

*IAS Amsterdam July 2019*

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Complexity and climate --  
From foundations to  
interventions

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Karoline Wiesner  
University of Bristol

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# Overview

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- ❖ Introduction – My research – What is a complex system?
- ❖ Complexity and evaluation of climate change mitigation and adaptation interventions
  - ❖ Goal of this project: “...how [the GCF] might use the complexity science perspective to improve the design and evaluation of GCF projects and programs.”
  - ❖ Result: Complexity analysis tool for socio-economic-ecological dynamic systems

My research in general

PhD in Physics (2004)  
Research since then focussing on  
Information theory and applications

# Background

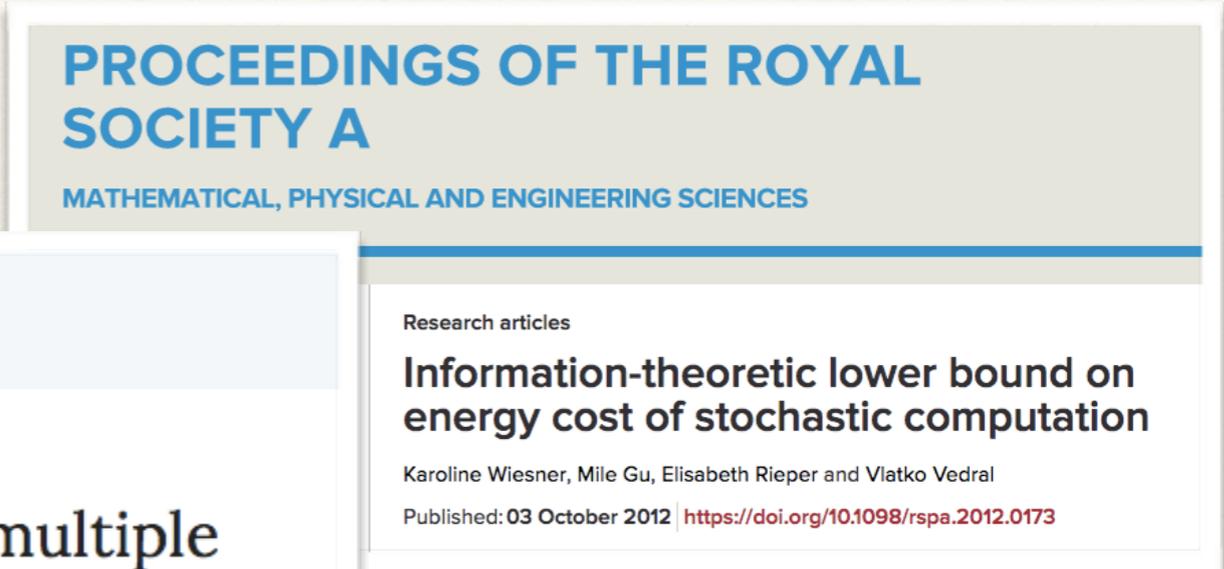


**nature COMMUNICATIONS**

Article | OPEN | Published: 22 January 2015

## Mutual information reveals multiple structural relaxation mechanisms in a model glass former

Andrew J. Dunleavy, Karoline Wiesner, Ryoichi Yamamoto & C. Patrick Royall



**PROCEEDINGS OF THE ROYAL SOCIETY A**

MATHEMATICAL, PHYSICAL AND ENGINEERING SCIENCES

Research articles

## Information-theoretic lower bound on energy cost of stochastic computation

Karoline Wiesner, Mile Gu, Elisabeth Rieper and Vlatko Vedral

Published: 03 October 2012 | <https://doi.org/10.1098/rspa.2012.0173>



**PLOS ONE** PUBLISH ABOUT BROWSE

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RESEARCH ARTICLE

## A New Method for Inferring Hidden Markov Models from Noisy Time Sequences

David Kelly, Mark Dillingham, Andrew Hudson, Karoline Wiesner

Published: January 11, 2012 • <https://doi.org/10.1371/journal.pone.0029703>

# Stability of democracy – A complex systems perspective

Collaboration across computer science, economics, mathematics, philosophy, physics, political science, and psychology

