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EMPIRICAL SYSTEM DYNAMICS: THE SOCIO ENVIRONMENTAL INFORMATION SYSTEM FOR DEMOCRACY AND SUSTAINABILITY

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Abstract
In the state of Jalisco lies one of Mexico's most critical regions: the Santiago-Guadalajara sub-basin. This region's significance stems from its specific weight in the regional economy. Due to the production of tequila, the cultivation of berries and avocados, and the manufacturing of a wide variety of goods, the sub-basin is a crucial driver in the North American integration process. As a result, the sub-basin has undergone accelerated socio-environmental degradation processes with significant social implications.

In this context, the essay describes a cybernetic tool, a public good, that aims to catalyze community-driven dynamics: the Socio-Environmental Information System for Democracy and Sustainability (SISA).

The essay begins with an introduction defining the area of influence and describing the research problem. The second section explains the intervention model, known as SISA. The third section analyzes the model's main advocacy instruments: the Shame Index and the Citizen Duty for Compensation. The fourth section discusses the results. The essay concludes with some preliminary conclusions.

Keywords
systems dynamics, sustainable management, citizen participation, aquifer, transdisciplinary.

1| Introduction

The Santiago-Guadalajara sub-basin is one of the most essential hydrological regions in the country. Some of the most significant municipalities in Jalisco, in terms of population and industrial and agricultural activities, are located within the sub-basin. Below, in Exhibit 1, the geographical distribution of the sub-basin and its location within the state of Jalisco are visually and more thoroughly represented. (see Exhibit 1).

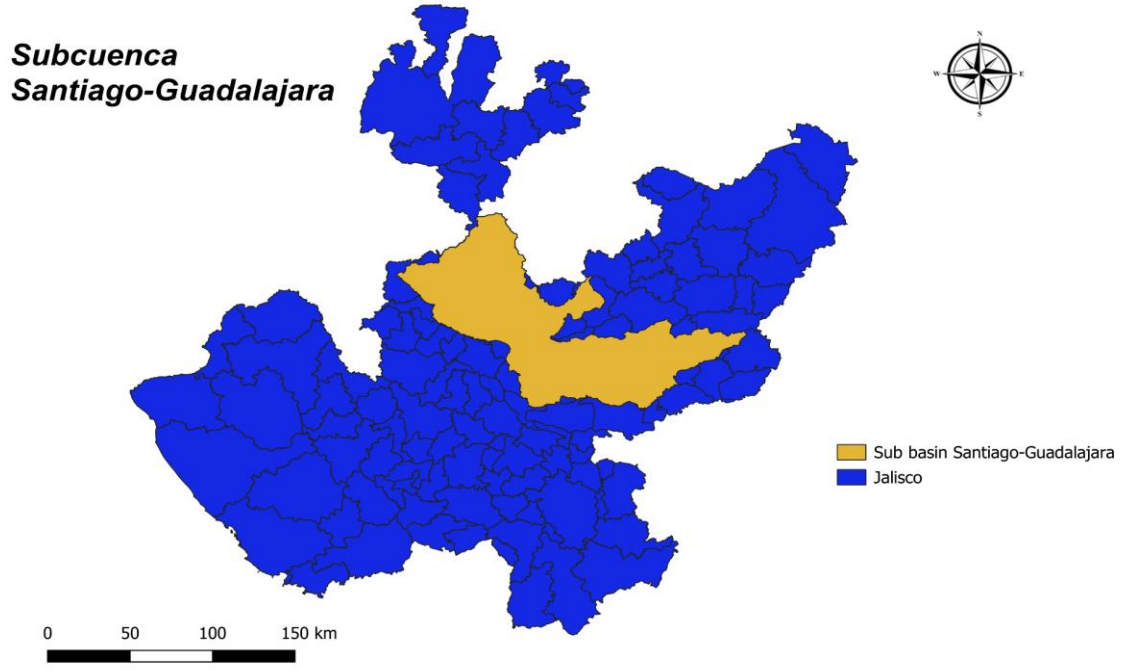
The sub-basin covers a total area of 10,090.52 km² and includes various bodies of water necessary for the economy and urban development. These include the Santiago, Verde, and Zula rivers and Lake Chapala, the largest lake in Mexico.

