CASA

Information Framework for Critical Decision-Making in Contexts of Environmental Pressure

Complex Society Lab and Infinitum Humanitarian Systems

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Resilience in social systems, particularly within the context of escalating climate change, is critical for mitigating the impacts of crises on communities globally. With the increase in frequency and severity of extreme climate-related disasters, it is imperative to inform and strengthen community resilience with quantitative, science-based evidence across multiple scales, from household to national levels.

We introduce the Complex Analysis for Socio-environmental Adaptation (CASA) model, a novel framework designed to assist key decision-makers. It enables the evaluation and enhancement of resilience across diverse settings, including cities, urbanizations, and informal settlements. Additionally, it provides predictive tools for assessing potential damage propagation in infrastructure and human capital, which are critical for system functionality. The proposed model advances the Analysis of Resilience for Integrated System Effectiveness by integrating complexity and systems thinking, employing global scientific knowledge and complex network methodologies. This approach enables the incorporation of intricate interdependencies within social systems, offering a comprehensive perspective on resilience that aligns with sustainable development goals.

The CASA framework emerges as an innovative pioneering tool in territorial resilience assessment, leveraging Complexity Science and big-data analytics to provide actionable insights for enhancing adaptive capacities in the face of climate disruption. Through its comprehensive approach, CASA addresses the immediate challenges posed by climate change and contributes to the broader discourse on sectoral mitigation actions and their implications for development.

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The CASA Framework. A Decision-Makers' Tool

Our team focused on the development of a model that would address the responsiveness of the social system to adaptive pressures. For this, it was necessary to consider the social complexity involved, that is, how the different components associated with social resilience are linked.

In that sense, our research considered the different social dimensions of resilience described in the literature, using the ARISE model as a fundamental basis. Developed a decade ago as a straightforward but extensive spreadsheet, the ARISE framework provides a tool for evaluating resilience levels by collecting extensive public (non-PII) data sources and manipulating the resulting values to form indices. It was initially used by the Center of Excellence in Disaster Management and Humanitarian Assistance (COE-DMHA) within Tripler Army Medical Center in Hawaii to assess the resilience of Pacific Rim countries. The values derived from an ARISE analysis provide a resilience snapshot for a point in time for a certain country.

The ARISE model is structured around five primary pillars. The model categorizes resilience into distinct sectors under each pillar, and these sectors further break down into specific components, offering a detailed framework for assessing and enhancing resilience at various levels.

However, the fundamental linear design of ARISE model is unsuited to the dynamic complexity of climate change adaptation and ignores interdependencies among the elements that constitute the framework. This detachment among elements primarily challenges the forecasting of future scenarios involving interactions, cascade effects, and feedback loops. This could also hinder understanding the ramifications of alterations in one component on others within the same level, potentially instigating further changes across various levels. Secondly, it is vital to formulate indicators that capture a range of disparate elements not inherently connected in the ARISE framework, including those from other sectors or pillars.

The model's relatively simplistic structural design limits the systemic methodology required by a contemporary grasp of complexity - an aspect our proposal intends to address enhancing the model's complexity by incorporating an advanced approach to synthesizing contemporary global scientific knowledge.

In order to enhance the model, we selected specific elements from the ARISE framework, complemented with others, to establish a comprehensive systemic framework. To elucidate the intricate interconnections among these elements and to construct an interconnected network, we conducted exhaustive literature searches in scientific databases from 2008 to 2023 considering more than 70 million documents.

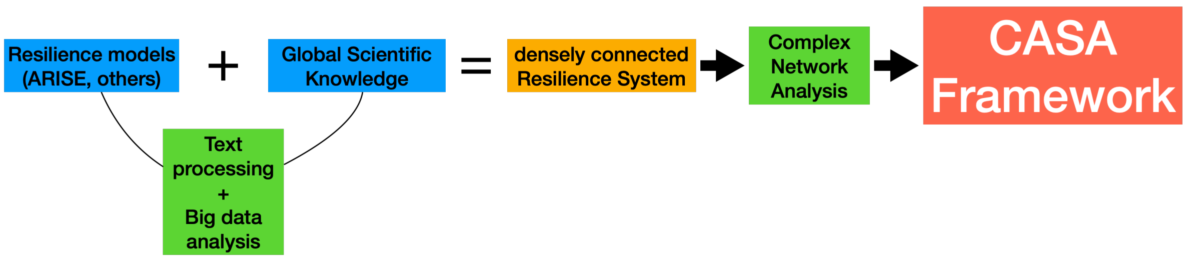

Figure 1. *Methodology implemented to obtain the CASA framework.*

The initial resulting analysis, displayed a remarkably high density, incorporating numerous links between resilience components. This level of complexity presented significant challenges for network analysis and interpretation. To address this, we applied tools from Complex Network Theory to maintain the overall structure of the network while focusing on the most substantial and influential relationships. The implemented methodology (Fig. 1) gives us, for free, i.e., without previous design, the structure of a system of social resilience, the CASA framework shown in Figure 2: what the theory behind social resilience suggests is essential, but now part of a connected whole.

