Guidelines on methodological approach to impact assessment of water access and quality on health in Blue Nile Basin (BNB)

Deliverable EIWR.3

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Abstract

H2020 WEFE interdependencies across the Nile River Basin

Among the multiple challenges The Blue Nile Basin (BNB) poses, figures boldly the impact of land use on the Water Quality. Consequently, the impact produced on human health as a result of water quality deterioration is a cause for high concern. Therefore, in anticipation of a sound methodology for the assessment of the change made to the state of water quality and the impact on public health produced by water quality deterioration, a team of experts of the Ethiopian Institute of water resources proposed the Integrated Analytical Framework (IAF).This tool innovatively integrates three well-known frameworks: The Driver-Pressure-State-Impact-Response framework; the Systems Approach Framework and the Social-Ecological Systems Framework. This methodological approach is envisaged to provide an interdisciplinary and broad platform for the investigation of the ecological dysfunction of the aquatic ecosystem in the basin, land use pattern that caused the water quality deterioration and the impact on public health. The methodology allows for large stakeholders engagement in identifying the issue of concern and collectively finding solutions for the problem through a series of consultative and deliberative workshops where scenario simulations are carried out.

Chapter 1: Overview of the methodological approach and the method chosen

1. **Introduction** (economic activities, demography,social conditions,health info)...1pp

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INFO on water use.............................

In order to assess and analyze the prevailing socio-economic activities, land use and the consequent changes on the state of the water bodies regarding water quality, and most importantly the impact produced on the public health, sound methodological approaches should be adopted. The identification, selection, processing and analyzing information about the issue needs a sufficiently robust and updated tool...............

Therefore, The Integrated Analytical framework (IAF) has been proposed to serve as a research methodology for the assessment of changes on the water quality in the BNB due to land use and the consequent impact on the public health produced by water quality deterioration. This method integrates three well known frameworks, namely: The Driver-Pressure-State-Impact-Response (DPSIR) framework, the Systems Approach Framework (SAF) and the Social-Ecological-Systems Framework (SESF). On top of that It has a Strength-Weakness-Opportunity-Threats (SWOT) analysis incorporated in it. It is envisaged that the IAF would serve as a truly interdisciplinary research methodology as it makes use of various disciplines such as ecology, sociology and economics, including governance. The methodology was developed by one of the present authors (Sirak Robele Gari) and theoretically tested in the Afro-Colombian Community Council of Alto and Medio Dagua, Cplombia on water quality issues.

2. Methodology

Appropriate adaptive management is necessary for the sustainability of social-ecological systems (SES). Frameworks, as broad structuring devices, use to bridge the gap between disciplines and theories as well as between inductive and deductive approaches, to facilitate the depiction of a system under study (Schlüter and Madrigal, 2012). They are useful tools to identify and analyse problems related to the use of natural resources. The assessment of the problems arising out of the interactions between society and the biophysical environment will help prioritize actions against problems. Based on the information obtained using the frameworks, that leads to a better understanding of an SES, natural resource managers and concerned stakeholders can jointly make locally adapted, appropriate management systems.

As briefly explained in the introduction, the IAF integrated DPSIR, SAF and SESF into a single tool. This tool is a generic, analytical framework that can be applied to any environmental compartment at any ecosystem scale. Before commencing with description of the steps of IAF and its operational features, it is worthwhile to describe its individual component frameworks.

A. The Driver-Pressure-State-Impact-Response framework (DPSIR)

The DPSIR framework evolved from the Stress-Response (S-R) framework developed by Statistics Canada in 1979 (Friend and Rapport, 1991) and the Pressure-Stress-Response (P-S-R) framework used by the Organization of Economic Cooperation and Development (OECD, 1993). It was first applied in its present form (DPSIR) by the European Environment Agency (EEA) in the Dobris Assessment of Europe’s environment (Air, Water, and Soil) (EEA, 1995).

The categories of DPSIR are defined by EEA (2003) as follows: **driving forces** describe the social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption, and production patterns; **pressure** indicators describe developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities; **state** indicators give a description of the quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fish stocks) and chemical phenomena (such as atmospheric CO_2 concentrations) in a certain area; the changes in state produce **impacts** on the functions of the environment, such as human and ecosystem health, resources availability, losses of manufactured capital, and biodiversity; and finally **response**s are the actions taken by groups (and individuals) in society as well as the governments` attempts to prevent, compensate, ameliorate or adapt to changes in the state of the environment.

In the DPSIR framework, the causal links are expressed in such a way that the driving forces produce pressures causing a change in the state of the environment, which create impacts on ecosystem functions and human welfare, eventually leading to societal responses (EEA, 1999).

The five categories of the framework occupy unique positions in the sequence and yet are connected and create feedback loops (Gari et al., 2015).