The Santiago-Guadalajara sub-basin is home to one of the most significant socio-environmental conflicts in the country. The issue arises from a diffuse regulatory framework that needs to allow for the necessary flow of information for the sustainable management of natural resources and energy. The lack of clarity regarding the responsibilities of the government institutions involved in the environmental management processes of the sub-basin has created fertile ground for the exploitation of natural resources, where their use depends on the balance of power among local and regional interest groups. As a result, political and economic factors determine the approach to natural resource exploitation, which promotes unlimited growth.

In summary, we observe that the basin's collapse stems from the destructive emergent behavior of the hydro-social system and the ineffectiveness of the existing regulatory instruments, i.e., a massive and accelerated failure of public policy.

The failure expresses itself in unsustainable everyday practices, such as the widespread granting of concessions for the overexploitation of surface and groundwater sources, non-compliance with pollutant emission standards, the absence of an efficient inspection program, and other issues that not only affect ecosystem health and the dynamics of resource distribution but also exacerbate structural economic inequalities (McCulligh, 2019; CEA, 2011).

Exhibit 1.
The Santiago-Guadalajara Sub-basin.



Source: Own elaboration based on data from INEGI 2024

Finally, the feedback loop of unsustainability in public policy closes with the authorities' approach to the socio-environmental collapse: governments focus their efforts on short-term solutions based on large-scale engineering projects, such as the construction of wastewater treatment plants, large dams, and sophisticated water collection and extraction systems. In the long term, these "solutions" exacerbate existing socio-environmental conflicts.

The social impact of this model's functioning is significant. The Santiago River became a risk factor for all surrounding communities. What was once an essential provider of ecosystem services has now become a threat to human health (Greenpeace, 2012).

2| **The Socio-Environmental Information System for Democracy and Sustainability (SISA).**

In light of the environmental catastrophe in the Santiago-Guadalajara sub-basin, we proposed constructing a model for generating and managing information to provide a foundation for developing cybernetic tools and intervention processes for remediation and adaptation by the affected communities.

The model, referred to as SISA (Socio-Environmental Information System for Democracy and Sustainability), is a common good based on the principles of systems dynamics. This holistic approach

identifies the interrelations among the system's elements that determine its emergent behavior. Following the ideas proposed by Liévano and Lodoño, the system begins with recognizing that the relationships or interactions among the components are more important than the elements in determining the system's behavior (2012, p. 47).

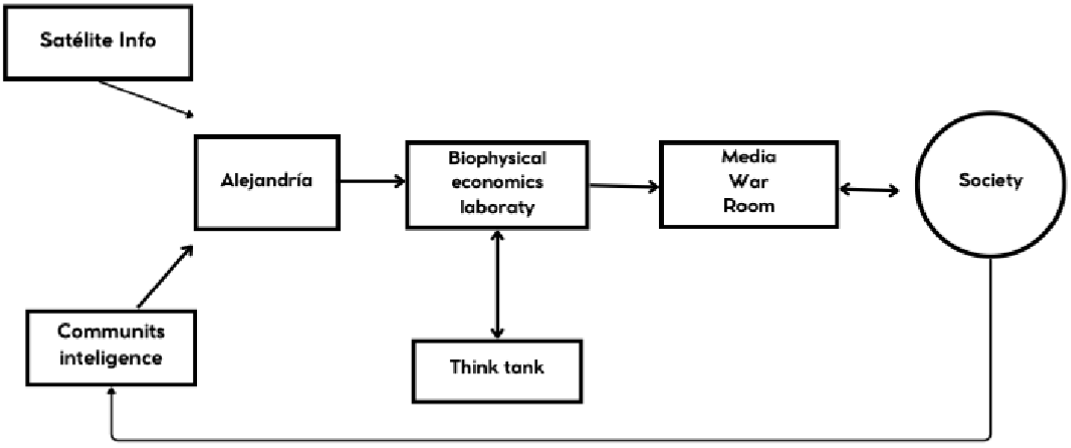
The nature of the described model allows for the design of intervention strategies with greater effectiveness and long-term sustainability by addressing the deep-rooted issues within the system. This model avoids the sterile blame game and the confusion of limiting our efforts to superficial symptoms.

The practical objective of SISA, as a tool for the sustainability of the basin, is to make visible the severity of the socio-environmental conflicts at critical points in the Santiago-Guadalajara sub-basin, highlighting the causal feedback loops to provide alternative proposals and technical-scientific resources for recovery. The transdisciplinary strategy and the openness to post-normal science within the model enable integrating researchers from national and international backgrounds across various fields of knowledge and the involvement of different civil society organizations and the affected communities.

