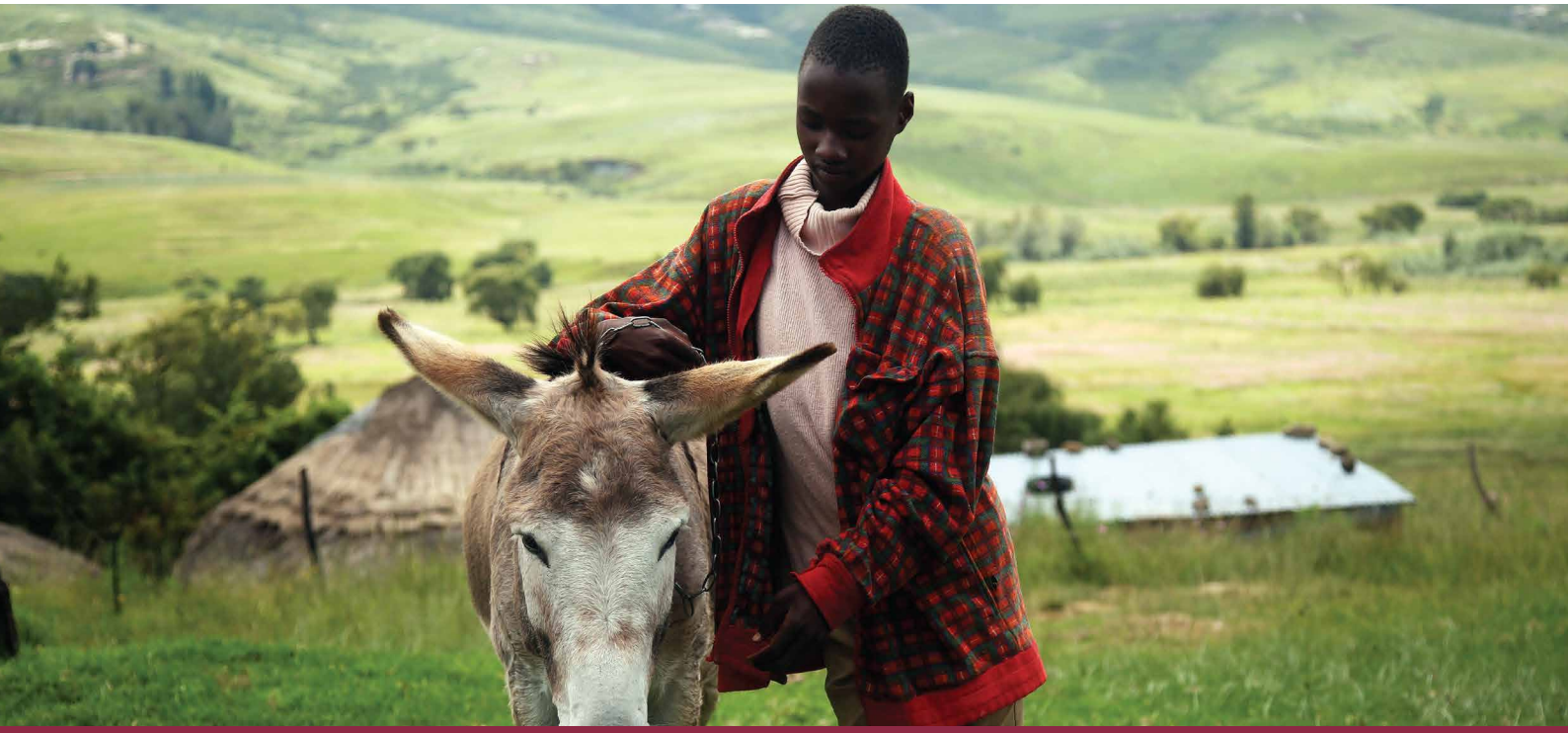
# KEY FEATURES OF COMPLEX ADAPTIVE SYSTEMS

## AND PRACTICAL IMPLICATIONS FOR GUIDING ACTION



CST POLICY BRIEF 2018 | **RIKA PREISER**

UNIVERSITEIT iYUNIVESITHI STELLENBOSCH UNIVERSITY 100 1918 · 2018
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CST Centre for Complex Systems in Transition

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The growing recognition of the intertwinedness of society and the environment is driving a reframing of the conventional divide between social and natural systems and has given rise to the study of social-ecological systems (SES) as being complex adaptive systems. This reframing offers new theoretical frameworks, empirical understanding, and practical heuristics to better respond to the challenges of the Anthropocene.