The framework has been extensively used on both the terrestrial and the aquatic environment. The reason for its wide use is that it provides a framework for multidisciplinary assessment of the environment in relation to anthropogenic activities. It considers human activities as an integral part of the ecosystem and brings together natural science, social science and economics in one framework for adaptive management (Zaldívar et al., 2008). Similarly, Smeets and Weterings (1999) gave two reasons for the wide application of the framework: (a) it structures the indicators with reference to the political objectives related to the environmental problem addressed; and (b) it focuses on supposed causal relationships in a clear way that appeals to policy actors. Gari et al. (2015) reviewed the applications of DPSIR, particularly on coastal social-ecological systems and found a number of appreciations in regard to the framework. Thus, the DPSIR was appreciated as a broad analytical framework (Bidone and Lacerda, 2004), a powerful scoping framework for complex environmental issues (Karageorgis et al., 2006), and useful for the evaluation of the cost effectiveness of policy responses (Nobre,2009) ; a framework with communicative power, cause-effect linkages of environmental problems, multidisciplinary approach and provision for stakeholder participation (e.g. Bidone and Lacerda, 2004; Giupponi, 2007; Ojeda-M. et al., 2009; Atkins et al., 2011; Kelble et al., 2013).

However, The DPSIR framework has been subjected to a considerable number of criticisms. The first cautionary words regarding the use of DPSIR come from the EEA itself, which warns that since the real world is far more complex than can be expressed by simple causal relations as in DPSIR, clear and specific information on the five categories is needed for the purpose of making policies (EEA, 1995). Although DPSIR is useful for describing the origins and consequences of environmental problems, the links between them should be focused in order to understand their dynamics, because the level of influence of each category on the other is determined by ecological, technological and social factors (EEA, 1999).

Rekolainen (2003) mentions four shortcomings of the framework: (i) it creates a set of static indicators that serve as a basis for analysis, not taking into account the changing dynamics of the system; (ii) it does not capture trends except by repeating the study of the same indicators at a regular intervals; (iii) DPSIR does not illustrate clear cause-effect relations for environmental problems; and (iv) it suggests linear unidirectional causal chains in the context of complex environmental problems.

Others associate it with power difference in which it favors the elite as response makers at the expense of the lower section of the society (Carr et al., 2007). Svarstad et al. (2008) argue that it falls short of establishing good communication between researchers, on the one hand, and stakeholders and policy makers on the other; furthermore, it does not address multiple definitions of issues by different stakeholders. Some other criticisms are that it is too simplistic and ignoring synergy (Maxim et al., 2009), a devise with low precision and unavailable to the wider public (Bell, 2012), a framework which lacks precise definition of categories, with unclear boundary between state and impact (Cooper.2012).

Some of the criticisms (e.g. low communication power, low cause-effect relations) are a direct contrast to the very objective DPSIR was created for. Some arguments against these assumptions can be found in Gari et al. (2015). These authors, however, found out how the definitional discrepancies of the DPSIR information categories stand out in the reviewed works. This was not because of the inherent characteristics of the framework but according to Gari et al. (2015), due to differences of opinions, the characteristics of the cases under study (context), misunderstanding of the concepts and an unclear understanding of the system under consideration. To overcome the real limitations of the framework several researchers have suggested various methods such as combining DPSIR with other methods, models and a change in the definitions of some terms (see Gari et al., 2015).

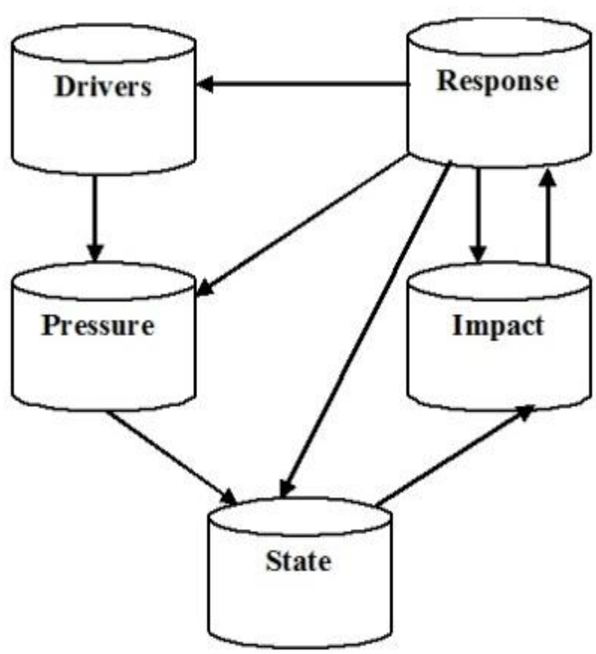

Figure 1: The DPSIR framework (source: Gari et al, 2015)

B. The Systems Approach Framework (SAF)

B.1. Systems thinking

A systems thinking is as old as Greek civilization dating back to the times of Aristotle where the word *Synistanai*, meaning to *bring together* or *combine* was the basis for the term *System*. A system, according to von Bartalanffy (1968) consists of interacting parts, which usually contain feedback loops that create emergent properties additional to that of individual parts. Moreover, systems have boundaries and hierarchies (sub-systems), and could be either open or closed. Similarly Churchman (1968) states that a system is a set of interacting and interdependent entities (real or abstract) that form a whole. Since the property of a system is not simply determined by the sum of its components, these works advocate the study of the system as a whole in order to understand its functioning. In line with this the Systems Approach Framework (SAF) was adopted and tested as a methodological framework in the EU Science and Policy Integration for Coastal Systems Assessment (SPICOSA) project on 18 European coastal sites (Hopkins et al, 2011).

SAF combines the general (hard) system methodology (GSM) that considers parts of a system are real, and the soft system methodology (SSM) that considers a system as a mental construct used to understand the world (Tett et al, 2011). To illustrate this combination , the authors further explain that SAF believes in the existence of the complex coastal SES (GSM), but because they are too complex, only the elements most relevant to the issue at hand should be conceptualized (SSM). Finally, the SAF is holistic, contrasting the focus on parts, and addresses multiple issues and tradeoffs. (Tett et al, 2011).