European Journal of Physics

PAPER • OPEN ACCESS

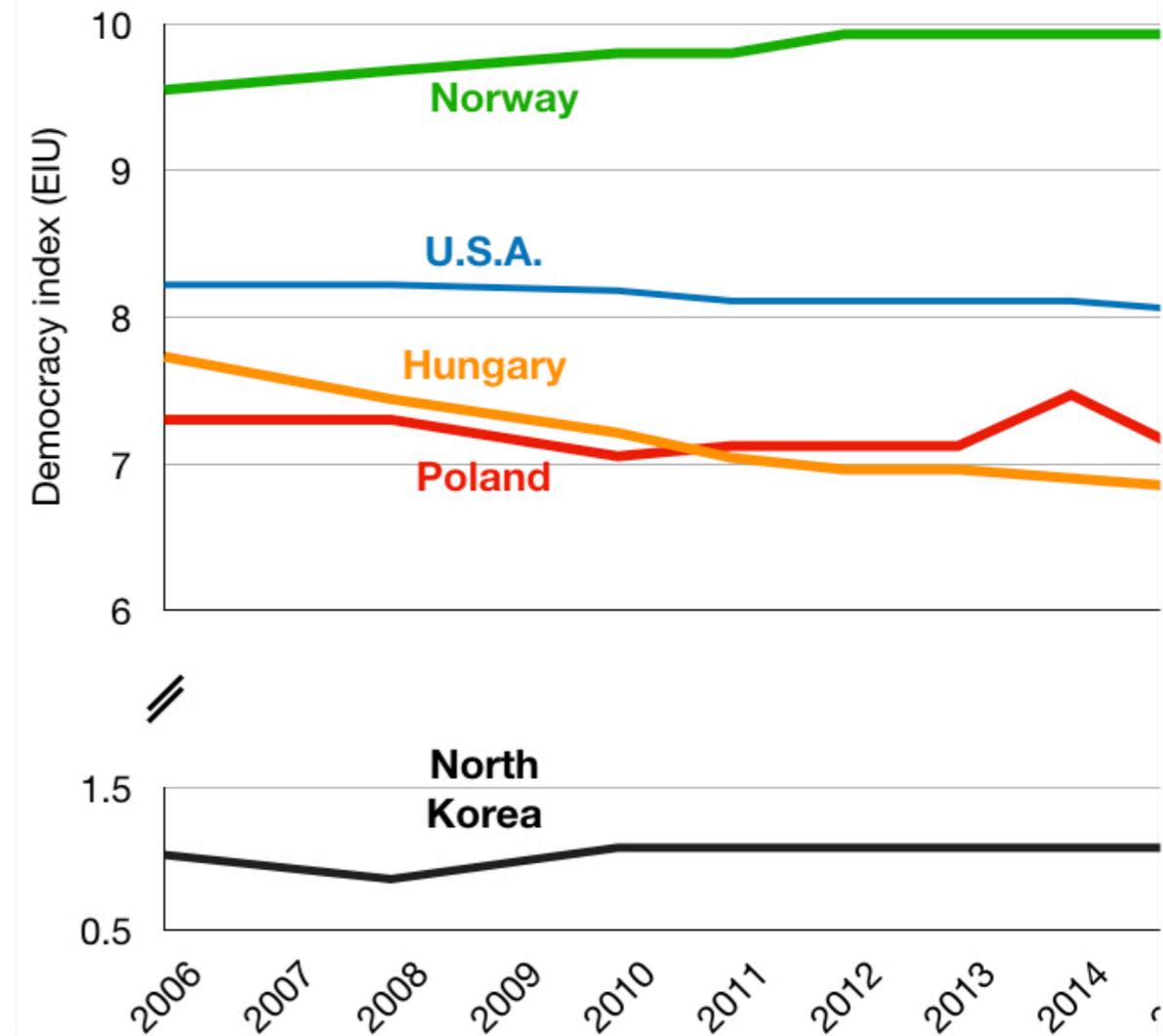
## Stability of democracies: a complex systems pe

K Wiesner<sup>1,2</sup> , A Birdi<sup>3</sup>, T Eliassi-Rad<sup>4</sup> , H Farrell<sup>5</sup>, D Garcia<sup>2,6</sup>, S Lewandowsky<sup>7</sup> , P Palacios<sup>8</sup>,  
D Ross<sup>9,10,11</sup> , D Sornette<sup>12</sup> and K Thébault<sup>13</sup> 

Published 27 November 2018 • © 2018 European Physical Society

[European Journal of Physics, Volume 40, Number 1](#)

[Focus on Complexity](#)



What is a complex system?

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# Examples of complex system

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The Universe

The Climate System

Ant Colonies

Honey Bee Hives

Markets and Economies

The World Wide Web

The Human Brain

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Karoline Wiesner &  
James Ladyman

*Yale University Press*  
(2020)

previous work:

European Journal of  
Philosophy of Science  
(2013)

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# Conditions for complexity

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- ❖ **Numerosity:** complex systems involve many interactions among many components.
- ❖ **Disorder and Diversity:** the interactions in a complex system are not coordinated or controlled centrally, and the components may differ.
- ❖ **Feedback:** the interactions in complex systems are iterated so that there is feedback from previous interactions on a time scale relevant to the system's emergent dynamics.
- ❖ **Non-Equilibrium:** complex systems are out of thermodynamic equilibrium with the environment, and are often driven by something external.

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# Products of complexity

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- ❖ **Spontaneous Order and Self-Organisation:** complex systems exhibit structure and order that arises out of the interactions among their parts.
- ❖ **Nonlinearity:** complex systems exhibit nonlinear dependence on parameters or external drivers.
- ❖ **Robustness:** the structure and order of complex systems is stable under relevant perturbations.
- ❖ **Nested Structure and Modularity:** there may be multiple scales of structure, clustering and specialisation of function in complex systems.
- ❖ **History and Memory:** complex systems often require a very long history to exist, and often store information about history.
- ❖ **Adaptive Behaviour:** complex systems are often able to modify their behaviour depending on the state of the environment and the predictions they make about it.

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# Complexity and evaluation of climate change mitigation and adaptation interventions

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work commissioned by  
Independent Evaluation Unit  
of the Green Climate Fund

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# Disclaimer

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I have ignored most existing discussions on evaluation, and human-natural system modelling, planning, and policy making. For three reasons:

1. Ignorance
2. Novelty
3. Time constraint

# Green Climate Fund - Introduction

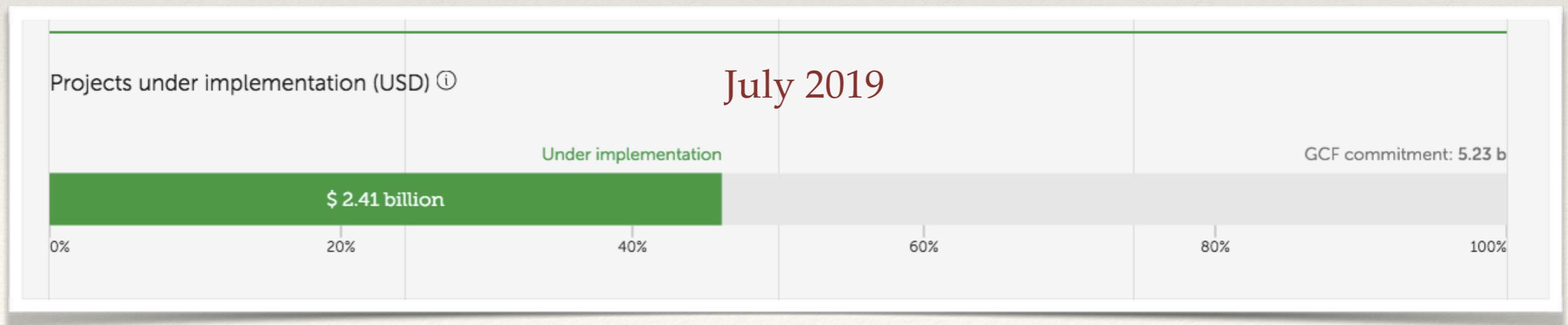
# Green Climate Fund

- ❖ Set up in 2014, as an operating entity of the financial mechanism of the UNFCCC.

GCF AT A GLANCE		
	No. of Projects	<a href="#">VIEW OUR CURRENT PORTFOLIO &gt;</a>
	111	<a href="#">BROWSE OUR PROJECTS &gt;</a>
Anticipated tonnes of CO2 equivalent avoided	Anticipated number of people with increased resilience	Total GCF financing committed (USD)
1.5 b	310.3 m	5.2 b

# Green Climate Fund

- ❖ The Green Climate Fund was established with the purpose of **making a significant and ambitious contribution to the global efforts towards attaining the goals set by the international community to combat climate change**. In the context of sustainable development, the Fund will promote the paradigm shift towards low-emission and climate-resilient development pathways by **providing support to developing countries to limit or reduce their greenhouse gas emissions and to adapt to the impacts of climate change**.



# One GCF project

## INVESTMENT DATA

Financing:	<b>PUBLIC</b>	PUBLIC / PRIVATE	PRIVATE	
Project size:	MICRO	<b>SMALL</b>	MEDIUM	LARGE
E&S Risk category:	CATEGORY A	CATEGORY B	<b>CATEGORY C</b>	

\$21.8m

Total project investment

FP035

ADAPTATION

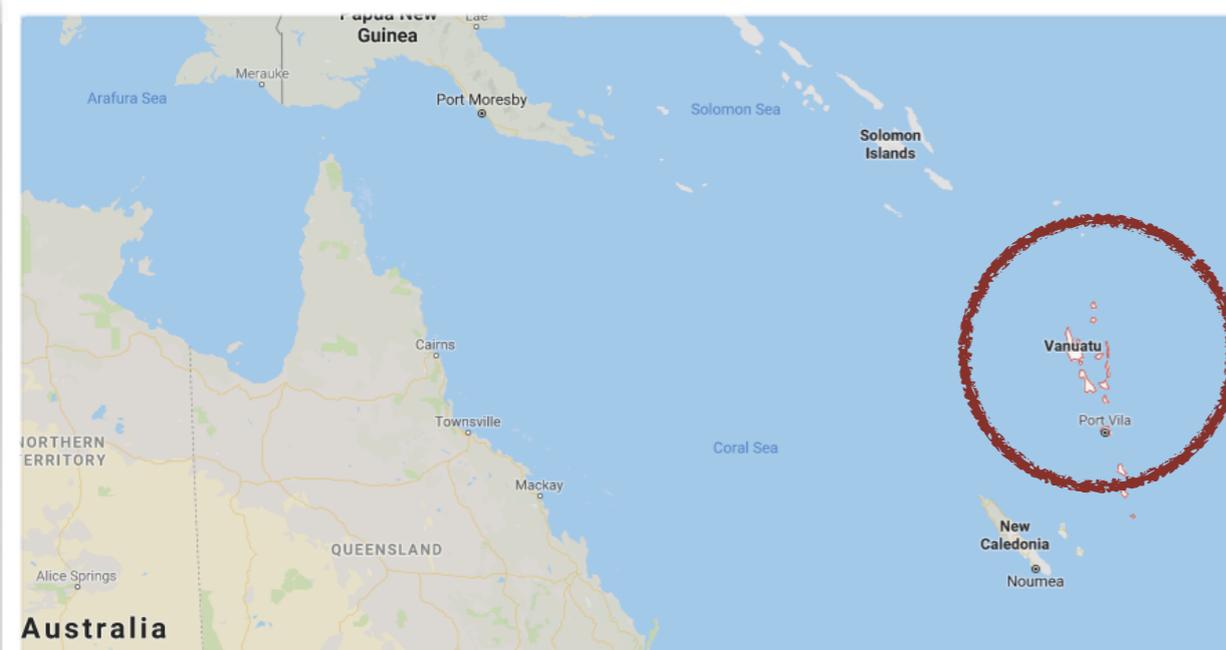
VANUATU

Climate Information Services for Resilient Development in Vanuatu

260.7k

BENEFICIARIES

Anticipated number of people with increased resilience



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# GCF's Independent Evaluation Unit

