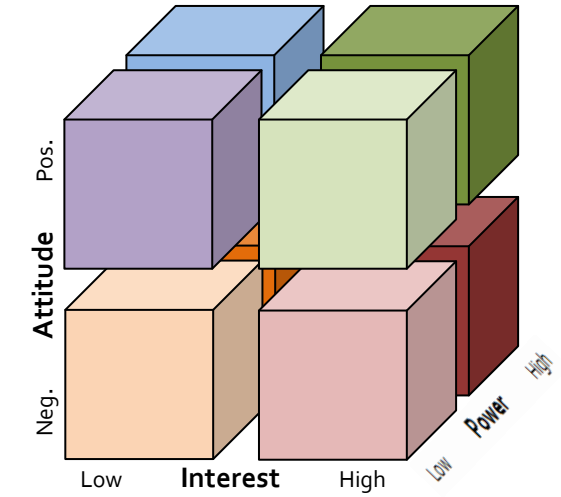
Figure 10. An example of an AIIM.



Source: *Adapted from Mendizabal, 2012.*

Other visualizations include a third dimension, in order to have a more fine-tuned image of the stakeholders, like 3D AIIM that uses 3 dimensions, putting Power vs. Interest vs. Attitude. The example given by Murray-Webster & Simon (2006) (see Figure 11) shows how each stakeholder could influence an organization or SES. This kind of analysis is more complete, but at the cost of a lesser readability.

Figure 11. 3D stakeholder mapping.



- Sleeping giant: Influential passive backer
- Saviour: Influential active backer
- Acquaintance: Insignificant passive backer
- Friend: Insignificant active backer
- Time Bomb: Influential passive blocker
- Saboteur: Influential active blocker
- Trip Wire: Insignificant passive blocker
- Irritant: Insignificant active blocker

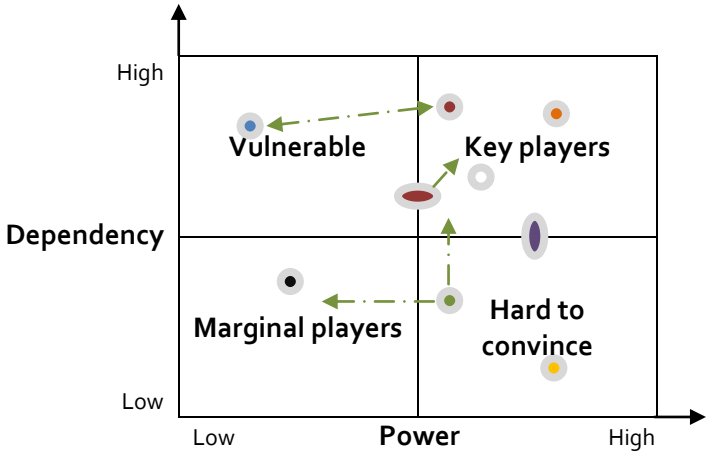
Source: *Adapted from Murray-Webster & Simon, 2005.*

As mentioned, most of these stakeholder analysis techniques are based on a company-centred view, evaluating which stakeholders could have the biggest positive or negative impact and how to change this in favour of the company. When adapting these to the analysis of the stakeholders in a SES, it should be taken into account that not only the most influential persons for that SES are important, but also those that are the most influenced. Indeed, in order for the SES to be sustainable, the persons that are the most influential as well as the most influenced by the SES are to be included in its management.

When plotting power vs. dependency, 4 interesting categories appear:

1. High dependency, low power: Vulnerable users
2. High dependency, high power: Key players
3. Low dependency, low power: Marginal players
4. Low dependency, high power: Hard to convince

Figure 12. Power/dependency matrix.



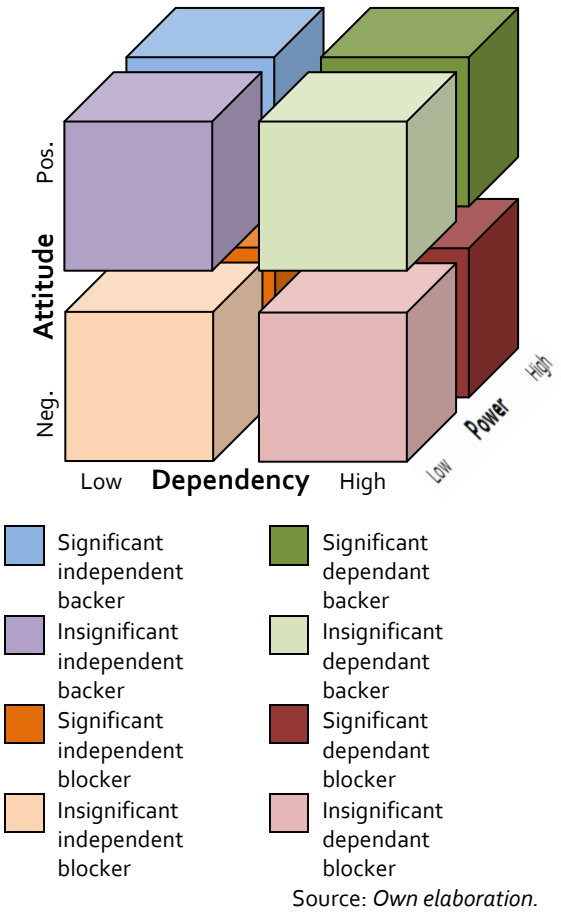
Source: *Own elaboration.*

This power/dependency grid can be useful in detecting which stakeholders are vulnerable and should be protected by, for example, linking them up with the key players. One category, the 'Hard to convince' stakeholders, should be more analyzed for knowing if they have a positive or negative attitude towards the SES in question. When possible, actions should be undertaken to move hard to convince stakeholders with negative attitudes towards marginal players of key players for reducing risks (see green arrows in Figure 12). If their attitude is positive, efforts should concentrate on moving them into the key player cluster.

As the attitude of the stakeholders can be seen as a very important property when including them in the development of participatory methodologies (COMET-LA's learning arena) or SES descriptions (adapted Ostrom framework), including this property in the above grid gives a strong tool for mapping the stakeholders.

These 3 dimensions, Dependency, Power and Attitude, are visualized like the 3D AIIM (Murray-Webster & Simon, 2006) in Figure 13.

Figure 13. 3D stakeholder mapping.



Source: *Own elaboration.*

This analysis combines the most important stakeholder properties into in 8 categories, which can easily be used for the next step: stakeholder prioritizing.

1.4 Stakeholder prioritizing

Once a clear image of the stakeholders is obtained, the information is organized by priority for further actions. It is not possible nor wanted to engage with all stakeholders with the same intensity, so choices are made.

The most effective way of communicating and focussing energy towards the right stakeholders, is prioritizing among them and choosing only the essential. When using the 3D grid proposed in Figure 13, 8 categories of stakeholders are to be analyzed (seeTable 18).

Table 18. 8 categories of 3D stakeholder analysis.

Dependency	Power	Attitude	Outcome	Examples
Low	Low	Neg.	Insignificant untouchable blocker	?
Low	Low	Pos.	Insignificant untouchable backer	?
Low	High	Neg.	Significant untouchable blocker	Corrupt governments, mining industry, illegal croppers, big fishing companies, water and energy companies
Low	High	Pos.	Significant untouchable backer	Governments (regional to national), National agencies, NGOs and international concerned organizations
High	Low	Neg.	Insignificant influenced blocker	Small users of resources competing by the use of resources
High	Low	Pos.	Insignificant influenced backer	Small users, young people and women
High	High	Neg.	Significant influenced blocker	Free-riders from outside SES, organizations of users competing by the resources
High	High	Pos.	Significant influenced backer	User cooperatives, communities, local-level governments, NGOs working at local level, local CSOs

Source: Own elaboration.

According to the relevance and influence of these groups in the SES, some actions could be developed to involve them in the SES's sustainable management. However, if their interests are conflicting with this management, quite often the room of manoeuvre to involve powerful stakeholders is rather limited.