B.2. The steps of SAF

The SAF comprises four steps (fig.X). They are System Design, System Formulation, System Appraisal and System Output (SPICOSA, DoW, 2009, Hopkins et al, 2011, Gari et al., 2014).Tett et al. (2011), on the other hand, separate the Issue identification as one step and raise the number of steps to five. Issue identification forms part of the system design in the other works. The latter five step approach is followed in the present paper.

In the issue identification step where the economic activities producing impact and the stakeholders are identified and mapped. Once the issue linking the impact with the drivers (socio-economic activities) and the responses is identified, scenarios linked to several policy options are developed and indicators are defined. The system design step deals with defining the system boundary and system elements relevant to the issue. Then a conceptual model, representing the virtual system in which the most relevant relationships in the complex SES are depicted, is developed. Furthermore, the methods to be employed in the study and the likely information sources are identified at the system design step. The correspondence of the conceptual model with the issue as well as the prospect of data availability is also verified.

The System Formulation step deals with the development of a mathematical model out of the conceptual model constructed in the System Design step. The models represent the Ecological, Social and Economic aspects of the social-ecological system, thus termed ESE models. The necessary inputs for running the models are determined at this step. The next step, System Appraisal involves linking the ESE models and running scenario simulations. The results of the simulations are interpretatively analyzed. The final step is System Output, where the output package is prepared and disseminated to the stakeholders, policy makers and the public in appropriate formats.