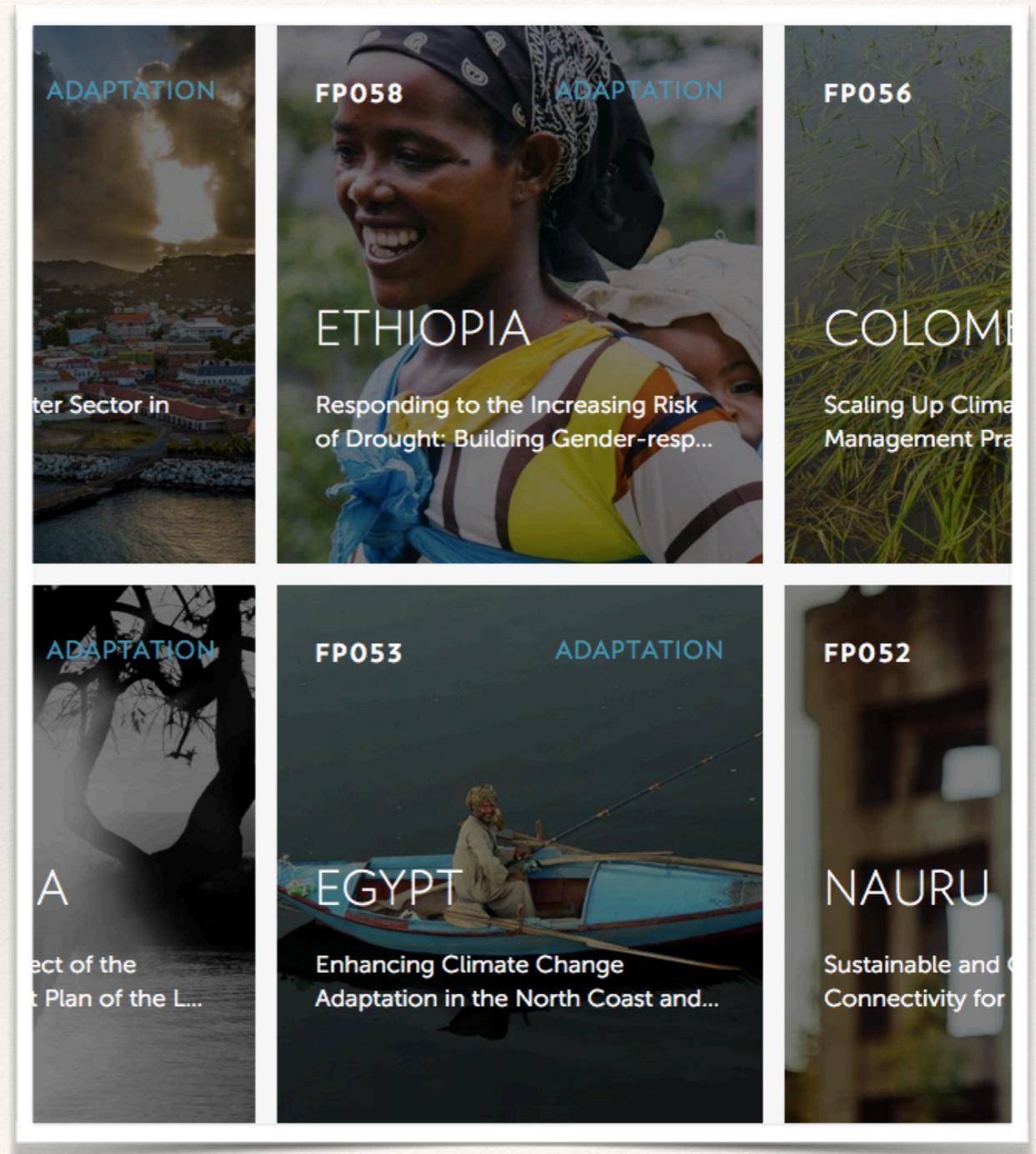
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The IEU was established by the GCF Board as an independent unit, to provide objective assessments of the results of the Fund, including its funded activities, its effectiveness, and its efficiency. The IEU fulfils this mandate through four main activities: evaluation, learning and communication, advisory and capacity support, engagement.

- ❖ **Evaluation:** Undertakes independent evaluations at different levels to inform GCF's strategic result areas and ensure its accountability.
- ❖ ...“measure the causal and attributable effects of development programmes”

# Goal of my research, set by IEU

- ❖ “...how [the GCF] might use the complexity science perspective to improve the design and evaluation of GCF projects and programs.”
- ❖ Time frame Nov 2018 - Mar 2019
- ❖ Recurring questions: “How complex is any given project?”



“[A] variety of different measures would be required to capture all our intuitive ideas about what is meant by complexity.”

*–Murray Gell-Mann (Complexity, 1(1):16–19, 1995 )*

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# Measuring complexity not feasible

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- ❖ Disorder / Diversity.....
- ❖ Feedback.....
- ❖ Out of equilibrium .....
- ❖ Order / Self-organisation.....
- ❖ Nonlinearity.....
- ❖ Robustness.....
- ❖ Nested structure / Modularity.....
- ❖ History / Memory.....
- ❖ Adaptive behaviour.....
- ❖ Shannon entropy
- ❖ Modelling
- ❖ ?
- ❖ Correlation functions, mutual information
- ❖ Power laws, modelling
- ❖ ?
- ❖ Clustering in networks, self-similarity
- ❖ Correlation functions
- ❖ Modelling

My approach: Bridging the gap

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# Evaluation vs complexity criteria

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## OECD criteria for evaluation:

- ❖ **Relevance** – The extent to which the aid activity is suited to the priorities and policies of the target group, recipient and donor
- ❖ **Effectiveness** – The extent to which an aid activity attains its objectives
- ❖ **Efficiency** – A measure of the ratio between outputs and inputs
- ❖ **Impact** – The positive and negative changes produced by a development intervention
- ❖ **Sustainability** – The extent to which benefits of an activity are likely to continue after donor funding has been withdrawn