Possible **threats** to the sustainability of the SES are the significant blockers (see Table 18), as they can have a strong negative impact on the SES. Some ideas about how to contact/involve the two categories (untouchable and influenced) of significant blockers indicate:

- Significant untouchable blocker: Reach through international lobby groups, monitor closely.
- Significant influenced blocker: Involve closely in the project, try to change 'blocker' to 'backer' using the fact that this stakeholder is influenced by the SES.

COMET-LA focuses mainly on the **actors and users,** so all influenced backers (see Table 18) are important for the project. The two categories (significant and insignificant) of influenced backers indicate how to contact/implicate them:

- Insignificant influenced backer: This category of vulnerable users are difficult to involve in the project as they are very diffuse. When possible, some kind of grouping (e.g. guilds, cooperatives) could be done for easing communication and strengthening this category (changing from insignificant to significant).
- Significant influenced backer: This group is very motivated in joining SES improvement activities. They can easily be reached and involved.

The last category important enough for involving in COMET-LA, are the **significant untouchable stakeholders** (see Table 18), as they are important, but hard to convince (see Figure 12). The two categories (backer and blocker) of significant untouchable stakeholders indicate how to contact/implicate them:

- Significant untouchable blocker: See threats.
- Significant untouchable backer: Reach through intensive communication, provide extensive information on the project and try to involve on an organizational level within the project.

The other 3 categories that are not included in this prioritization are all insignificant. They should all be monitored, but no more energy should be invested in these:

- Insignificant untouchable blocker
- Insignificant untouchable backer
- Insignificant influenced blocker

2 References

Olson, E., Prepscius, J., Baddache, F. (2011). Stakeholder mapping. BSR.org. http://www.bsr.org/reports/BSR_Stakeholder_Engagement_Stakeholder_Mapping.final.pdf

Savage, G. T., T. W. Nix, Whitehead and Blair (1991). Strategies for assessing and managing organizational stakeholders. Academy of Management Executive (5:2).

Mendelow, A. (1981). Environmental scanning: the impact of stakeholder concept. Proceedings of the second international conference on information systems, December 1981. Cambridge, Mass.

Mendizabal, E. (2012). The Alignment, Interest and Influence Matrix (AIIM) guidance note. http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6509.pdf

Murray-Webster, R., Simon, P. (2006). Making sense of Stakeholder Mapping. PM World Today - November 2006, Vol. VIII, Issue 11.

Annexe III: Participatory techniques

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1 Introduction

Collective action for natural resource management has been, in practice and theory, one of the biggest challenges for academia, international cooperation, NGO´s and States. Two questions guide collective action studies. The first one is, how collective action works in natural resource management? And the second one is, how to generate collective action for natural resource management? However, some methodological approaches have been used to solve those normative and critic questions about collective action.

Important scientific efforts have been devoted to deliver specific methodological approaches that answer to theoretical questions and that foster a real appropriation by the communities dealing to natural resource management. But it has been proven that participatory research helps to integrate in an effective fashion particular communitarian conditions and conservation strategies.

2 Participatory approaches

The participatory approach is considered a particular qualitative research strategy and it comes from the participatory research (PR) background. Qualitative research seeks on defining, analyzing and interpreting qualitative aspects of a specific social context. Then, participatory research takes into account the social relationships and interaction strategies of social groups (Chambers, 1997). Participatory approach is inspired on pluralism and democratic knowledge construction and helps local communities to define their research objectives towards improvement of living conditions. Aspects like gender, poverty, marginal groups and pluri-ethnicity are taken into account when participatory research projects are designed (Fals Borda, 2008).

Within the framework of PR and qualitative research, a methodological and instrumental framework emerges named the "**Participatory Rural Appraisal (PRA)".** It can be explained as "*a systematic, semi-structured activity performed on the terrain by a multidisciplinary team and focused on obtaining rapid and efficient information and new hypotheses on resources and life in rural environments"* (Schonhuth and Kievlitz, 1994). PRA has a participatory approach, implying that research results are useful for knowledge creation both for external researchers and for local inhabitants. Participatory approaches have four basic functions (Salas, 1997). Those functions are:

Cognitive: Refers to the generation of knowledge (for the community and researchers). General knowledge is obtained from direct relation with individuals, with the different players and according to their perceptions of reality.

Social: Refers to the satisfaction of the community's basic needs, its expectations, and its future perspectives.

Instrumental: Refers to the use of techniques and tools that enable participation from everyone without regard to their level of education or without

restrictions to their participation according to their position within the community (Visual techniques like those of PRA and mobile visualization).

Political: To articulate the strategies proposed by the communities with those proposed by the State.

Among the points in favor that have been recognized from the use of the PRA within social research, can be identified (Chambers, 1997):

1. Recognition of the skills of the local inhabitants to mapping, modeling, observing, quantifying, estimating, comparing, and describing their geographic, social, environmental, and economic contexts.
2. Empathy and the form in which research is developed allows, through horizontal relations with the community, the generation of situations of trust. A trustfully environment then, improves community participation and decreases the possibilities of a "cultural shock" that prevent the development of the objectives.
3. The used methodological tools and visualization methods help to generate an effective learning- discussing environment.
4. Allow the participation in the discussions of people without a specific knowledge.
5. The use of instruments in a specific sequence helps to generate a learning environment.
6. Each of the tools used can be refined and the results deepen based on the experience, the previous information. Furthermore, it always allows participants reformulating or discussing particular disagreements'.

3 The Methodological process

A participatory approach should starts defining the goals, the community needs and the basic context analysis. Then, the important step is to define the possible research tools to create a win – to – win environment. For COMET-LA, the methodological process is proposed as follows:

3.1 The Stages

1. Research objectives definition with the participation of the local communities
2. Selection and training of interested stakeholders. They can be called co-researchers.
3. Application of research tools by the whole research group (University and co-researchers)
4. Discussion of the methodological process and the outcomes
5. Analysis and triangulation of the information
6. Generation of reports

4 Some of the suggested PRA tools to use in characterizing SES´s

Some PRA tools have been selected from Geilfus (1997) as interesting to be used in COMET-LA CSs.

4.1 Productive profile

The productive profile is commonly used to understand the productive features of the community, and to determine the level of dependence of natural resources, agriculture or other activities. Using the productive profile the researchers and the local inhabitants acquire general information about market trends, cultural or inherited productive activities and the level of dependency of natural resources.

4.2 Historic diagram or chart

The objective of the "historic diagram" is to collect important information about specific topics or issues for the local community. The collected information serves to analyze changes, ideas, and barriers or drivers to the research objective. It also provides an effective overview about the community and the resources to be characterized.

4.3 Venn diagram (Organizational diagram)

It is used to identify the organizations and groups related to the community. The described relations are not necessary win – to – win relations or cooperative. It also helps to identify the relational patterns and the institutions around the community.

4.4 Rules and norms matrix

The rules and norms matrix is used to list, recognize and evaluate the type of institutional arrangements made for natural resource management. This matrix has been designed to recognize the set of informal (locally made – customs) norms and the rules that are applying at the local level.

4.5 Matrix of conflict analysis

Used to recognize, identify and design a strategy to solve local social conflicts around natural resources and their management.

4.6 Individual and collective actions for natural resources management

This tool is used to prepare working in groups a matrix to compare and analyze the strategies made by individuals or groups to manage natural resources. It gives a view about the way social relations affect natural resource management.

4.7 Social mapping – "yesterday, today and tomorrow"

This research tool is used to recognize the "reality" and the "perceptions" about natural resources and particular conditions. Three maps are used to compare the conditions of the natural resources and the perspectives of the local users. This visualization process helps to

create a common knowledge about the past and current conditions and to recognize the expectations of the group.

4.8 Transect walk and communitarian diagraming

The transect walk is used to collect in situ aspects and information about natural resources condition, availability and patterns of use. It also provides information about human – environmental relations. The results are portrayed in a diagram, which helps to explain to others and to promote a critic analysis about the resources, the problems of use and the governance response.