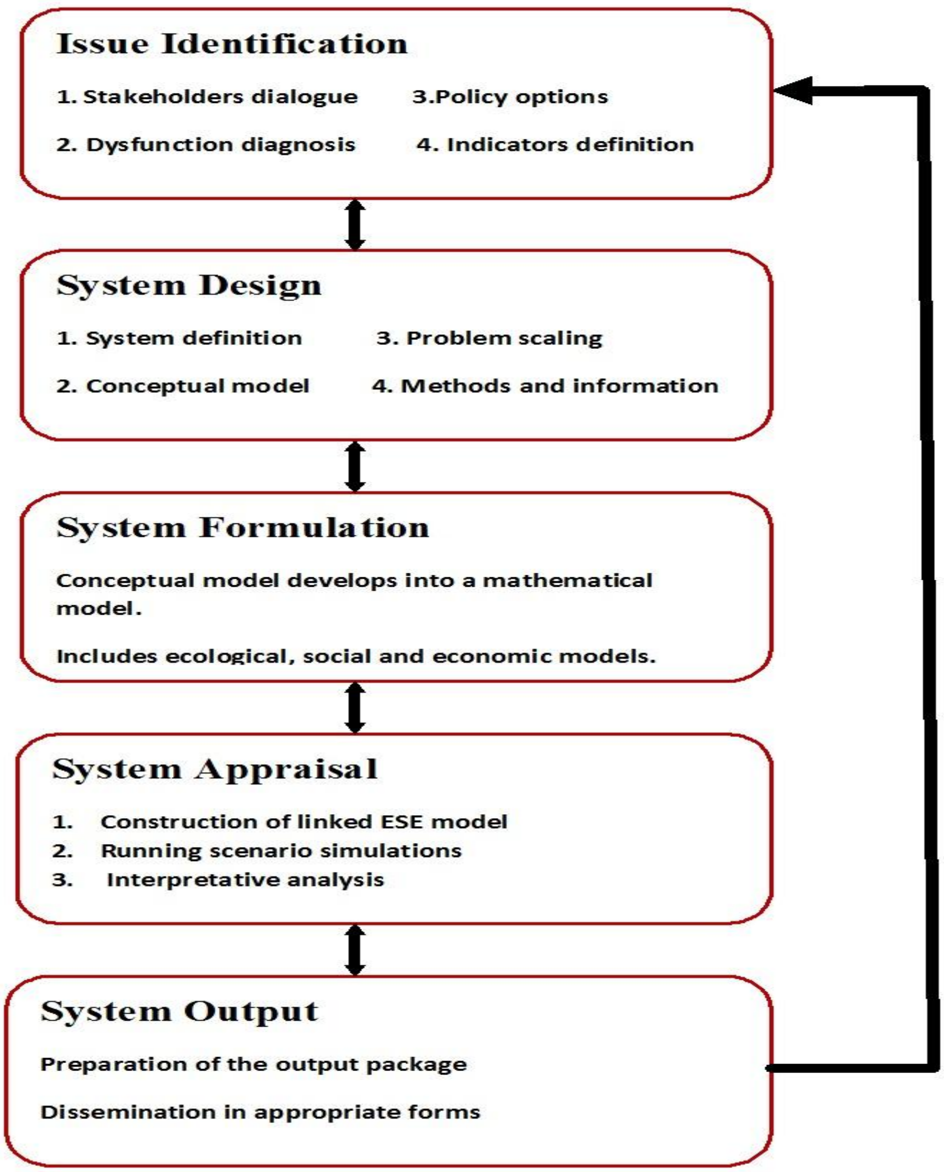

Figure 3: the Systems Approach Framework (SAF) steps

The SAF was developed by the Science and Policy Integration for Coastal Systems Assessment (SPICOSA) project and tested in 18 Study Site Applications (SSAs) in different parts of Europe (Tett et al., 2011; Hopkins et al., 2011, Hopkins et al., 2012). It was applied for different coastal zone issues ranging from ecological problems to the testing of the *stakeholders-research* mutual influence. Based on the SPICOSA project which classified the research tasks executed on the 18 SSAs into 7 classes (www.costal-saf.eu) the cases could ,however, be broadly classified into 5 classes as follows: (1) Those which assessed fisheries management (e.g. Canu et al., 2011; Moksness et al., 2012), (2) Those which specifically assessed the interaction between N-load, eutrophication and socio-economic activities and the consequent ecological impact (e.g. Franzen et al., 2011; Dinesen et al., 2011; Schernewski et al., 2012;Vermaat et al., 2012), (3) Research tasks dealing with shellfish, fishing and aquaculture (e.g. Caroppo et al., 2012; Konstantinou et al., 2012). (4)Studies on the impact of socio-economic activities on water quality (e.g. Tomlinson et al., 2011; Guimarães et al., 2012; Tolun et al., 2012; Monchova et al., 2012), and (5) assessment on water management (e.g. Mongruel et al., 2011).

In addition to the 18 study sites the SAF approach was used to assess conflicts between recreational yachting and shellfish aquaculture (Mussel farm) in Loch Fyne, Scotland (Tett et al., 2012).Similarly, the interaction between stakeholder (mussel farmers) and scientists and the role of funding institutions was assessed through the SAF, in the Gulf of Trieste, Adriatic sea (Canu and Solidoro, 2014). Furthermore, SAF was tested for the management of eutrophication in the Ria Formosa, Portugal (Gari et al., 2014).

The strong point of the SAF approach is inclusion of the stakeholders in the study from the outset. This starts from the identification of the issue and proceeds into the output step, where the research results are presented, discussed and disseminated. Even after that, the iterative nature of the approach allows further communications among the stakeholders, policy makers and scientists. According to Franzen et al (2011) the WFD identifies three levels of stakeholders' participation: Information, consultation and active involvement. The SAF highly encourages an active involvement of not only the stakeholders but also policy makers during the whole process of application of SAF. Stakeholders' involvement has been praised to be highly beneficial to a research project in the identification of policy issues, policy options and management scenarios, building trust among them (Franzen et al., 2011; Caroppo et al,2012; Kratzer et al., 2014). Multidisciplinary of the study team, conceptualization of the complex SES into a virtual system, coupling the ecological, social and the economic models and simulation in the presence of participants, facilitated communications , iteration and self-evolution are features that make the SAF useful for finding solutions to coastal zone problems. Hopkins et al. (2011) lists some of the useful characteristics of SAF as follows: Question-driven, holistic, hierarchical, iterative, system independent and self evolving.

Noted limitations of the SAF were the study might not address the broader stakeholders' perspective. For example, in the case of Himmerfjarden, due to model simplification owing to deficient availability of data and other technical considerations, a narrower issue of nitrogen management was considered instead of eutrophication; moreover fewer policy options and a narrower system was modeled (Franzen et al. 2011). Stakeholders' participation may be low if the perceived benefits are lower than the participation costs and where there exists distrust among the stakeholders (Canu and Solidoro, 2014). Moreover there is no single effective strategy to guarantee stakeholders participation. It requires the art of communicating with different stakeholder types, taking in to consideration the cultural, educational and professional background.

C. The Social-Ecological Systems Framework (SESF)

Ostrom´s general SES framework (SESF) for analyzing social-ecological systems, developed in 2007 (Fig.2) has its roots in the previous works of institutional analysis and development (IAD). The IAD and Robustness frameworks constructed by Ostrom et al. (1994), and by Anderies and Ostrom (2004) respectively have contributed to the development of SESF. The SESF can organize different variables identified by different disciplines in a common framework , and facilitates multidisciplinary efforts toward a better understanding of complex social-ecological systems Ostrom (2009).It enables researchers of diverse disciplinary backgrounds to share a common vocabulary for the construction and testing of alternative theories and models (McGinns and Ostrom, 2014). This framework was revised to generalize its application to complex multi-source systems. The restrictive term *user* was replaced with the more generic term *actor* and more complex patterns of interactions among multiple actors and resource systems in the context of overlapping governance systems were introduced (McGinns and Ostrom, 2014).

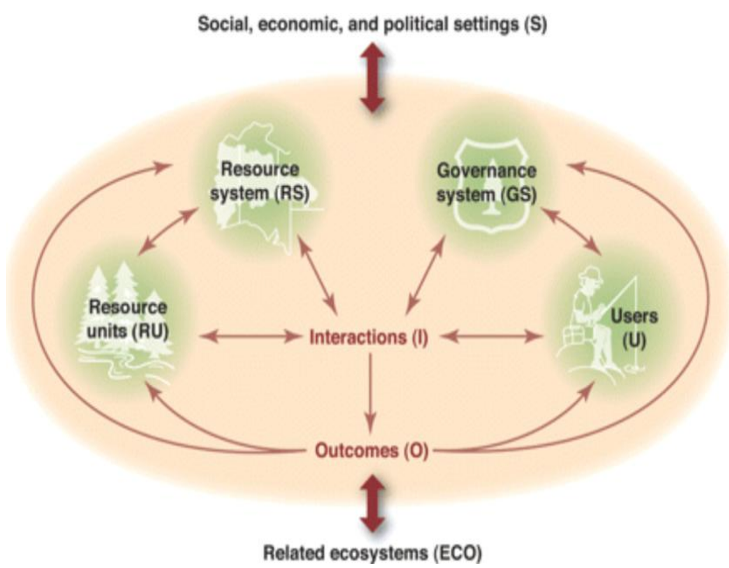

Figure 3: An overview of the framework, showing the relationships among four first-level core subsystems (first- tier variables) of an SES that affect each other as well as linked social, economic, and political settings and related ecosystems (Ostrom, 2009).