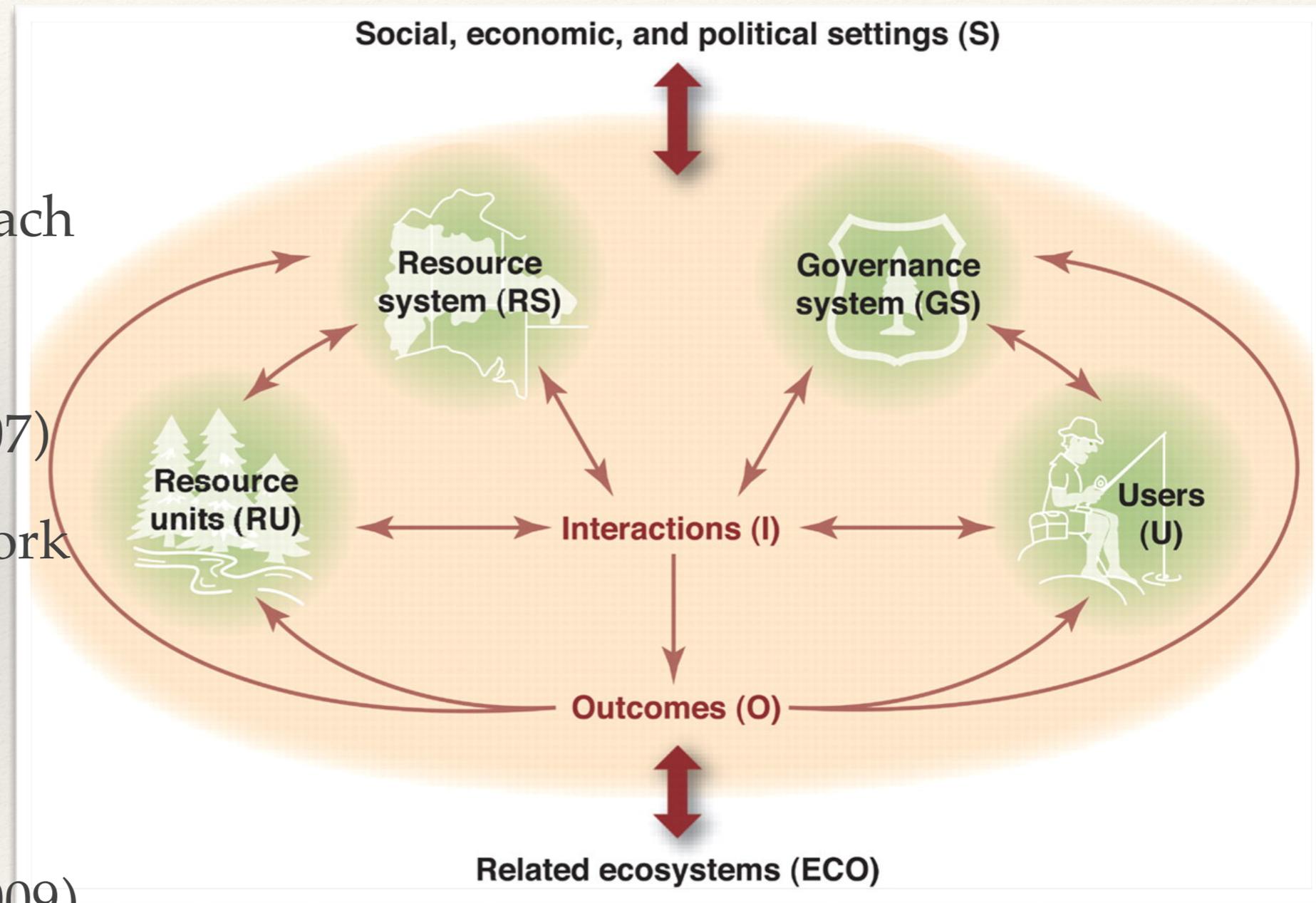
## Complexity criteria:

- ❖ Order / Self-organisation.....
- ❖ Nonlinearity.....
- ❖ Robustness.....
- ❖ Nested structure / Modularity.....
- ❖ History / Memory.....
- ❖ Adaptive behaviour.....

# Ostrom's framework of socio-economic systems (SES)

## References

- ❖ A diagnostic approach for going beyond panaceas, Elinor Ostrom, PNAS (2007)
- ❖ A General Framework for Analyzing Sustainability of Social-Ecological Systems, Elinor Ostrom, Science (2009)



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## Extending the SES framework: Socio-economic-ecological dynamic systems (SEEDS)

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- ❖ Environment (atmosphere, ocean) vs Core systems
- ❖ Core systems (Government System, Resource System, User System)
  - ❖ Resource systems: ecosystem, farming, infrastructure, information services, financial investment
  - ❖ Government: central government, community government
  - ❖ User system: enterprise, local population
- ❖ Variables, such as sea-level rise, aqua-farming yield, income of women-led enterprises