The anticipated results from the construction of SISA aim to change the system's emergent behavior, relying on science-based solutions to establish an alternative development model that differs from the prevailing framework based on economic rationality and extractivism (Svampa, 2018).

SISA is founded on six general and interrelated components that mutually reinforce each other and the communities to provide reliable information and management tools. These components include the satellite imagery service, the environmental activism and community intelligence center, the information management center (Alexandria), the biophysical economy laboratory, the think tank, and the media war room.

Exhibit 2
Structure and circulation of information in SISA.



Source: Own elaboration.

The model's components systematize information regarding territorial changes, ecosystem degradation, community health risks, and socio-environmental conflicts. Each element has a specific objective.

1. Satellite Imagery Service.
   SISA begins with a satellite imagery service focusing on areas of interest (provided by the Sentinel satellite), which offers evidence of changes in land use and the deterioration dynamics of local ecosystems.

2. Environmental Activism and Community Intelligence Center.
   The second component is a community center for real-time information. The resulting databases provide empirical evidence of spatial transformation.

3. Information Management Center (Alejandría).
   This component aims to collect, store, and organize multitemporal, multiscale, and multidimensional data on hydrological and geomorphological changes, water quality, air quality, health risks, pollution-related morbidity, public policy indicators, and economic data.

4. Biophysical Economy Laboratory (LEB), Charles Hall.
   The laboratory develops the tools necessary for carrying out SISA's functions, including analysis, public policy proposals, community resistance strategies, university training, and economic forecasting: interactive maps and testimonial tools for citizen information and activism.

5. Think Tank
   This component serves as a space for quality control, theoretical-methodological analysis, and specialist feedback regarding the integrity and robustness of databases and maps, the instruments generated by the LEB, and the dissemination strategies derived from the work conducted in the Media War Room.

6. Media War Room (CGM).
   This component is responsible for communicating SISA's findings and tools to society through communication and socialization strategies of the results obtained. The CMG is in charge of evaluating the success of SISA's performance by measuring its media reach within the population.

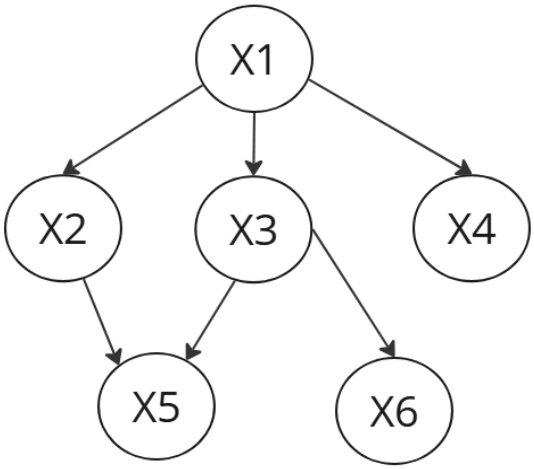
SISA functions as a tool that promotes transformation in the local governance model by changing the relationships among the elements of the socio-environmental system through the use of science, information, technology, cybernetics, and citizen intelligence. In this way, the socio-environmental management processes proposed by SISA will evolve into a new citizen agenda.

3| The central tools of SISA: the combination of the Shame Index and the Civic Duty.

The most essential cybernetic tools of SISA, developed in the biophysical economy laboratory, are the Shame Index and the Civic Duty.

The Shame Index is an indicator aimed at highlighting socio-environmental degradation trends in the area of influence. It uses the information obtained in the foundational components of the model. The index serves as an aggregate that groups information on levels of environmental degradation, its impacts and social costs, and the incidence of governmental strategies and policies. The Shame Index is constructed in real-time using an algorithm applying Bayesian methodology. It indicates the range of values that allow for the identification of the basin's condition and dynamics.

Exhibit 3
Visual representation of a Bayesian network.



Source: Own elaboration.

The advantages of using the Bayesian method in constructing the index include, among others (Sugar, 2006):

- The incorporation of historical information through prior distributions.
- The ability to make direct and intuitive interpretations using probability ranges
- High flexibility and adaptability to complex data structures.
- Improved management of uncertainty in parameters using posterior distributions.
- Assurance of greater robustness with smaller sample sizes.
- The capability to update the model as new data becomes available.
- Bayesian inferences inherently account for uncertainty, making predictive intervals more accurate.