4.9 SWOT Analysis

SWOT analysis is a whole analytical system comprising the strengths, the weaknesses, the opportunities and the threats existing in the analyzed context. It has been made as an ex-ante evaluation of the alternatives that can be defined to reach a goal, to continue with a process or to evaluate priorities. The SWOT analysis highlights advantages, disadvantages, and possible problems. SWOT is a particular design used in different programs and processes

5 References

Chambers, Robert. (1997). Diagnóstico Rural Participativo. GTZ, Alemania.

Chambers, Robert. (1995). DRP a gran escala: haciendo lo mejor posible. Forests, Trees, and people, Newsletter N. 26/27.

Fals Borda, Orlando (2008). Orígenes Universales y Retos Actuales de la IAP (Investigación Acción participativa) en Revista Peripecias Nº 110. 20th of August.

Geilfus, Frans. (1997) 80 herramientas para el desarrollo participativo. IICA Holanda, IICA San Salvador.

Schönhuth, M. y U. Kievlitz. (1994). "Diagnóstico Rural Rápido, Diagnóstico Rural Participativo: métodos participativos de diagnóstico y planificación en la cooperación al desarrollo. Una introducción comentada". Schriftenreihe der GTZ nº 244. Eschborn. pp. 137.

Annexe IV: Understanding climate variability

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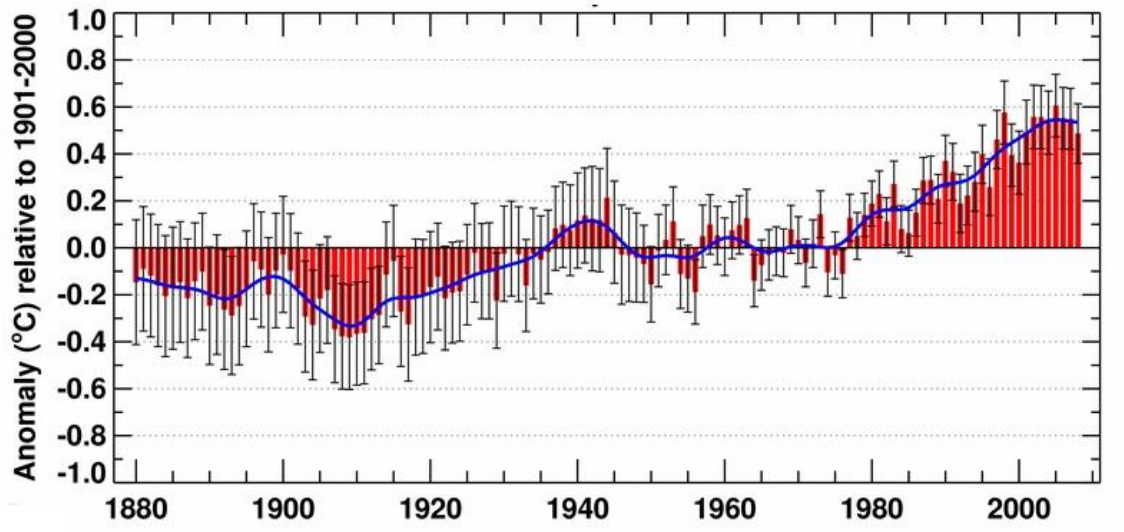
1 Introduction

There is an international consensus in the scientific community that we are in the presence of a global warming produced by the increased concentrations of Greenhouse Gases (GHGs) and aerosols (Figure 1). According to the Intergovernmental Panel on Climate Change (IPCC) in 20th Century the Earth surface increased its temperature in almost 0.7 ºC (IPCC, 2007). The estimation of how this global warming can affect regional climates is difficult and, in some cases, it has a very low reliability. We still do not know how changes in climate may vary and how the future socio-economic and environmental conditions will evolve due to its effects. However, since it is possible to provide some information on how climate change will affect ecosystems and human economy, we therefore can analyze what measures can be taken to prevent it or decrease the damages. The analysis of future climate scenarios for determining when a system or a specific sector is potentially vulnerable to climate change can be provided to the society. The limits within which the impacts will become negative or severe can also be recognized.

Figure 14. Anomalies considering January- December mean temperature over land and ocean.



Source: NCDC/NESDIS/NOAA

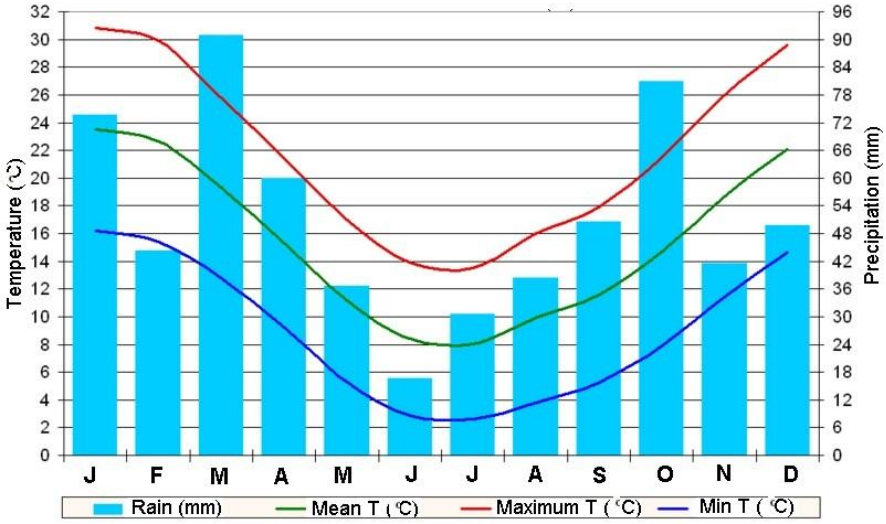
There is often confusion in the general public about the difference between the climate and the weather. Weather involves the description of the atmospheric condition at a single instant of time for a single occurrence. They are short lasting meteorological events and the characteristic time scale is of a few days. Examples of an atmospheric condition are a storm, the passage of a low pressure system, strong winds, the passage of a high pressure system generating clear skies, scarce clouds, etc.

Climate may be thought of as an average of weather conditions over a period of time including the probability for distributions from this average (Houghton, 2002). The classic definition of climate indicates that it is the average state of the atmosphere for a given time scale (month, season, year, decade, etc.) and in general for a specified geographical region. The average-state statistics for a given time scale including all deviations from the mean are

obtained from the ensemble of conditions recorded for many occurrences for the specified period of time (Houghton, 2002). As an example, Figure 2 shows two principal elements of the climate of Bahia Blanca city located at 10 km of the Bahia Blanca Estuary, where the COMET LA Argentine coastal study sites are located. The figure shows the mean temperatures and the annual mean monthly precipitation considering a period of 30 years.

The average-state description involves a wide range of variables depending on what is of interest. Temperature and precipitation are the most commonly variables used; however, the list may include wind, cloudiness and sunshine, pressure, visibility, humidity and elements with noteworthy human impacts such as severe storms, excessively high and low temperatures, fog, snow and hail. The description method focuses on statistical parameters, the mean and measures of variability in time such as the range, standard deviation, etc. (Houghton, 2002).

Figure 15. Monthly mean precipitation and temperature for the Bahia Blanca city. Period 1961-1990.



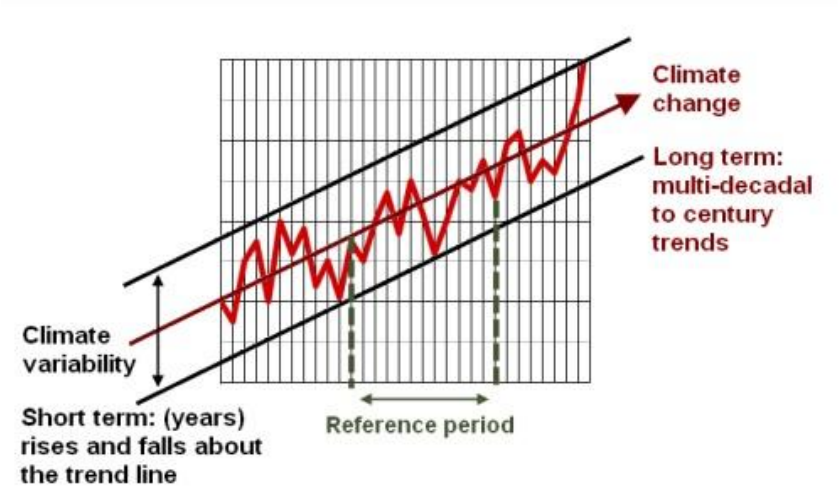
Data from the National Argentine Meteorological Service, figure adapted from Wikipedia.