In this context, gaining a deeper understanding of the features and patterns of the behaviour of complex adaptive systems would result in innovative and more sustainable SES governance approaches based on integrated knowledge and decision-making strategies that bridge various disciplines and action domains.

## WHAT ARE COMPLEX ADAPTIVE SYSTEMS?

The word 'system' in this context refers to several interacting elements and relations forming an integrated whole, often with a shared purpose or function. Systems generally have:

- a dynamic structure, which is defined by the context, the elements and their structural compositions;
- behaviour that processes inputs and generates outputs as well as interconnectivity between their parts in terms of structure and function.

Complex adaptive systems are a special instance of systems based on the recognition that these systems contain adaptive components and capacities. The adaptive components allow systems to change and evolve over time in response to feedbacks and changes in the system context. The agents in complex adaptive systems are well-connected and actions often result in non-linear and disproportionate outputs that can be difficult to predict. Through this network of connections, the system exhibits emergent behaviour which is different from the behaviour of the individual components. Examples of complex adaptive systems include the stock market, climate, the brain and business organisations.

## WHY IS IT IMPORTANT THAT WE UNDERSTAND THE FEATURES AND DYNAMICS OF COMPLEX ADAPTIVE SYSTEMS?

The study of complex adaptive systems attempts to explain how complex structures and patterns of interaction arise based on the underlying features and mechanisms that bring about emergent behaviour. Prominent scholars have compiled well-known lists of properties and features of complex adaptive systems. These have recently been organized into a set of six organizing principles (see Table 1) that offer a basis for identifying key systemic concepts to inform different types of tools and methodologies for responding to intractable real-world SES challenges.

**TABLE 1.** Key complex adaptive systems features and attributes with related practical implications for understanding and governing complex adaptive systems (CAS) (based on Preiser et al., 2018 in print).

| | UNDERLYING FEATURES OF CAS | KEY FEATURES AND ATTRIBUTES | RELATED CONCEPTS AND CAPACITIES THAT CHARACTERIZE CAS FEATURES | PRACTICAL IMPLICATIONS FOR ENGAGING WITH CAS |
|---|---|---|---|---|
| STRUCTURE-RELATED FEATURES |  1. CONSTITUTED RELATIONALLY | Process-dependent interactions on multiple scales result in networks of interactive relations. CAS are defined more by the interactions among their constituent components than by the components themselves. | Netlike structures, hierarchies, diverse components, built-in redundancy, heterogeneity. | – The nature and structure of relationships between components in a system have to be considered explicitly;<br>– Collaborative processes should be fostered to build trust and social networks;<br>– Diversity is key and allows for different kinds of interactions to take place. |
| |  2. RADICALLY OPEN | All systems exhibit hierarchy in that every system is part of a wider system and is made up of sub-systems.<br>How we describe (or identify) systems is a function of our individual points of view.<br>Systemic interactions generate effects that have impacts across scales and domains. | Permeable boundaries, embeddedness, nestedness, exchange of matter, information, energy, teleconnections. | – Projects are not closed and contained entities, therefore any intervention will influence and shape systems and realities that are situated outside of the scope of the project's aims and objectives;<br>– Changes at local scales from individual decisions result in cumulative changes that have impacts globally and similarly, global events have impacts on local ecosystems and communities. |
| |  3. CONTEXT DEPENDENT | The identity and functions of CAS are defined by the context in which they exist. | CAS are continuously shaped by dynamic interactions with its environment. | – Systems must be understood in the context of their environment;<br>– Changing a system affects both its sub-systems and the environment in which it is embedded;<br>– Transformative spaces should be created for activating systemic change processes. |
| PROCESS-RELATED FEATURES |  4. ADAPTIVE | CAS have self-organising capacities and can adjust their behaviour as a response to changes in their environments. | Self-generating, self-organisation, decentralised control, has memory, evolutionary, concurrent persistence and change (resilience), anticipatory capacities. | – Guard against rigid planning and strategy design and implement adaptive co-management practices that foster iterative learning and participatory collaborative processes of engagement;<br>– Foster iterative learning and participatory collaborative processes of engagement;<br>– Assess resilience and anticipate possible future organisational patterns and pathways. |
| |  5. DYNAMIC | Non-linear dynamic processes bring about the behavioural patterns of CAS.<br><br>As a result of non-linear feedback loops that can dampen or amplify perturbations, small changes can have significant, cascading effects resulting in multiple modes of system-wide re-organisation or regime shifts. | Far-from-equilibrium, non-linear interactions, attractors, thresholds, tipping points, regime-shifts, feedback loops (enabling and constraining), cross-scale interactions. | – Map systemic feedbacks across different spatial and temporal scales to identify systemic thresholds, traps, and indicators that could help detect possible leverage points;<br>– Assess which mechanisms build or inhibit systemic agency and resilience. |
| |  6. COMPLEX CAUSALITY | Through the interaction of the individual components, novel qualities and phenomena emerge. Hence, the whole is more than the sum of its parts, meaning that systems cannot be understood, nor their behaviour predicted based solely on information relating to the individual parts. | Emergence and novelty come about through complex underlying mechanisms. | – Cause-and-effect cannot be traced in linear causal trajectories, thus manage for emergence and expect unintended consequences;<br>– CAS are inherently unpredictable and deeply uncertain.<br>– Foster responses that are flexible to redefine outcomes and responses as necessary. |