Under the components shown in figure 3, 51 second-level variables which grew in to 56 (table 1) were also listed by Ostrom that were identified in many empirical studies as affecting interactions and outcomes within an SES. Ostrom (2009) details the usefulness of the framework as providing a common set of potentially relevant variables such as these to be used in the design of data collection instruments, the conduct of field work and analysis of findings of the sustainability of a complex SES. She further explains that it helps identify factors that may affect the likelihood of policies enhancing sustainability in one type and size of a resource system and not in others.

Table 1: First and second tier variables. (Source: McGinnis and Ostrom, 2014).

Social, economical and political settings (S)	
S1- Economic development. S2- Demographic trends. S3- Political stability. S4- Government resource policies. S5- market incentives. S6- Media organizations. S7- Technology	
Resource systems (RS) 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	**Governance systems (GS)** GS1 – Government organizations GS2 – Nongovernment organizations GS3 – Network structure GS4 – Property-rights systems GS5 – Operational-choice rules GS6 – Collective-choice rules GS7 – Constitutional-choice rules GS8 – Monitoring and sanctioning rules
Resource units (RU) RU1 – Resource unit mobility RU2 – Growth or replacement rate RU3 – Interaction among resource units RU4 – Economic value RU5 – Number of units RU6 – Distinctive characteristics RU7 – Spatial and temporal distribution	**Actors (A)** A1 – Number of relevant actors A2 – Socioeconomic attributes A3 – History or past experiences A4 – Location A5 – Leadership/entrepreneurship A6 – Norms (trust-reciprocity)/social capital A7 – Knowledge of SES/mental models A8 – Importance of resource (dependence) A9 – Technologies available
Action situations: Interactions (I) →	**Outcomes (O)**
I1 – Harvesting I2 – Information sharing I3 – Deliberation processes I4 – Conflicts I5 – Investment activities I6 – Lobbying activities I7 – Self-organizing activities I8 – Networking activities I9 – Monitoring activities I10 – Evaluative 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	

As the framework was developed relatively recently, it is not yet widely applied to diagnosing the functionality of an SES. However, several works can be mentioned. It was applied on small scale fishery CPRs on the gulf of California, Mexico (Basurto and Ostrom, 2009; Basurto and Nenadovich,2012), on intentional forestry communities of Southern Indiana, USA (Fleishman, 2010) and on voluntary environmental initiatives in tourism in different parts of the world (Blanco,2010). Ostrom (2010) theoretically applied the SESF to four cases studied by Coman (1911) on irrigation CPR in the arid / semi arid plains of the American west. It was also used by Madrigal et al. (2010) to study four contrasting cases related to drinking water supply in Costa Rica. Similarly, Schlüter and Madrigal (2012) applied SESF on a community development organization that harvest turtle eggs along the pacific coast of Costa Rica. Schluter et al. (2014) tested the application of SESF for constructing a dynamic SES model representing a recreational fishery.

The European project COMET-LA (2012-2015) (www.comet-la.eu) , which was tasked to finding community-based sustainable management and governance models to the marine and coastal systems in Argentina, water and biodiversity in Colombia and forest systems in Mexico applied the SESF for analyzing the social-ecological systems selected for the study. The management models thus identified and analyzed are supposed to be up scaled to wider geographical areas.

In appreciation of the framework, Schlüter and Madrigal (2012) declare the SESF to be a broad analytical tool applicable across all types of ecological systems. It allows the interpretation of rational human behavior and the intrinsic motivations guiding their actions. Schlüter et al. (2014) appreciate the SESF for its suitability to develop dynamic SES models due to its theory-neutrality and capacity to integrate knowledge, theories and approaches of different disciplines. The framework guides the identification of relevant variables and processes, facilitating the conceptualization of the structure and interactions of an SES in a consistent and transparent manner (Schlüter et al., 2014).

On the other hand, the same authors reveal some of its limitation such as ambiguity of a few terms, and lack of detailed instructions on the measurement of variables. Epistein et al. (2014) assert that SESF, owing to its origin in the institutional analysis, does not lend sufficient attention to the ecological side of an SES. Cole et al (2014) criticizes the framework for its lack of dynamism. Hinkel et al. (2014) highlight a few limitations of the SES framework such as ; ambiguity of some variables attached to actors, and inadequate information on the relationships between the outcome metrics and the relevant variables of RS,GS,RU, and A. Moreover, the names of the variables under *interactions* suggest an interpretation that they are processes rather than variables and SESF does not provide adequate information about which lower tier variables are involved in *action situations.*