If we focus only on climate processes, then we must define what is meant by climate change and climate variability. Society must make different decisions to prevent possible damages from climate change and/or climate variability. According to the time scale considered, the variations observed in meteorological parameters acquire a different denomination. Climate Change is defined as a difference over a period of time (with respect to a baseline or a ***reference period***) and corresponds to a statistical significant trend of mean climate or its variability, persistent over a long period of time (e.g. decades or more). Climate change may be due to both natural (i.e. internal or external processes of the climate system) as well as anthropogenic forcing (Environment Canada, 2012).

On the other hand, Climate Variability is defined as a deviation from the overall trend or from a stationary state, and refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and

spatial scales. Climate variability can be thought as a short term fluctuation superimposed on top of the long term climate change or trend (Figure 3). During a particular year, there are recorded values above or below normal. The Normal Climatological or normal value is used to define and compare the weather and generally represents the average value of a continuous series of measurements of climatic variable over a period of at least 30 years. The difference between the carrying value of the variable and its average is called *Anomaly*. In different years, the values of the climate variables (temperature, precipitation, etc.) fluctuate above or below normal. The sequence of these oscillations around the normal, known as variability and its evaluation is accomplished by determining anomalies.

Figure 16. Climate change and variability concepts.



Source: Elaine Barrow, Environment Canada, 2012

The climatic system alteration appears around the world in different ways such as floods, droughts, heat and cold waves, etc. In the last decades there are evidences that these phenomenons are more frequent and their severity is increasing (ONU, 2013). The atmospheric variability in a particular time scale is often linked to a specific set of dynamical and physical processes. It is essential then to understand the nature and origin of atmospheric variability on different time scales (Grimm, 1999). Cycles of high and low values of weather events (e.g., drought, floods) are not considered climate change unless prolonged over many decades. Therefore, it is important to analyze the inter-annual variation of the meteorological variables. The climatic statistics show significant variability from year to year, above the intrinsic random variability, associated with patterns that have characteristic properties in space and time (ie., EL Niño-Southern Oscillation (ENSO)).

The climate variability can be of low or high frequency. Low frequency variability refers to phenomena such as the North Atlantic Oscillation (NAO) or El Niño which occur at a decadal scale or longer. High frequency variability refers to meteorological events and their distribution (for example, frequency, duration and intensity of strong winds) at yearly, seasonal or monthly timescales (Environment Canada, 2012).

The largest impacts come through the meteorological parameters of precipitation and temperature. However, the atmospheric variability is intimately linked to the behavior of other components of the climate system (Grimm, 1999). For this situation, different adaptation strategies through policies and practices should be prepared to generate the necessary conditions to deal with the effects of climate variations (ONU, 2013).

2 Proposed methodology

The main objective of this work is to propose a common methodology to determine and compare the climate variability of the study sites of the COMET LA project. The main task is to understand the vulnerability of the different study sites to climate phenomena and develop possible scenarios of future weather conditions. Each study site is located in different climatic zones, different cultures and different ideas about how to focus science, etc. But the purpose of this work is to suggest easy ways to analyze meteorological information to establish the typical climate and climate variability of each region. To achieve the general objective, the following methodology is proposed. To study the climate of a given region the use of in situ data and numerical models are described. To analyze the climate variability, the different times scales that range from days to decades are briefly describe with some examples. Depending of the time series of the available meteorological data of each region, it will be possible to estimate the different climate variability.

2.1 Climate

2.1.1 From in situ data (meteorological stations)

To determine the climate of a region we must obtain a long time series of meteorological information. If there is no meteorological station in the study site, normally there is one nearby or in the region. With standard statistical methods we can analyze the information and obtain the mean values of each meteorological variable (atmospheric pressure, temperature, precipitation, relative humidity, solar radiation, winds) to describe the climate of the study zone. National Meteorological Services or any other private or government agency can provide national data. We must take in account that there are diverse meteorological data sources. Data collection varies according to each season, may be in months, days and even minutes. If we find a significant number of measuring stations in the study area, all the information should be studied to obtain a best possible climate characterization of the region.

The amount of data available will determine the type of analysis we can apply in a given region. If we have a continuous monthly data series of 50-100 years, it is possible to determine very precisely the climate and the climate variability of the region. Anomalies on the order of decades or more for any meteorological parameter may be defined. If we have a short time series of meteorological information, we still can perform the statistical analysis, but the data should be complemented with other techniques, such as the use of numerical models to determine the climate of the study area.

One of interesting theme to analyze is the behavior of the temperature and precipitation in each study site to know if they are experiencing changes related to global warming.

2.1.2 From numerical models

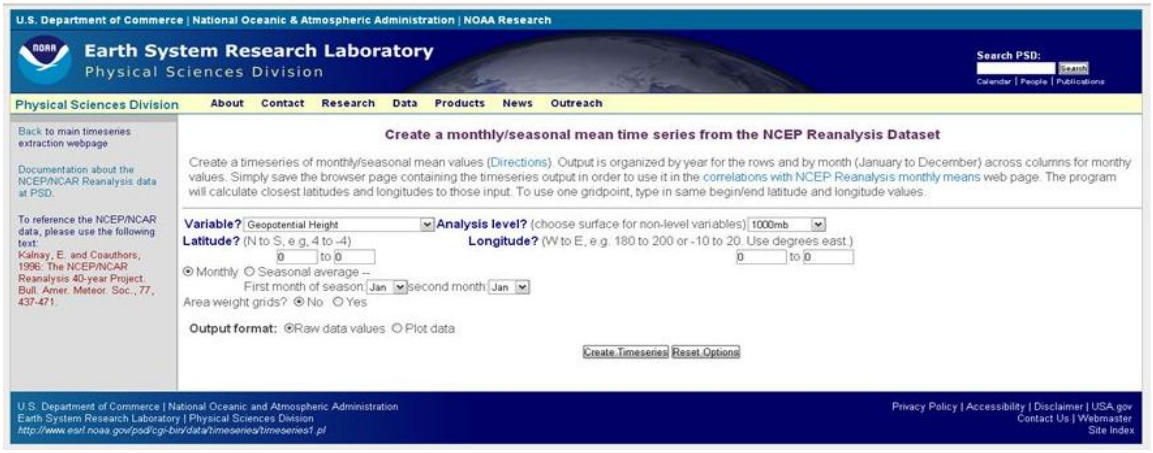
The use of numerical models to obtain climate data is increasingly used by scientists. Spatially interpolated climate data on grids are used in many applications, particularly in environmental, agricultural and biological sciences. Therefore, numerical models are useful tools to use in the COMET LA project. In literature we found several numerical models that provided climate data. Hijmans et al. (2005) describe the different ones. For the scientist that uses Geographical Information System, the Worldclim, Global Climatic data, is a free climate data model for ecological modeling. Bioclim (http://www.worldclim.org) is a model that provides bioclimatic variables that are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). The knowledge of GIS is necessary to use the Bioclim.

Another very functional model to obtain climatic information from various meteorological parameters is the Reanalysis (NCEP / NCAR) from Kalnay et al. (1996). This model is the result of a joint project from the National Center for Environmental Prediction (NCEP), the National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration/Climate Diagnostics Center (NOAA/CDC) (http://wesley.wwb.noaa.gov/Reanalysis.html). The method is based on numerical weather prediction worldwide from various meteorological parameters from 1948 to the present (Kalnay et al., 1996, Klister et al., 2001). The spatial resolution is 2.5 ° latitude and longitude. Reanalysis data may not be accurate in subtropical latitudes and mountain areas.