Despite the increase in the application of complex adaptive systems perspectives in various fields of study and practice, complex adaptive systems-based approaches do not provide magic bullet type solutions for solving intractable real-world problems. Instead, such approaches offer more integrated frameworks and process-based modes of engagement for understanding why these problems may be difficult (or sometimes impossible) to solve, which in turn can inform practical strategies for governing more resilient SES.

## IMPLICATIONS FOR GUIDING COMPLEX ADAPTIVE SYSTEMS-BASED PRACTICE

The framing of SES as complex adaptive systems has direct consequences for understanding, studying and managing complex SES. The following principles offer a point of departure for developing complex adaptive systems-based approaches and practices::

### ADOPT HABITS OF MIND THAT CULTIVATE COMPLEX ADAPTIVE SYSTEMS THINKING

Complex adaptive systems thinking offers a way of 'interconnected' thinking about the world that allows us to see the dynamic behaviour and patterns of change that such systems display. Complex adaptive systems thinking challenges commonly held assumptions about the nature of a problem and conventional solutions that are based on control and demand-based planning and decision-making approaches and anticipates surprises and accepts that there are no quick fixes for solving complex real-world problems.

### ASSESS SYSTEMIC FEATURES AND DYNAMICS TO UNDERSTAND AND INFLUENCE PATTERNS OF BEHAVIOUR

By identifying the key variables, components and processes that characterise the system in question, important connections, leverage points and cross-scale drivers that influence the behavioural patterns of the system can be uncovered, understood and influenced to bring about systemic change. Assessing systemic features offers a rich and integrated systemic view of the phenomena under study. Most wicked problems are intractable problems that are interconnected in a synergistic fashion, and that therefore can only be navigated properly through systemic interventions.

### 3 NURTURE COMPLEX ADAPTIVE SYSTEMS-BASED CAPACITIES AND PRACTICES

Create conditions that nurture the system's capacity for developing creative responses to unintended consequences resulting from deep uncertainty and non-linear dynamics. Strengthen personal and institutional capacities that can guide systemic insight and action that result in the ability to adapt when necessary. Facilitate transformative dialogues to foster trust and new relationships. Allocate resources that allow for critical reflexivity, shared learning experiences and constructive evaluation to take place regularly.

To summarise, a complex adaptive systems orientation to understanding the intertwined nature of SES and the challenges that governing these systems pose, offers a way of building more resilient responses that shift interventions based on the need to control to actions that encourage collaboration, from competition to a greater recognition of interdependence, from hierarchical to participatory and reflexive decision-making processes.

### FURTHER READING


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**FOR FURTHER INFORMATION PLEASE CONTACT:**

**CENTRE FOR COMPLEX SYSTEMS IN TRANSITION**
Stellenbosch University, Private Bag X1, The Stables at 19 Jonkershoek Road, Stellenbosch, South Africa
**Tel:** +27 21 808 9607 | **Website:** www.sun.ac.za/cst