2.1. The Integrated Analytical Framework

As explained earlier, the integration of the above three frameworks is not based solely on complementariness. It rather draws on the strengths of the frameworks. It is believed that combining frameworks with an aim to make use of the strong features of each is an indirect but more efficient way of complimenting one another. Thus, the SAF with its emphasis on the stakeholders' involvement, communication among participants, and science and policy integration will form the base of the framework. It has clear cut, iterative steps which make it a suitable framework for easier information flow and communication. Moreover, it is a holistic, dynamic framework which simulates different management scenarios based on multiple policy options and addresses multiple issues at a time. Its dynamism is expressed also in its iterative nature which facilitates self evolution which resonates with the characteristics of an adaptive management. The DPSIR is useful for the identification of the cause-effect relationship between human activities and their consequences. Integrated in the SAF after the issue identification step, it serves to make linkages between the five categories in the DPSIR chain, thereby elucidating what happens in the system. The SESF, while considering the ecological system and calls for multidisciplinary approach for the management of complex SESs, however, emphasises more the institutional arrangements in governing SESs. The framework contains about 56 variables, belonging to the first and second tier variables, encompassing the governance, socio-economic, political and ecological characteristics of an SES. Furthermore, it supplies the possibility of subdividing the second tier variables in to 3rd or even 4th level variables if necessary (Mardigal,2011). So, in combining the SESF framework it is envisaged that, the framework can serve as a reservoir of variables out of which the researchers can use relevant ones for the study. This ensures no relevant features of an SES are left out. Therefore, in the SAF when the ESE model is constructed it can serve as a source of relevant ecological and social variables as suggested by Schluter et al. (2014).

In the SAF-DPSIR-SESF Integrated Framework (Fig. 4), SAF is taken as the stem framework to which the DPSIR and the SES frameworks are integrated. The DPSIR is used in the System Design step as a component part of the information gathering task. It links anthropogenic activities to the pressure on, and change in the environment and the consequent impacts on humans. In the SAF approach impact is perceived as an effect both on humans and the environment. But according to the recent development of DPSIR, impact refers to those on human welfare. In this study the latter view is followed, while the environmental impact belongs to the state change. Response is put in parenthesis to indicate that though SAF is more concerned with future responses, past responses are also considered by the DPSIR framework. Past responses could be included as policy options when running scenario simulations in the System Appraisal step.

The SESF, as a rich reservoir of variables belonging to the governance, ecological, social systems can be used at all steps of SAF. It can equally be used in the System Design step for stakeholder mapping, system description and construction of the conceptual model, as it can be used for construction of ESE models in the System Formulation step. Moreover, in the System Appraisal step where different governance options are considered and the likely scenarios are simulated, and in the System Output step, where stakeholders, policy makers and scientists deliberate, it ensures no relevant item is left out by providing numerous variables as reminders.

Strength-Weakness-Opportunity-Threat (SWOT) analysis is incorporated in the Integrated Framework. It is suggested to be done at two stages; Initially on the present system through the stakeholders interactions and literature review (Canu et al.,2011) in order to build upon the strengths and identify weaknesses to be addressed later, and after the Integrated Framework has been tested. True to the iterative nature of the SAF, the second step helps to exploit strengths and opportunities the IF produces whereas it enables to redress weaknesses and remove threats that might arise out of the application of the IF. Making use of the feedback from the SWOT analysis, the Integrated Framework can be modified and be used as an adaptive management tool. Hence several feedback loops can be identified in this framework. First there are iterative processes along the steps, second the Output Step supplies a feedback to the System Design step, and third the SWOT analysis gives a feedback as the overall performance of the framework.