Use of Reanalysis is very simple. Upon entering the website you must complete the latitude and longitude of the area of interest (with a negative sign before the number if the location is on the South hemisphere and in the Western) (Figure 4). Then you must select the variable you want to study (for example temperature, humidity, precipitation, etc. (Figure 5). These variables may be those obtained at sea level, 1000 mb, 850 mb, etc. Once completed the preference options, you must press the button "Create timeseries" to access the data.

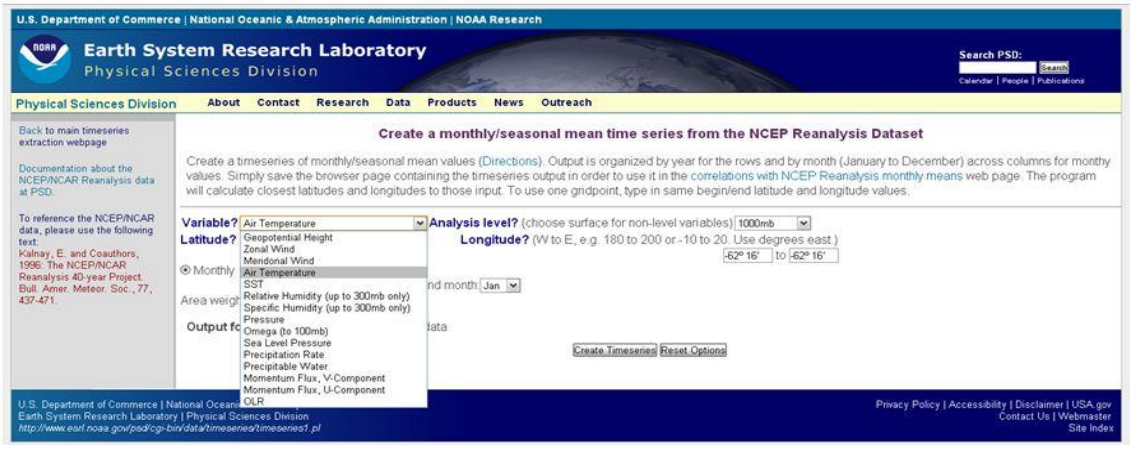
When the latitude and longitude of the study area, the meteorological variable and, the atmospheric height you want to work with is incorporated in the model, the data set is created and in the screen you can obtain the data chart from 1948 to date. The row represents the year and the columns, from left to right, the months from January to December (Figure 6).

Figure 17. Access Page to the Reanalysis model..



Source: www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl

Figure 18. Access Page to the Reanalysis model. List of variables the model offers.



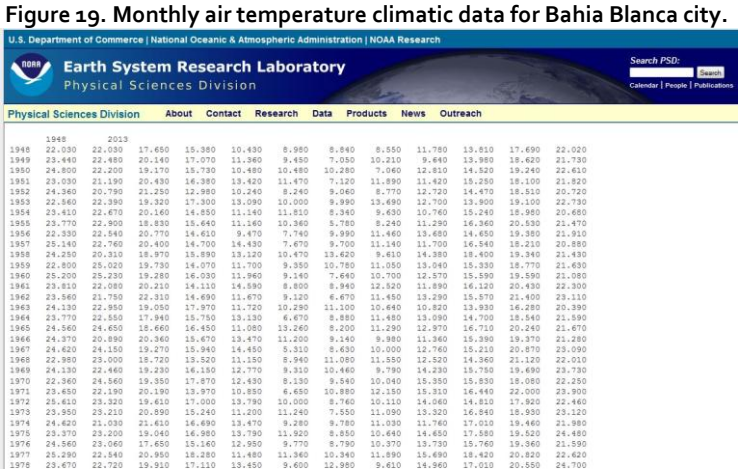
Source: www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl

According to the results of different investigations, the model is not always accurate for all sites. Therefore, it is important to validate the model data with in situ measurements, if available. Figure 7 presents an example of the comparison between the temperatures measured in situ (and the calculated the mean monthly value) in Monte Hermoso coastal city (Buenos Aires Province, Argentina) and the monthly data from the reanalysis model. The seasonal temperature patterns are well represented in almost all the seasons, except in summer, where the model overestimates the temperature. One possible explanation is the low resolution of the model (2.5°) and the influence of the sea that is not incorporated in the model. The model does not represent very well the monthly behavior of the relative humidity of Monte Hermoso (Figure 7). Undoubtedly, the influence of the sea is important in the water content of the air of the coastal site.

2.2 Climate Variability

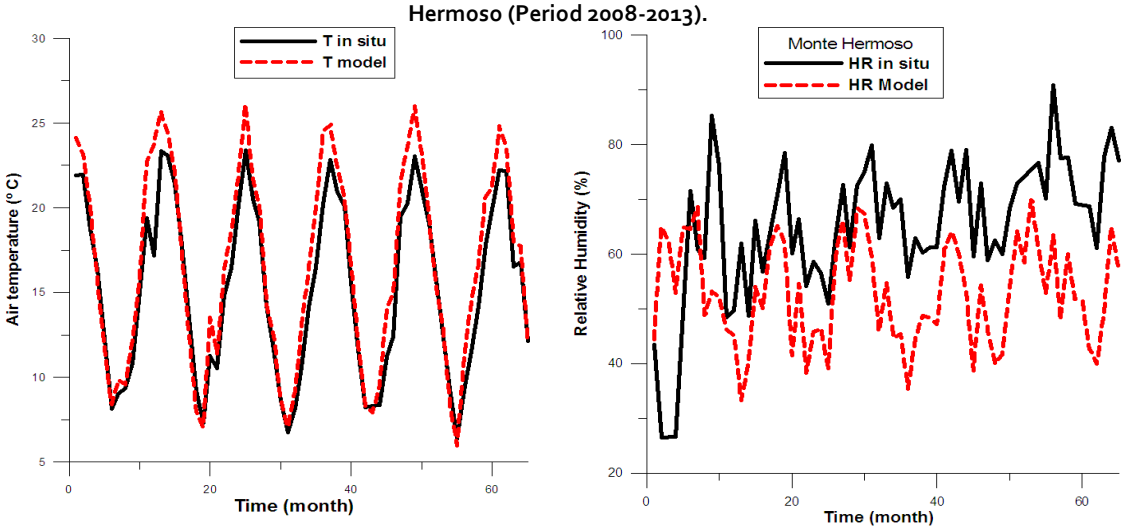
The climate variability presents different time scales. Therefore, to study the different atmospheric processes (daily, monthly, seasonal or annual), it is fundamental to generate the different manners of adaptation or mitigation to these changes. The different times scales are (Grimm, 2009):

Figure 19. Monthly air temperature climatic data for Bahia Blanca city.