The Shame Index departs from the culture of blame. It generalizes responsibility for environmental degradation among various local actors according to their degree of accountability, whether social groups or spatially localized actors.

The key to the Shame Index's functioning lies in its relationship with Civic Duty. Civic Duty constitutes a tax administered sovereignly by local actors in a transparent and democratic manner within a community institution created specifically to address the impacts of pollution on the affected population. In particular, it covers the costs of medical treatments related to exposure to pollutants and environmental degradation in the area of influence.

The relationship between the index and the civic Duty is direct and exponential; that is, each recorded increase in the index corresponds to a rise in the civic Duty covered by polluting agents as a whole. In this way, all polluters share the responsibility and costs of degradation, generating coordinated emergent behavior among the actors. Combining the Shame Index and the Civic Duty produces a different emergent behavior in the system, creating a positive feedback loop. This situation means that the duo generates a systemic interest among polluters to reduce degradation levels in the area of influence.

4| Discussion

We start from the premise that the primary problem faced by communities in their struggle to achieve sustainable practices is the need for mechanisms for citizen participation. Community participation is often used merely as a political decoration or a symbolic measure in the various municipalities that make up the

Santiago-Guadalajara sub-basin. Therefore, the SISA model works on the idea that collective management of natural resources is critical to achieving a genuine state of sustainability. Consequently, it is essential to involve the community, utilizing the knowledge gained from daily experiences and the wisdom passed down through generations.

The principle underlying this approach is that a resource management model based on community knowledge brings us closer to correctly understanding the environment and the complex problems that characterize socio-environmental systems in crisis. Indeed, as Shirky (2008) states, organizing without organizations enables citizens to collaborate and solve complex problems more efficiently and quickly than traditional hierarchical structures (p. 17).

SISA considers the necessity of including the social sphere in decision-making and resource management for the sub-basin and the challenges communities face in asserting their voice and opinion. This approach contributes to scientific research by providing unique perspectives that complement quantitative data (Ravetz, 1993).

5| Conclusions

In light of the socio-environmental collapse affecting the Santiago-Guadalajara basin, we propose a cybernetic tool to promote democracy and sustainability. SISA is a public good aimed at serving as a mechanism for generating tools that foster alternative community strategies, resistance, and adaptation to socio-environmental collapse.

Through a systemic approach, SISA can identify and analyze behavioral patterns, facilitating the implementation of holistic and sustainable solutions with a medium- to long-term focus. The deep understanding of socio-environmental systems provided by the system is essential for developing more effective strategies in response to contemporary sustainability challenges.

6| References

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. Futures, 25(7), 739-755. https://doi.org/10.1016/0016-3287(93)90022-L

Greenpeace. (2012). *Estudio de la contaminación en la cuenca del río Santiago y la salud pública en la región*. México.

Instituto Mexicano de Tecnología del Agua (IMTA) y CEA Jalisco. (2011). *Actualización del estudio de calidad del agua del Río Santiago (desde su nacimiento en el Lago de Chapala, hasta la Presa Santa Rosa)*. México: IMTA.

INEGI. (2024). *Simulador de Flujos de Agua de Cuencas Hidrográficas*. Retrieved from https://antares.inegi.org.mx/analisis/red_hidro/siatl/

Liévano Martínez, F., & Londoño, J. E. (2012). *El pensamiento sistémico como herramienta metodológica para la resolución de problemas*. *Revista Soluciones de Postgrado EIA, 8*, 43-65. Retrieved from https://revistas.eia.edu.co/index.php/SDP/article/view/354/347

McCulligh, C. (2019). Corrupción institucionalizada y el mito de las multinacionales: la lógica tras la contaminación industrial del río Santiago, Jalisco. *Sociedad y Ambiente, 233*-252. https://doi.org/10.31840/sya.v0i20.1990

Shirky, C. (2008). *Here comes everybody: The power of organizing without organizations* . Penguin Books.

Sucar, L. , & Tonantzintla, M. (2006). Redes bayesianas. Aprendizaje Automático: conceptos básicos y avanzados, 77, 100.

Svampa, M. (2018). *Las fronteras del neoextractivismo en América Latina* (1.ª ed.). Editorial Universidad de Guadalajara. https://editorial.udg.mx/gpd-las-fronteras-del-neoextractivismo-en-america-latina.html