Figure 2. *CASA framework, web version. Networks displays different social dimensions related to resilience linked according to the global scientific knowledge. In this representation, node color represents different communities detected by network analysis and named (colored boxes at the top) according to the criteria of artificial intelligence.*

Universality of CASA framework

One of the fundamental aspects of our work refers to the universal nature of the structure of the CASA model. Given that its structure emerges spontaneously when considering global scientific knowledge, we could be in the presence of a quasi-universal structure where different components of the social system are interconnected into a minimal architecture that accounts for the organization of the different social dimensions associated with resilience.*

This means that the CASA model has a universal structure independent of territory, and independent of the nature of the forces that exert adaptation pressures on the system. In other words, it could be applied in different parts of the world, and in different crisis contexts (e.g. environmental, social, etc.).

** It depends on the scientific knowledge which may be biased and not be the only source of knowledge.*

Applying the universality of the CASA framework

Although the structure of the CASA network could be universal, it is necessary to mention that its applicability does depend on local properties, that is, on the characteristics that define the territory (locality, city, region, etc.) where it will be applied.

CASA, like its predecessor ARISE, considers specific data that feeds each of the system components (network nodes). These data will account for the installed capacities in each of them for that territory. Thus, the CASA model considers the resilience capacities of the territory, arranged on a universal substrate.

The concept of Topological Resilience

The conjugation between the resilience capacities of a territory, superimposed on a relational structure, allows us to define the concept of Topological Resilience, that is, resilience capacities limited by the structure and location of each component in the system architecture. In other words, the resilience capacity of a system will then depend on the individual capabilities of its components and how these are located in the framework. Figure 3 shows those leading components given their location on the network.

Figure 3. *Component Centrality in the CASA Model: The size of nodes and labels indicate the relative closeness of each component to others within the model. Node color represents different communities detected by network analysis.*

When local information is crossed with the capacities installed in each of the components, the result allows us to highlight those components with greater strength or weakness. Figure 4 shows a graphical representation of the installed capacities in each one of the framework communities for the town of Puchuncaví, Chile.

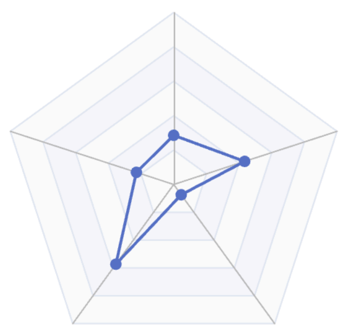

Fig. 4. *CASA Model for Puchuncavi, Chile. Installed capacities in each community of CASA framework. Note: data for Puchincaví was collected during 2023.*

Work in progress

Decision-Makers' Tool Webpage

One of the final objectives of our project is the development of a public web site that allows decision makers to act with science-based information. This web site will have a series of tools associated with the CASA model: visualization of Topological Resilience, comparison between territories according to Topological Resilience, geolocation of the CASA model over the territory, among others. To achieve this, our group is developing a series of lines of research:

Predictions: Dynamics on CASA Network

Since CASA is a connected structure, where it is possible to reach any component associated with resilience from another, it is possible to simulate the propagation of damage as a cascade of events respecting the connections between components.

Our group is currently working on a propagation model, which considers the Resistance of each component to the impact, determined by the capacities installed in it and obtained from local data, as well as the strength of the relationship between its neighbors in the CASA network, the distance that separates it from the initial affectation and, the time elapsed since it. With these rules, we are developing a model that will allow us to answer different questions such as what are the critical components of the territorial resilience system to protect given a possible crisis, or how robust the resilience of a territory is, among others.

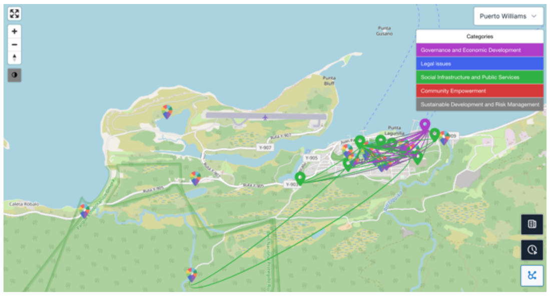

Fig. 5. *CASA Model projected on the city of Puerto Williams, Chile. Map pins represents critical infrastructure related to CASA model categories and the links between them according to CASA framework.*

Damage Propagation in Critical Infrastructure

One of the aspects that concerns us is mapping the different social dimensions of the CASA model to the critical infrastructure of the territory. In this way we can simulate, on the territory, those critical points (e.g. schools, banks, hospitals, etc.) that could be affected given the transmission of failures determined by the propagation model described above (Fig. 5).

From Topological Resilience to Social Crisis

Finally, we know that failure in different components of the social system are drivers of social conflict (affected subjects in Fig. 6). Our work focuses on this aspect using our developed knowledge from the Social Sciences, Complexity Sciences, and interviews with key local actors for the forecast of different social phenomena that could emerge given an impact on the system.*

Fig. 6. Simulation of a damage propagating in the *CASA Model on the city of Puerto Williams, Chile. Material, Social, Governance, Legal, and Economic affected subjects appear during the simulation.*

** Refs: doi.org/10.1155/2022/8980913; doi.org/10.3389/fphy.2021.650648; doi.org/10.1155/2018/9343451; doi:10.1016/j.physa.2018.03.03*

We are open to collaborating with you and receiving feedback to improve our research.

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