	1948	2013									
1948	22.030	22.030	17.650	15.380	10.430	8.980	8.840	8.550	11.780	13.810	17.690	22.020
1949	23.440	22.480	20.140	17.070	11.360	9.450	7.050	10.210	9.640	13.980	18.620	21.730
1950	24.800	22.200	19.170	15.730	10.480	10.480	10.280	7.060	12.810	14.520	19.240	22.610
1951	23.030	21.190	20.430	16.380	13.420	11.470	7.120	11.890	11.420	15.250	18.100	21.820
1952	24.360	20.790	21.250	12.980	10.240	8.240	9.060	8.770	12.720	14.470	18.510	20.720
1953	22.560	22.390	19.320	17.300	13.090	10.000	9.990	13.690	12.700	13.900	19.100	22.730
1954	23.410	22.670	20.160	14.850	11.140	11.810	8.340	9.630	10.760	15.240	18.980	20.680
1955	23.770	22.900	18.830	15.640	11.160	10.360	5.780	8.240	11.290	16.360	20.530	21.470
1956	22.330	22.540	20.770	14.610	9.470	7.740	9.990	11.460	13.480	14.650	19.380	21.910
1957	25.140	22.760	20.400	14.700	14.430	7.670	9.700	11.140	11.700	16.540	18.210	20.880
1958	24.250	20.310	18.970	15.890	13.120	10.470	13.620	9.610	14.380	18.400	19.340	21.430
1959	22.800	25.020	19.730	14.070	11.700	9.350	10.780	11.050	13.040	15.330	18.770	21.630
1960	25.200	25.230	19.280	16.030	11.960	9.140	7.640	10.700	12.570	15.590	19.590	21.080
1961	23.810	22.080	20.210	14.110	14.590	8.800	8.940	12.520	11.890	16.120	20.430	22.300
1962	23.560	21.750	22.310	14.690	11.670	9.120	6.670	11.450	13.290	15.570	21.400	23.110
1963	24.130	22.950	19.050	17.970	11.720	10.290	11.100	10.640	10.820	13.930	16.280	20.390
1964	23.770	22.550	17.940	15.750	13.130	6.670	8.880	11.480	13.090	14.700	18.540	21.590
1965	24.560	24.650	18.660	16.450	11.080	13.260	8.200	11.290	12.970	16.710	20.240	21.670
1966	24.370	20.890	20.360	15.670	13.470	11.200	9.140	9.980	11.360	15.390	19.370	21.280
1967	24.620	24.150	19.270	15.940	14.450	5.310	8.630	10.000	12.760	15.210	20.870	23.090
1968	22.980	23.000	18.720	13.520	11.150	5.940	11.080	11.550	12.520	14.360	21.120	22.010
1969	24.130	22.460	19.230	16.150	12.770	9.310	10.460	9.790	14.230	15.750	19.690	23.730
1970	22.360	24.560	19.350	17.870	12.430	8.130	9.540	10.040	15.350	15.830	18.080	22.250
1971	23.650	22.190	20.190	13.970	10.850	6.650	10.880	12.150	15.310	16.440	22.000	23.900
1972	25.610	23.320	19.610	17.000	13.790	10.000	8.760	10.110	14.060	14.810	17.920	22.460
1973	23.950	23.210	20.890	15.240	11.200	11.240	7.550	11.090	13.320	16.840	18.930	23.120
1974	24.620	21.030	21.610	16.690	13.470	9.280	9.780	11.030	11.760	17.010	19.460	21.980
1975	23.370	23.200	19.040	16.980	13.790	11.920	8.850	10.640	14.450	17.580	19.520	24.480
1976	24.560	23.060	17.650	15.160	12.950	9.770	8.790	10.370	13.730	15.760	19.360	21.590
1977	25.290	22.540	20.950	18.280	11.480	11.360	10.340	11.890	15.690	18.420	20.820	22.620
1978	23.670	22.720	19.910	17.110	13.450	9.600	12.980	9.610	14.960	17.010	20.550	24.700

Figure 20. In situ and numeric model (Reanalysis) monthly air temperature and relative humidity at Monte Hermoso (Period 2008-2013).



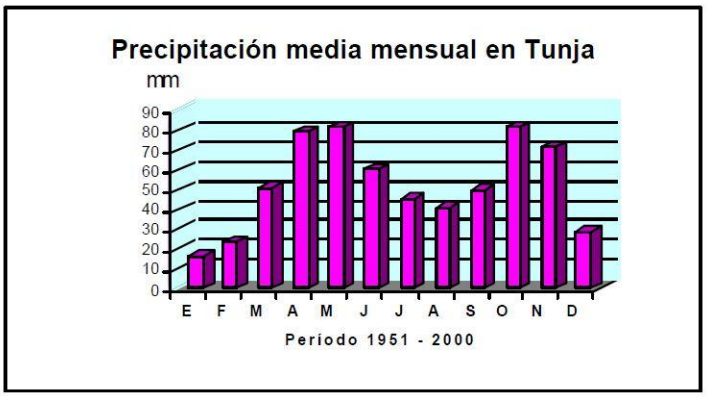
2.2.1 Seasonal and Intraseasonal variability

This variability involves processes that have periods ranging from about 10 days to a season. These processes are relevant to medium and long-range weather forecasting. Processes may vary within the seasons, generating oscillations that determine the weather conditions for weeks and even one or two months. Since its amplitude is small compared to the annual cycle, most of the time, these oscillations go unnoticed by the general public. This variability was unknown until very recently. Intraseasonal oscillations have been detected in the convective activity of the Eastern Tropical Pacific (ETP) and in the precipitation of tropical America. The

Madden-Julian Oscillation, discovered in 1971, is the largest component of the intraseasonal variability (30–90 days) in the tropical atmosphere associated to the ETP and precipitation in tropical Americas. Other examples are the persistent high pressure centers in the extra tropics (blocking), intraseasonal variations with periods of 10-30 days, etc.

The seasonal scale corresponds to the monthly level while the determination of the annual cycle from the climate elements is a key stage in climate variability. In middle latitudes, the common sequence of winter, spring, summer and fall is essential for the planning of activities that depends from this alternation, while in tropical latitudes, it is more important to know how frequent the occurrence of rainy and dry seasons are. The planning of activities, particularly agriculture, energy and transport, depend on the knowledge of such periodic sequence. The migration of the Intertropical Confluence Zone - ITCZ (rainfall producing system) is considered one of the most important climatic fluctuations at seasonal scale and its dynamics explains a large percentage of the variability of rainfall. In Colombia, Montealegre Bocanegra and Pabon Caicedo, (2001) studied the annual cycle of precipitation in Tunja (Figure 8) and they show the occurrence of two rainy seasons (April-May and October-November) and two relatively dry periods (January-February and July-August).

Figure 21. Annual rainfall distribution in Tunja (seasonal variability).



Source: Montealegre Bocanegra and Pabon Caicedo, 2001.

To study seasonal and interseasonal variability in our study sites, we can use daily meteorological information and analyze the intensity and frequency of the weather extremes (storms, strong winds, etc.), heat and cold waves, etc. by standard statistical methods.

2.2.2 Interannual variability

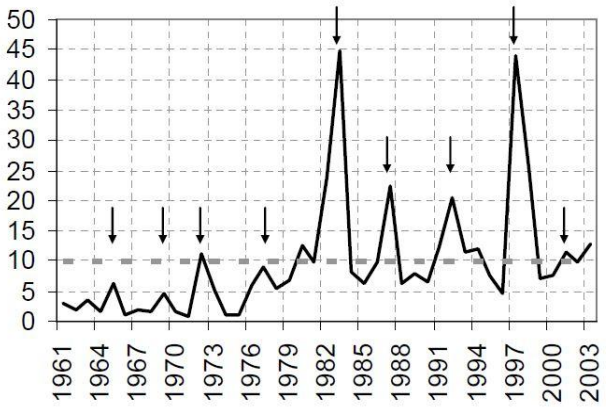
It is represented for processes of periods of several years and it is mostly related to interactive processes taking place at the air-sea and air-land interfaces, in view of the long memory embedded in many maritime and land processes. This variability is very well documented.

At this scale variables change from year to year. Normally, we perceive that the precipitation of the rainy season in a certain site is not always the same from one year to another, but fluctuates above or below normal. Climate variability, framed within this scale, could be related to changes in the global balance of radiation. A typical example of interannual climate

variability corresponds to the frame within the phenomena cycle El Niño - La Niña - Southern Oscillation. The ENSO phenomenon is the main example of interannual variability, but there are several significant works that shows different evidences of this variability. Following, two clear results of interannual variability are discussed.

In Chile an increase in the percentage of minimum temperatures (Conama, 2006) could be observed in five coastal stations between 18° and 30° S (Figure 9). Daily series of temperature extremes (maximum and minimum) in 16 Chilean stations were analyzed. Changes in the frequency of extreme thermal conditions such as occurrence of a maximum temperature below the 10 percentile (cold day) or above the 90 percentile (warm day), or a minimum temperature less than 10% (cold night) or above the 90 percentile (warm night) were evaluated. Preliminary results show that changes in the occurrence of this type of thermal conditions is strongly modulated by climate variability associated with the Pacific Decadal Oscillation (PDO). Thus, the phase shift of the PDO in the mid-1970s led to a relatively abrupt increase in temperature and an increase in the frequency of El Niño events which has had a strong impact on extreme indices of thermal frequency such as warm evenings as shown in Figure 9.