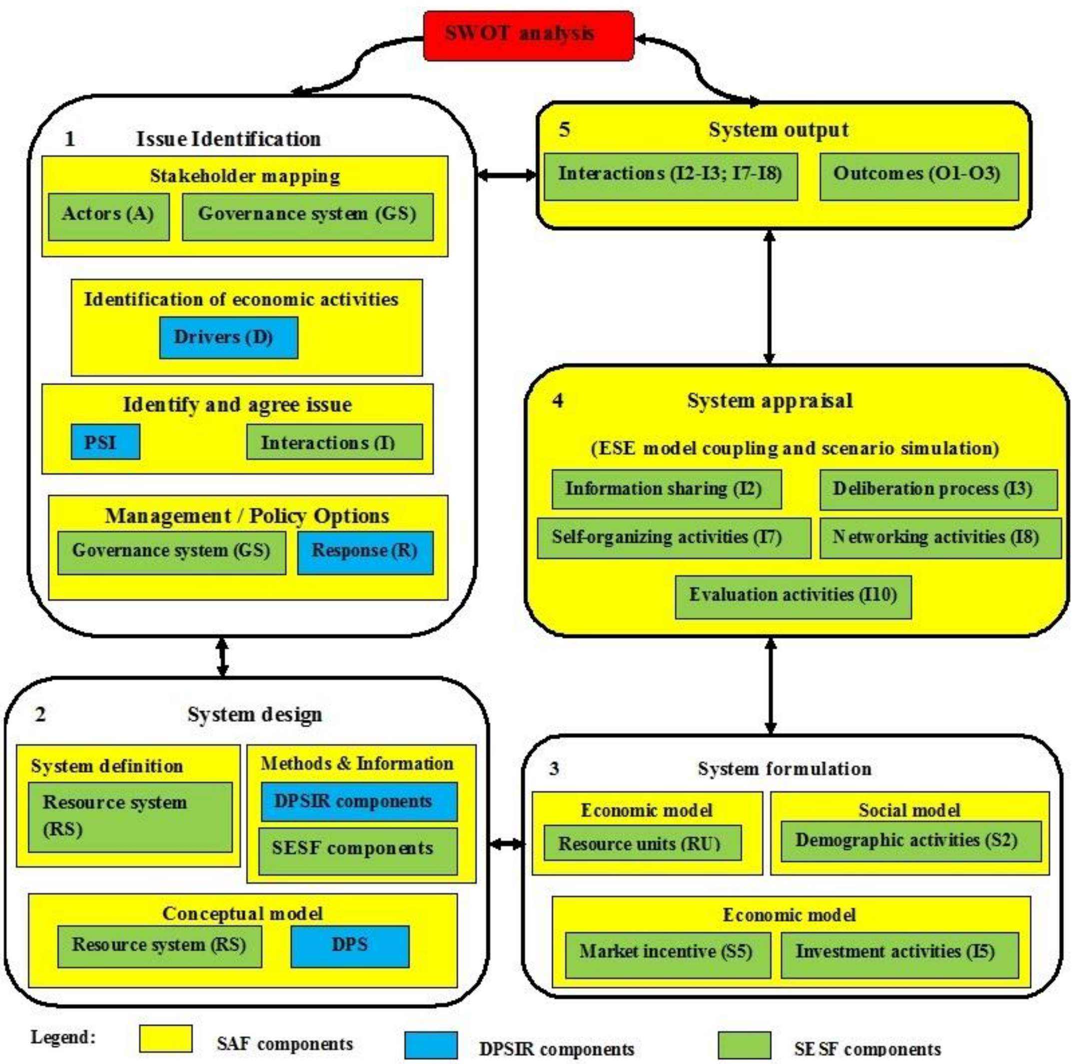

Figure 4: Integrated Analytical Framework

2.1.1. Operational description of the IAF

In figure 4 the variables provided by the three frameworks are color highlighted (DPSIR: Light blue; SAF: yellow; SESF: Green).

- **Issue identification** step:
    - Stakeholders are identified and mapped through the help of SESF variables: Actors (A) and Governance Systems (GS). SESF variables are listed in table X.
    - To identify economic activities, the DPSIR component ¨**D**¨ will be used.
    - To agree on an issue for the study, the DPSIR components ¨**PSI**¨ and SESF variables: Interactions (I) will be employed.
    - Several field and laboratory studies will be conducted. The tools to be used are GIS (land use mapping), Laboratory instruments (for water quality parameters measuring) and interviews (for general information)
    - To deal with management/policy options the SESF variables:¨**GS**¨ will be used.
    - In the same manner, different variables supplied by the three frameworks as indicated in figure X will be used in the subsequent steps.
- **System design** step:
    - The system to be studied will defined. Based on the virtual system conceptual model is made.
- **System formulation** step: Economic (E), social(S) and ecological (E) models are constructed and run.
- **System appraisal** step consists of coupling the **ESE** models and simulation of management scenarios.
- **System output** step: the results of the project are summarized and prepared in various formats for dissemination and communication. The **outputs** are reports, peer-reviewed articles, a model, policy briefs, newsletters and other types of deliverables.
- **SWOT** analysis is incorporated in the IAF at two stages:
    - initially on the present system to build upon the strengths and identify weaknesses. For example, it can assess how predictable the stakeholders' participation in the project could be.
    - And after the IAF is used, to exploit the strengths and opportunities the IAF provides. The feedback from the SWOT analysis enables redressing weaknesses and removing threats that might arise out of the application of the IAF, making it an **adaptive management** method.
    - The double arrows indicate bi-directional information flow between any two steps. This serves to refine the steps and ensure IAF´s adaptive nature.

Remark: A number of information gathering approaches will be adopted. These include semi-structured interviews, observations, deliberative and demonstrative workshops. Moreover, literature search will be made through out the project cycle. Based on the results of the System design step, which provides inputs; specific ecological, social and economic models will be constructed using EXTEND-SIM modeling tool or alternative modeling tool depending on expertise , and other auxiliary models.

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Chapter 2: Detailed guideline to use the Integrated Analytical Framework (IAF)

As explained in chapter one, IAF goes through five steps. What should be accomplished in each step will be described in the following sections.

Step 1: Issue identification.

A. Stakeholder mapping is the first task to execute. Stakeholders will be identified and mapped based on their level of interest and power .
The relevant variables of the SESF , namely Actors (A) and Governance System(GS) will be highly utilized to identify and map stakeholders .

Actors (A)	**Governance system (GS)**
A1 – Number of relevant actors	GS1 – Government organizations
A2 – Socioeconomic attributes	GS2 – Nongovernment organizations
A3 – History or past experiences	GS3 – Network structure
A4 – Location	GS4 – Property-rights systems
A5 – Leadership/entrepreneurship	GS5 – Operational-choice rules
A6 – Norms (trust-reciprocity)/social capital	GS6 – Collective-choice rules
A7 – Knowledge of SES/mental models	GS7 – Constitutional-choice rules
A8 – Importance of resource (dependence)	GS8 – Monitoring and sanctioning rules
A9 – Technologies available	

B. Identification of economic activities is done after or concurrently with stakeholder mapping. For this purpose the DPSIR framework component Drivers will be used. **Driver** is defined as the social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption, and production patterns. Therefore Economic activities are drivers.