# Example

## Resource System

### ecosystem

health of land  
eco-system  
services

## User System

### enterprises

income of  
tourism  
enterprises

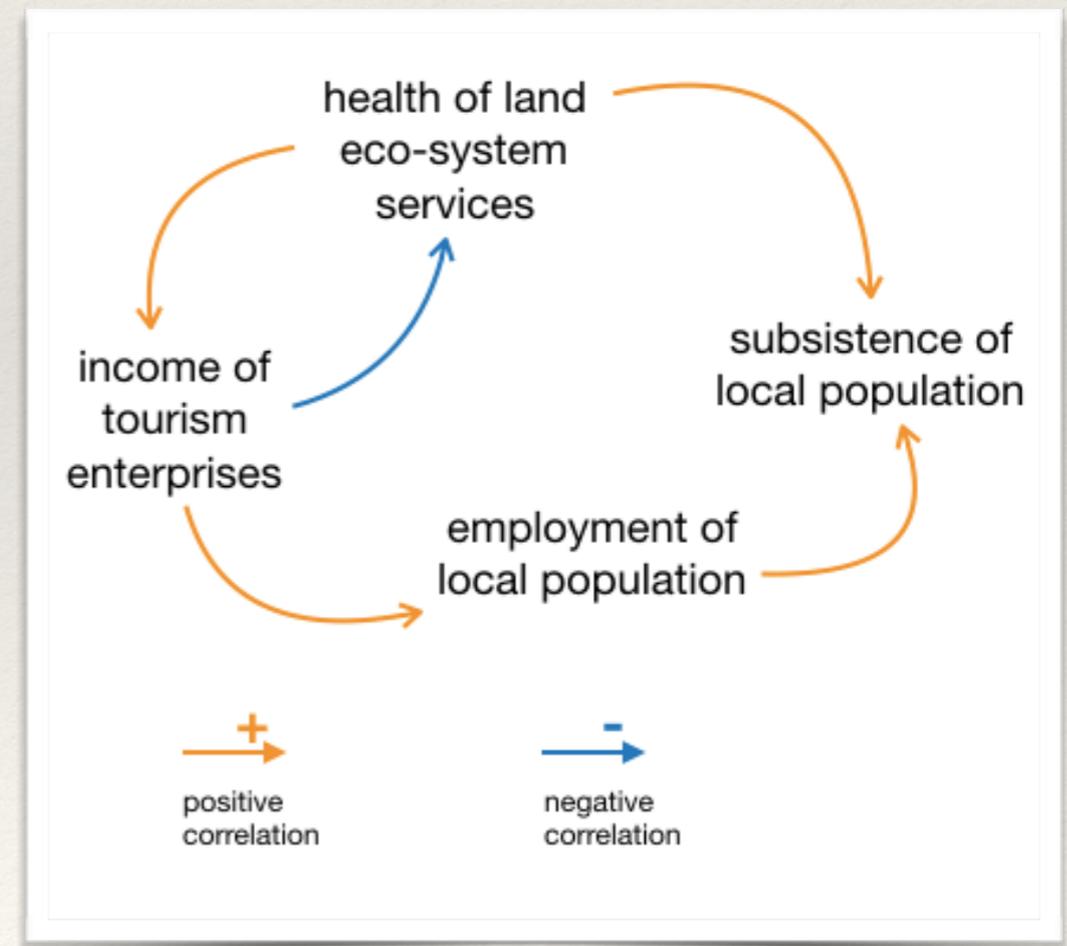
### local population

subsistence of  