Figure 22. Percentage of minimum temperatures in five coastal stations of Chile between 18° and 30° S.

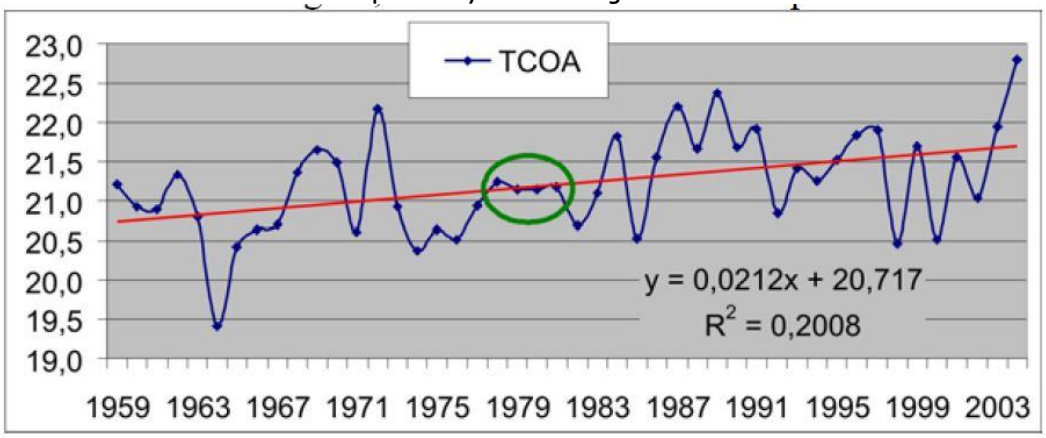


Source: Conama, 2006.

On the other hand, Agosta and Martin (2008) studied the interannual fluctuations of the summer temperatures in West-Central Argentina (COA). They calculated the temperature index series and found that the air temperature shows significant cuasi-oscillations in the spectral bands of roughly 11-yr and 18-yr (Figure 10). The former was linked to the solar forcing, the latter to the effects of the climate transition of the summer 1976/77 (IPCC 2001).

Different statistical methods are used to study the interannual variability of the different meteorological parameters: Empirical Orthogonal Functions, Fast Fourier transforms Wavelets, etc.

Figure 23. Temperature index series in the COA (TCOA). In circle: "plateau" between 1978-1981. R^2: variance explained by the linear regression.



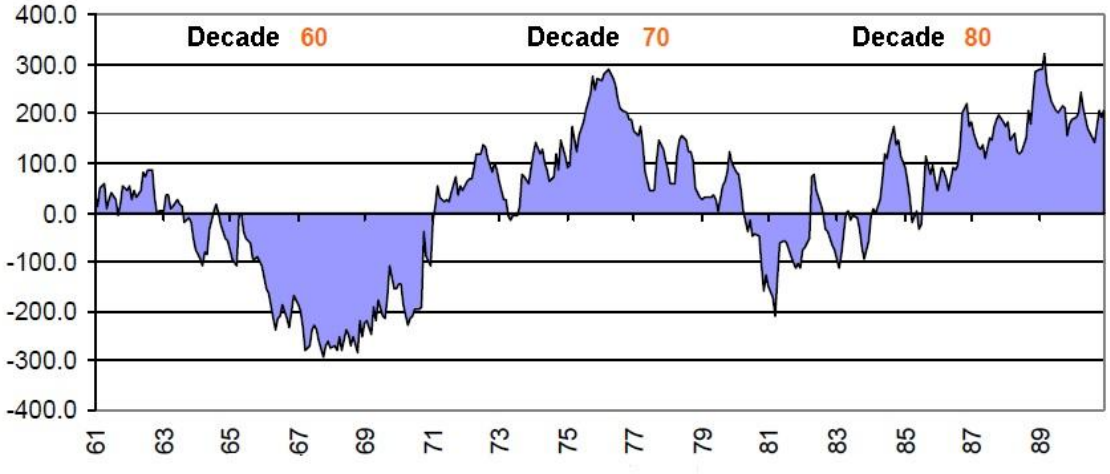
Source: Agosta and Martin, 2008.

2.2.3 Decadal / Interdecadal variability

This type of variability can be studied if we have a long time series of data. They consist of processes with long characteristic time scales, such as interactions with the deep ocean (thermohaline circulation) or the cryosphere, secular changes in the concentration of chemical constituents in the atmosphere and variations in the Earth's orbital parameters (Grimm, 2009).

On this scale, climate fluctuations manifest at the level of decades. Compared to the interannual variability, the amplitude of these oscillations is lower. This is one reason why this type of variability goes unnoticed for common people. However, these long-term fluctuations significantly influence the activities of society and decadal cycles are very important in determining possible trends in climate variables. Figure 11 shows the cumulative rainfall anomalies recorded at a meteorological station located in Funza (Cundinamarca) since 1961, with periods of near 10 years of rainfall (70s and 80s) and of deficit (early 60s).

Figure 24. Anomalies of precipitation in Funza, Colombia in three decades.



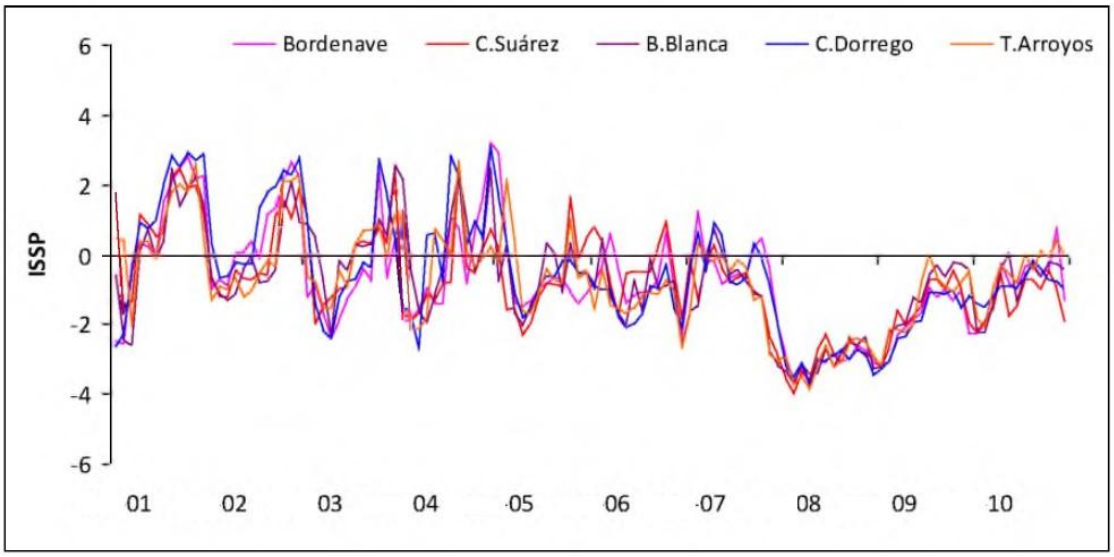
Source: Montealegre Bocanegra and Pabon Caicedo, 2001.

2.3 Drought Indices

For all human activities it is essential to know the interannual and decadal variability of precipitation. Several indices were written to determine periods of inundation or drought. Table 1 shows a review of these indexes (Hayes, M, 2002). The ***Palmer Drought Severity Index (PDSI, ISSP)*** (known operationally as the *Palmer Drought Index (PDI)*) is the most frequently used (http://www.drought.noaa.gov). The Palmer Drought Index, sometimes called the Palmer Drought Severity Index and often abbreviated PDSI, is a measurement of dryness based on recent precipitation and temperature. It attempts to measure the duration and intensity of the long-term drought-inducing circulation patterns. Long-term drought is cumulative, so the intensity of drought during the current month is dependent on the current weather patterns plus the cumulative patterns of previous months.

Since weather patterns can change almost literally overnight from a long-term drought pattern to a long-term wet pattern, the PDSI (PDI) can respond fairly rapidly. The index varies between positive and negative values. Values of the drought index greater than + 4 mean extreme humidity and values less than – 4 means extreme drought. Figure 12 shows the index for several cities of the Southern Buenos Aires province for the period 2001-2010 (Forneron, 2013). The years 2001, 2003 and 2004 were with a moderate humidity, but years 2008 and 2009 were years of extreme drought. Therefore, the figure clearly shows the extreme variability that a region can suffer in only one decade.