C. Issue identification and reaching consensus on the issue to tackle is the next step. This will be accomplished through the use of the DPSIR components of Pressure (P), State (S) and Impact (I). These three components are defined as follows:

Pressure indicators describe developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities

State indicators give a description of the quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fifish stocks)

and chemical phenomena (such as atmospheric CO
concentrations) in a certain area.

Impact: the changes in state produce impacts on the functions of the environment, such as human and ecosystem health, resources availability, losses of manufactured capital, and biodiversity;

Responses are the actions taken by groups (and individuals) in society as well as the governments' attempts to prevent, compensate, ameliorate or adapt to changes in the state of the environment.

In addition to these the relevant SESF variables: Interactions (I) will be used. These are:

I1 – Harvesting
I2 – Information sharing
I3 – Deliberation processes
I4 – Conflicts
I5 – Investment activities
I6 – Lobbying activities
I7 – Self-organizing activities
I8 – Networking activities
I9 – Monitoring activities
I10 – Evaluative activities

D. Management/Policy options

The choice of management options in response to the problem at hand can be tackled principally through the relevant variables of the SESF: Governance system (GS) and the Response (R) component of the DPSIR framework.

SWOT analysis

SWOT analysis is an integral part of step 1. This will be done to identify the strength that may exist in the institutional setup, in the social , cultural and academic arena that may be used as input to the application of IAF. It may assess the prospect of the anticipated stakeholders participation either as a strength or a weakness. Furthermore, the opportunities and threats that may be provided as a result of current and earlier situations will be explored.

Step 2: **System design**

System definition step is where the system to be studied is thoroughly defined and a conceptual model with basic system characteristics is drawn. Coneptual model should be drawn in such a way that it is not too much cluttered with minute system details. It must only capture the most important features to be studied. This will be useful when it is turned in to mathematical and numeric model in the subsequent steps.

A. System definition

The virtual system to be studied will be defined with its appropriate system boundaries using the relevant SESF variables: Resources System (RS) and Interactions (I).As the system consists of the social-ecological system, the physical resourse system and the reaction between it the society must be depicted. The variables are:

Resource system (RS)	**Interactions (I)**
RS1 – Sector (e.g., water, forests, pasture, fish)	I1– Harvesting
RS2 – Clarity of system boundaries	I2 – Information sharing
RS3 – Size of resource system	I3 – Deliberation processes
RS4 – Human-constructed facilities	I4 – Conflicts
RS5 – Productivity of system	I5 – Investment activities
RS6 – Equilibrium properties	I6 – Lobbying activities
RS7 – Predictability of system dynamics	I7 – Self-organizing activities
RS8 – Storage characteristics	I8 – Networking activities
RS9 – Location	I9 – Monitoring activities

B. Methods and information requirements

This is not a separate sub step but an integral part the step 2. While designing the virtual system sources of information and the way to collect the information must be considered. In case adequate resources are not available the system design should be adjusted to the available resources.

C. Conceptual model

Conceptual model incorporating the most important features of the system should be drawn making use of the SESF variables; Resource systems and the DPS as explained in section B of Step 2 above.

Step 3. System formulation

During this step ecologic, economic and and social models will be constructed using ExtendSim modelling software, or any other softwares that can perform the task. Training may be needed for this task. The models will be tested, caliberated , validatd and verified

Ecologic model: Making use of the relevant SESF variables Resource units (RU) as listed below the ecologic model showing important ecologic components will be constructed.

RU1 – Resource unit mobility
RU2 – Growth or replacement rate
RU3 – Interaction among resource units
RU4 – Economic value
RU5 – Number of units
RU6 – Distinctive characteristics
RU7 – Spatial and temporal distribution

Economic model: Economic activities related to the issue at hand will be captured in an economic model. Relevant variables of the Social, economical and political settings (S), especially Market Incentive (S5), Investment activities (I5) as well as other appropriate variables will be used.

Social model: Social model capturing different social dynamics related to the issue will be constructed. Relevant variables of the Social, economical and political settings (S), especially Demographic trends (S2) will be used.

Step 4: System appraisal

In this step, finding an appropriate linking variable the three models will be linked. Having finished with model caliberation, validation and verification, different scenarios will be simulated in the presence of stakeholders. To achieve this a stakeholders workshop should be called .This increases the transparency of the project. Relevant variables of the SESF , especially Information sharing (I2), Deliberation processes (I4) can be used as a guide for the deliberative process.

Step 5: System output

The last step of the IAF is system output where all that have been drone will be deliberated and summarized in reports, deliverables. Dissemination of outputs belongs to this step. Moreover SWOT analysis will be done to evaluate the positive and the negative points of the application as well as the project performance. Relevant variables of SESF , especially Interactions and Outcomes can serve as a guide in this step. The variables Outcomes (O) are listed below:

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

SWOT Analysis

SWOT analysis will be performed to exploit the strengths and opportunities the IAF provides. The feedback from the SWOT analysis enables redressing weaknesses and removing threats that might arise out of the application of the IAF, making it an **adaptive management** method. The double arrows indicate bi-directional information flow between any two steps. This serves to refine the steps and ensure IAF´s adaptive nature.