local population

employment  
of local  
population

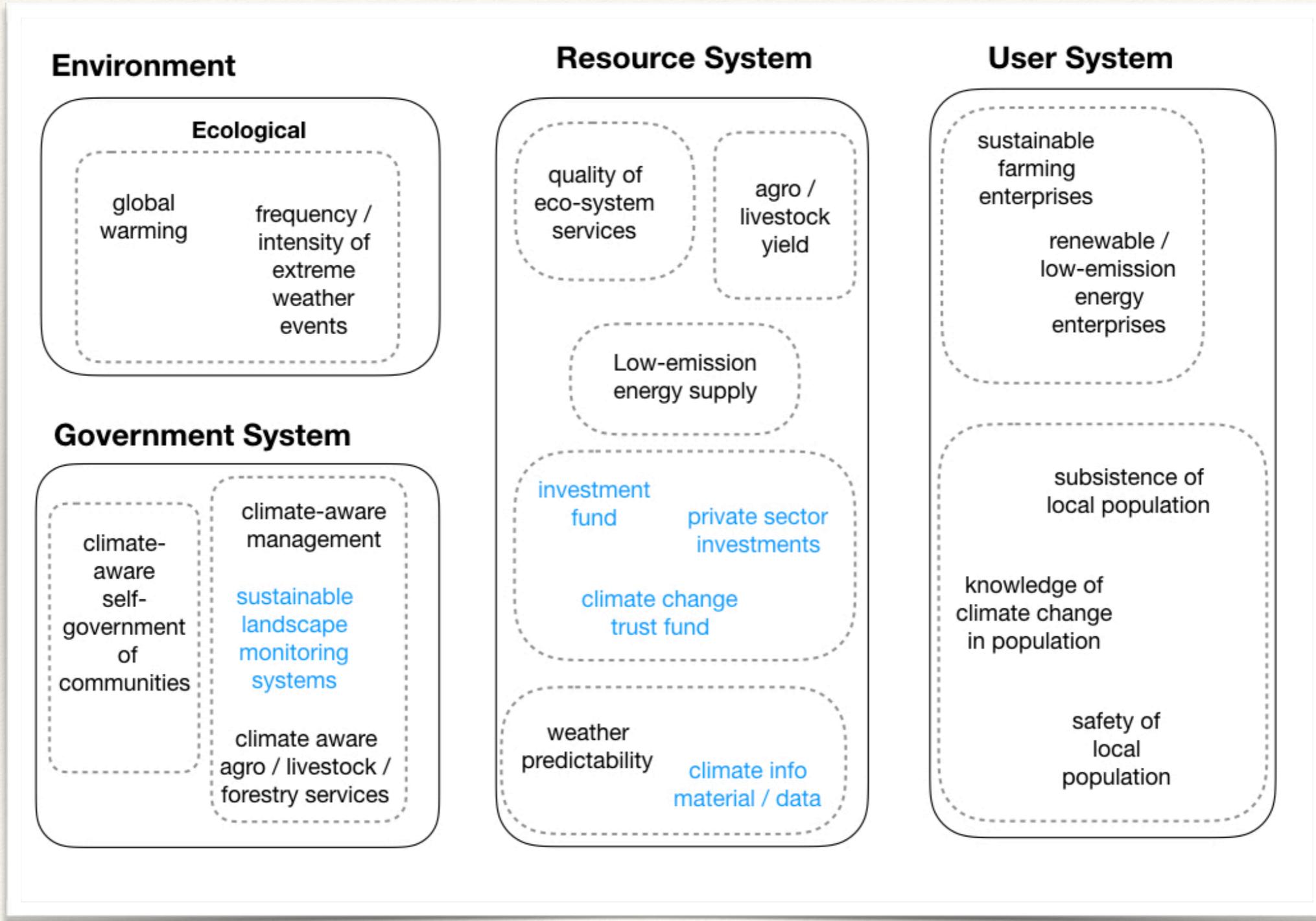
## SEEDS

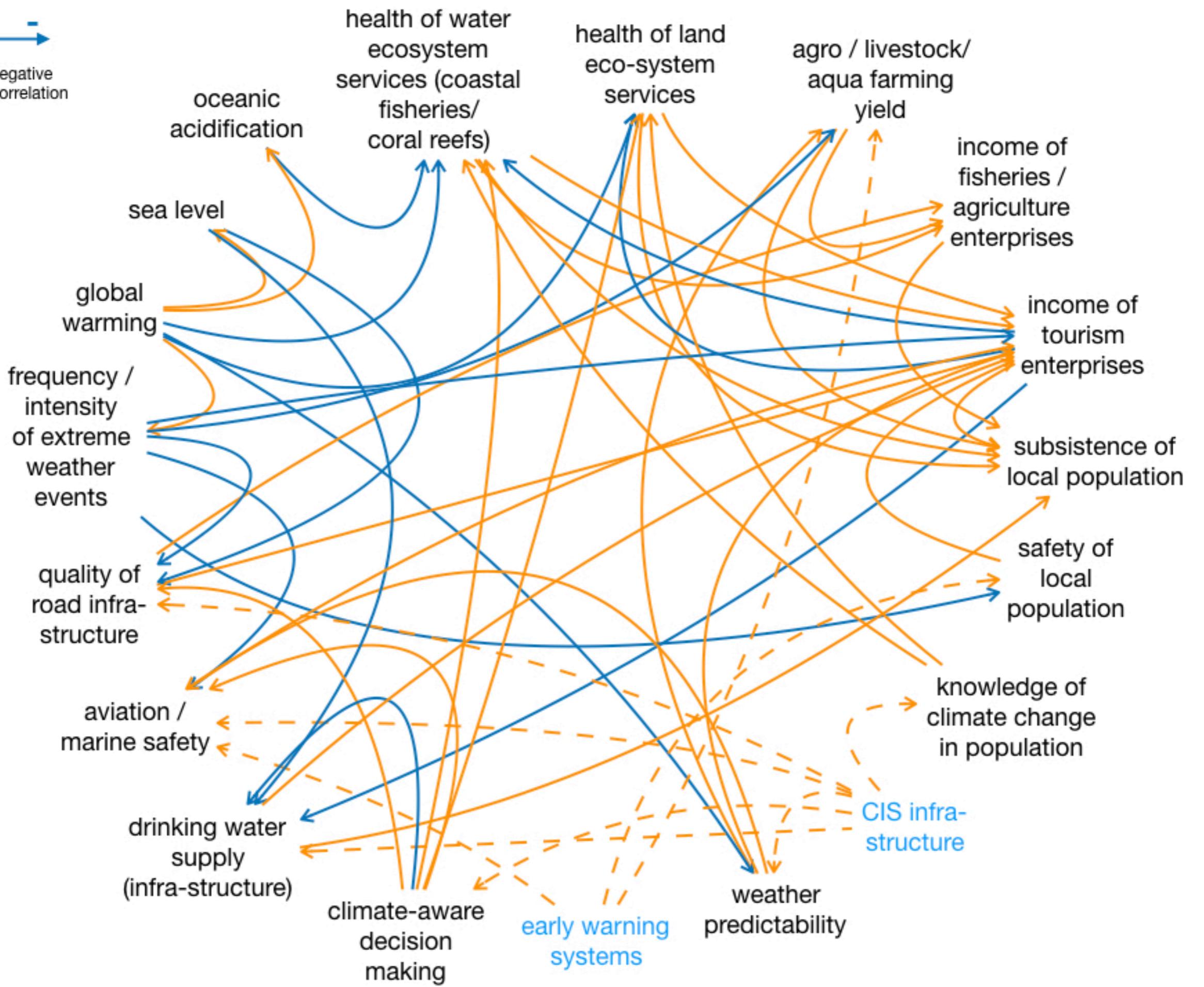
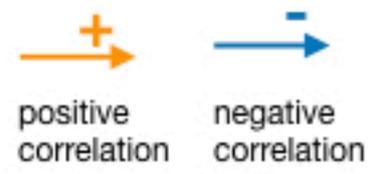
## Correlations between variables