Figure 25. Palmer drought index in several cities of the Southern Buenos Aires province, Argentina. Period 2001-2010.



Source: Forneron, 2013.

In summary, there are many methods that can be applied to study the climate and climate variability at different time scales. Depending of the meteorological information available to us we can apply certain methodology. The main objective is to identify predictors associated with climate variability, allowing seasonal, medium and long term climate forecasts to obtain the most successful adaptation measures and mitigate the damage that might be caused by hydro-meteorological phenomena. As a final result, we may develop climate scenarios, using numerical models for each study site for the years 2050 and 2100.

3 Acknowledgements

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4 References

Agosta, E. A. and Martin, P. B., 2008. Fluctuaciones interanuales a multidecádicas de la temperatura de verano en el centro-oeste de Argentina y procesos atmosféricos/oceánicos/astronómicos globales. GEOACTA, 33,48-56.

CONAMA, 2006. Variaciones climáticas en Chile Para el siglo XXI: Resumen Ejecutivo. Dept de Geofísica, Universidad de Chile.

Environment Canada, 2012. Climate Change Concepts. (**http://www.cccsn.ec.gc.ca**).

Forneron, C. F., 2013. Hidrografia de la Laguna Sauce Grande (Provincia De Buenos Aires) en epoca de sequia. Tesis doctoral. Universidad Nacional del Sur.

Grimm, A., 1999. Climate Variability. Time Scales - Processes Involved. Lectures Notes (http://yyy.rsmas.miami.edu)

Hayes, M., 2002. Drought Indices, National Drought Mitigation Center (http://www.drought.unl.edu/whatis/indices.htm). With modifications by Dev Niyogi and Umarporn Charusambot, Indiana State Climate Office, Purdue University (http://iclimate.org)

Hijmans,R. J.,Cameron, S. E.,Parra,J. L., Jones, P.G. And Jarvis, A., 2005. Very High Resolution Interpolated Climate Surfaces For Global Land Areas. Int. J. Climatol. **25**: 1965–1978.

Houghton, D. D., 2002. Introduction to climate change: Lecture notes for meteorologists, WMO-No. 926, pp 131.

IPCC, 2007

Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-Year Reanalysis Project. Bull. Amer. Meteor. Soc., 77, 437–471.

Kistler, R., and Coauthors, 2001. The NCEP–NCAR 50-Year Reanalysis:Monthly Means CD-ROM and Documentation. Bulletin of the American Meteorological Society, 2, 247-268.

Montealegre Bocanegra, J. E. and Pabon Caicedo, J. D., 2001. La variabilidad climática interanual asociada al ciclo El Niño-La Niña-Oscilación del sur y su efecto en el patrón pluviométrico de Colombia. Meteorologia Colombiana, 7 - 21.

ONU, Organización de las Naciones Unidas, 2013. Cambio Climático. http://www.un.org/es

Table 19. Review of draught indices.

Indices	Method	Application
Percent of Normal	Percent of Normal is a simple method to detect drought. It is calculated by dividing actual precipitation by normal precipitation –typically a 30-year mean and multiplying it by 100% for each location. Data are not normalized.	**Pros**: Percent of Normal is effective in single region or season. **Cons**: Percent of Normal cannot determine the frequency of the departures from normal or compare with different locations. Also, it cannot identify specific impact of drought or the inhibition factor for drought risk mitigation plans.
Standardized Precipitation Index (SPI)	SPI is a simple index which is calculated from the long term record of precipitation in each location (at least 30 years). The data will be fitted to normal distribution and be normalized to a flexible multiple time scale such as 3-,6-,12-,24- 48- and etc .	SPI is used to identify the meteorological drought or deficit of precipitation. **Pros**: SPI can provide early warning of drought and its severity because it can specify for each location and is well-suited for risk management. **Cons**: The data can be changed from the long term precipitation record. The long time scale up to 24 month is not reliable.
Palmer Drought Severity Index(PDSI)	PDSI complexity is calculated from precipitation, temperature and soil moisture data. Soil moisture data has been calibrated to the homogeneous climate zone. PDSI has an inherent time scale of 9 months. PDSI treats all forms of precipitation as rain.	**Pros**: PDSI has been widely used to trigger agricultural drought. PDSI can be used to identify the abnormality of drought in a region and show the historical aspects of current conditions.. **Cons**: The PDSI may lag in the detection of drought over several months because the data depend on soil moisture and its properties which have been simplified to one value in each climate division. The PDSI will not present accurate results in winter and spring due to the effects of frozen ground and snow. PDSI also tends to underestimate runoff conditions.
Palmer Hydrological Drought Index	PHDI has been derived from the PDSI index to quantify the long term impact from hydrological drought.	**Pros**: The PHDI has been officially used by NCDC to determine the precipitation needed for drought termination and amelioration which has a PHDI equal to -0.5 and -2.0 consecutively. It has been used Indiana for drought monitoring. **Cons**: The PHDI is developed from precipitation, outflow, and storage. PHDI may change more slowly than PDSI and it has sluggish response for drought.
Crop Moisture Index (CMI)	CMI is a derivative of PDSI which was developed from moisture accounting procedures as the function of the evapotranspiration anomaly and the moisture excesses in the soil. It also can be present as	**Pros**: CMI is used to monitor crop condition. It is effective for the detection of short term agricultural drought while the Z index determines drought on a monthly scale. It can detect drought sooner than PDSI and PHDI.

	the monthly moisture anomaly or Z index (ZNDX) as a product from PDSI calculation. CMI looks at the top 5 feet of the soil layer.	**Cons**: CMI is limited to use only in the growing season; it can not determine the long term period of drought.
Surface Water Supply Index(SWSI)	SWSI is used for frequency analysis to normalize long-term data such as precipitation, snow pack, stream flow, and reservoir level.	**Pros**: The SWSI is very useful for indicating snow pack conditions in mountain areas to measure the water supplied for community **Cons**: The index of different basins can not be compared with each other and has been computed seasonally. States such as Colorado, Oregon, Montana, Idaho, and Utah have used SWSI.
Reclamation Drought Index (RDI)	The RDI index is similar to the SWSI index. It combines the functions of supply, demand and duration. RDI also combines temperature features and duration in the index.	**Pros**: The RDI is used as the trigger to evaluate drought reclamation plans and to release drought emergency funds. **Cons**: The disadvantage of RDI is the same as the SWSI index. The state such as Oklahoma has used RDI.
Deciles	Deciles have been developed to use instead of percent of normal. Deciles are calculated from the number of occurrences distributed from 1 to 10. The lowest value indicates conditions drier than normal and the higher value indicates conditions wetter than normal.	**Pros**: The deciles index has been used in Australia; it provides accurate precipitation data for drought response. **Cons**: However, it's use requires a long climatology record to accurately calculate the deciles index.
Experimental Objective Blends of Drought Indicators	Drought Blend Indicators are divided into short-term and long-term blends. The short term blend includes PDSI, Z, SPI 1, 3-month, and soil moisture. The long-term blend includes PHDI, SPI 06 12 24 and 60-month, and soil moisture. The drought blend method has been used for US drought monitoring: http://www.drought.unl.edu/dm/monitor.html	In the short-term blend method, the indicators are weighted to the precipitation and soil moisture which use to identify the impacts of no irrigated agriculture, wildfire dangers, top soil moisture, and pasture conditions. The long blend index indicates the impacts of hydrological drought such as reservoir and well levels and irrigated agriculture. The drought indicator used in Drought Monitor provides the most widely used map for drought conditions across United States (and is suitable for Indiana).

Source: *Drought Indices, Michael J. Hayes, National Drought Mitigation Center (http://www.drought.unl.edu/whatis/indices.htm). With modifications by Dev Niyogi and Umarporn Charusambot, Indiana State Climate Office, Purdue University (http://iclimate.org)*