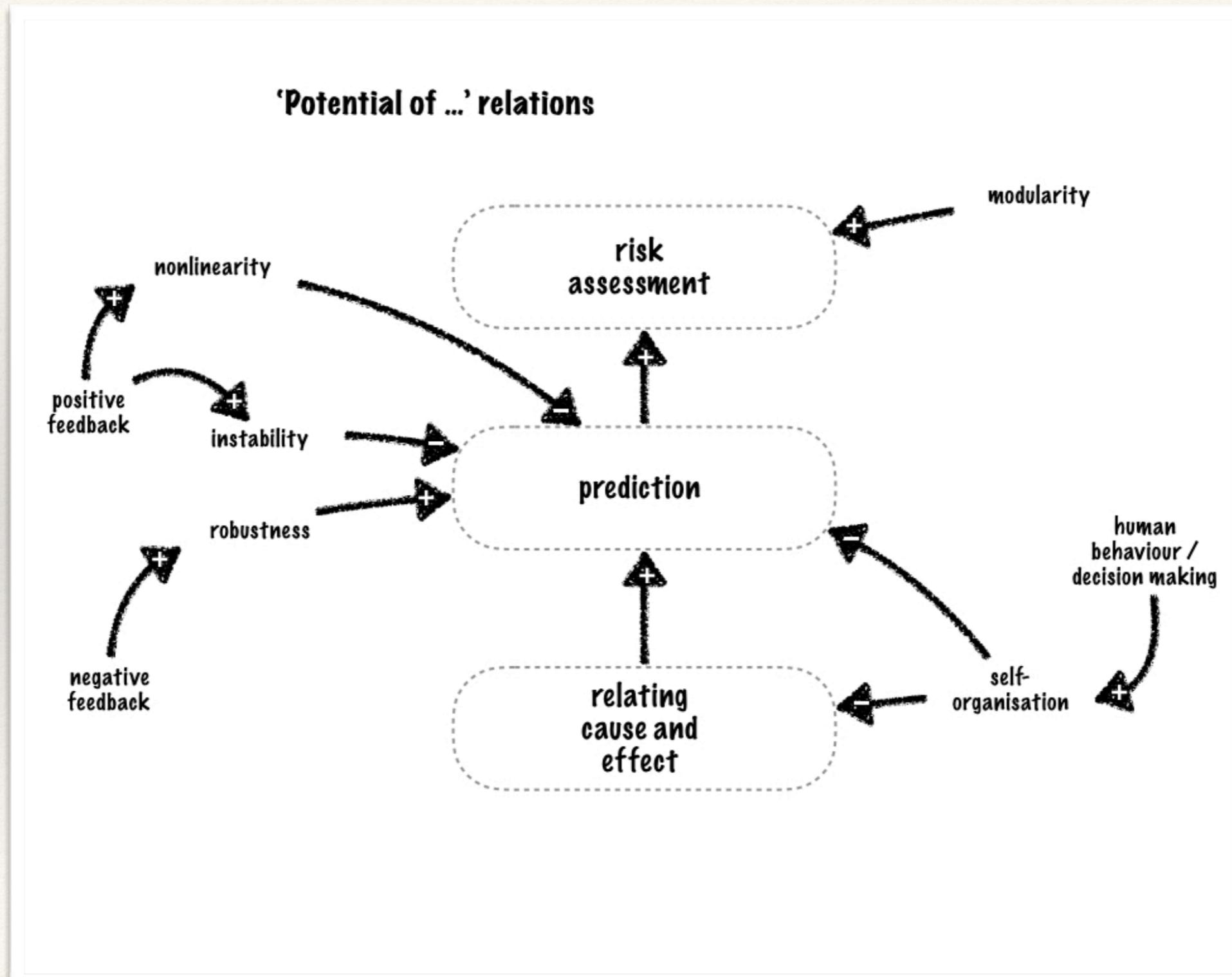
Towards a Complexity Analysis Tool  
for  
Socio-Economic-Ecological Dynamic Systems

# Example: Climate Information Services for Resilient Development in Vanuatu





# Complexity and Evaluation



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# Complexity analysis questions

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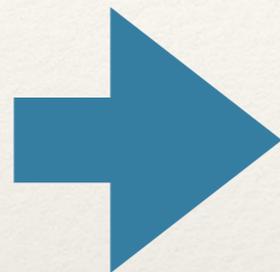
- ❖ Which variables rely on self-organising forces?
- ❖ Which variables represent objectives, and which variables represent facilitators for objectives?
- ❖ Which variables rely on decision making of individuals or groups?
- ❖ Which variables rely on individuals or groups that are not project partners?
- ❖ Which objectives rely on state change due to positive feedback?
- ❖ What is the 'size' of the environment relative to the core systems?
- ❖ What is the number of feedback loops?
- ❖ What are the relative time scales within a feedback loop?
- ❖ ...

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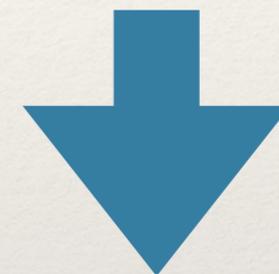
# First draft of a Complexity Analysis Tool for Socio-Economic-Ecological Dynamic Systems

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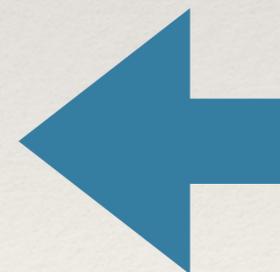
Identify systems, variables, and interactions in SEEDS



Separate system variables from variables introduced by project interventions



Identify feedback loops, modularity, and human behaviour in correlation diagram



Use 'potential of' relations to assess ability to relate cause and effect, predict, assess risk

Funded by



I acknowledge **Dr Jyotsna Puri** and **Andreas Reumann** from the Independent Evaluation Unit of the Green Climate Fund for their valuable input to this project during many discussions.