Global Tipping Points

Report
2023

GSI Seminar

February 7th 2024

David A. McKay, Josh Buxton & Steve Smith

Led by:

University of Exeter | Global Systems Institute

Funded by:

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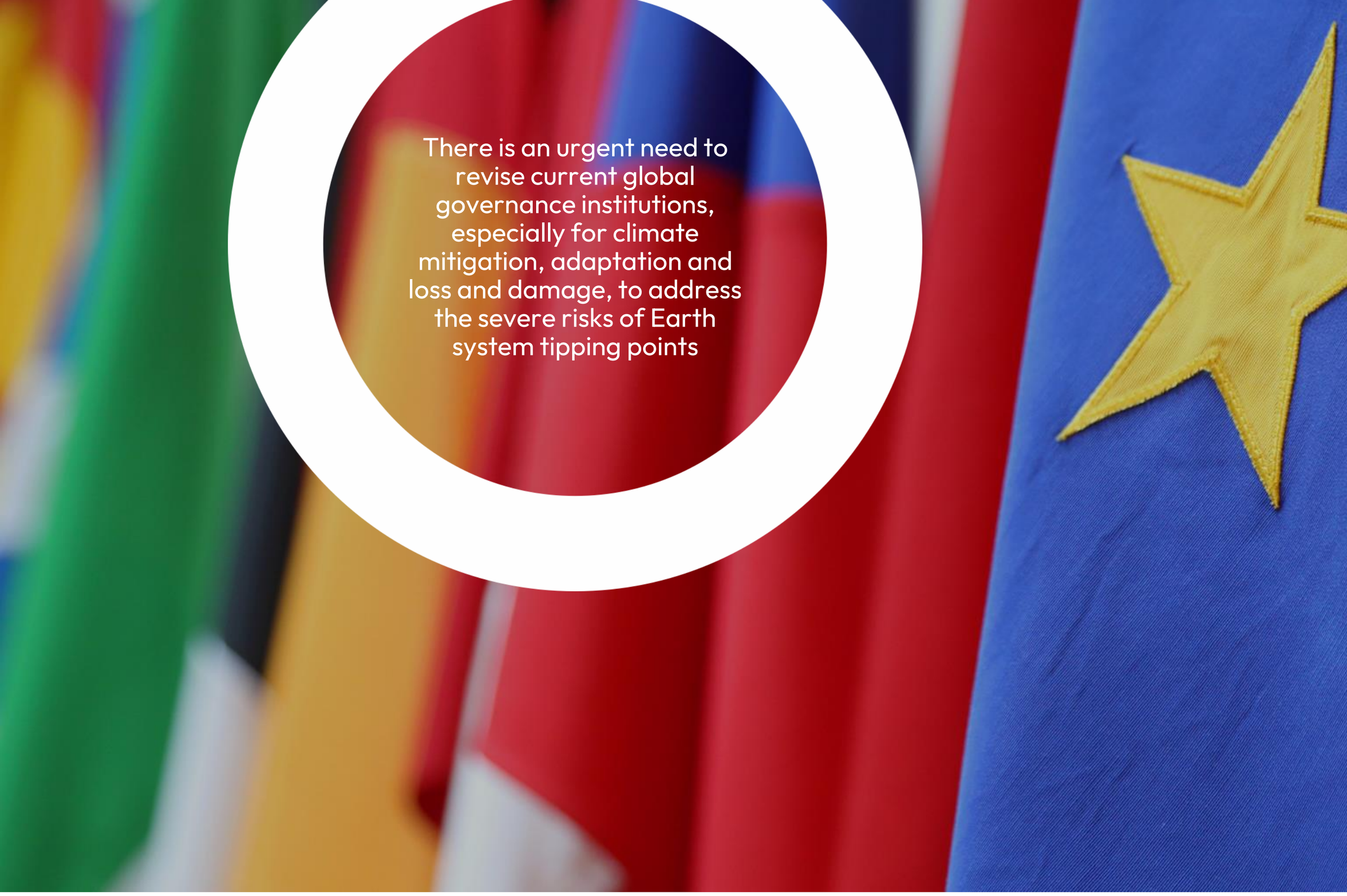
Harmful tipping points in the natural world pose some of the gravest threats faced by humanity. Their triggering will severely damage our planet’s life-support systems and threaten the stability of our societies

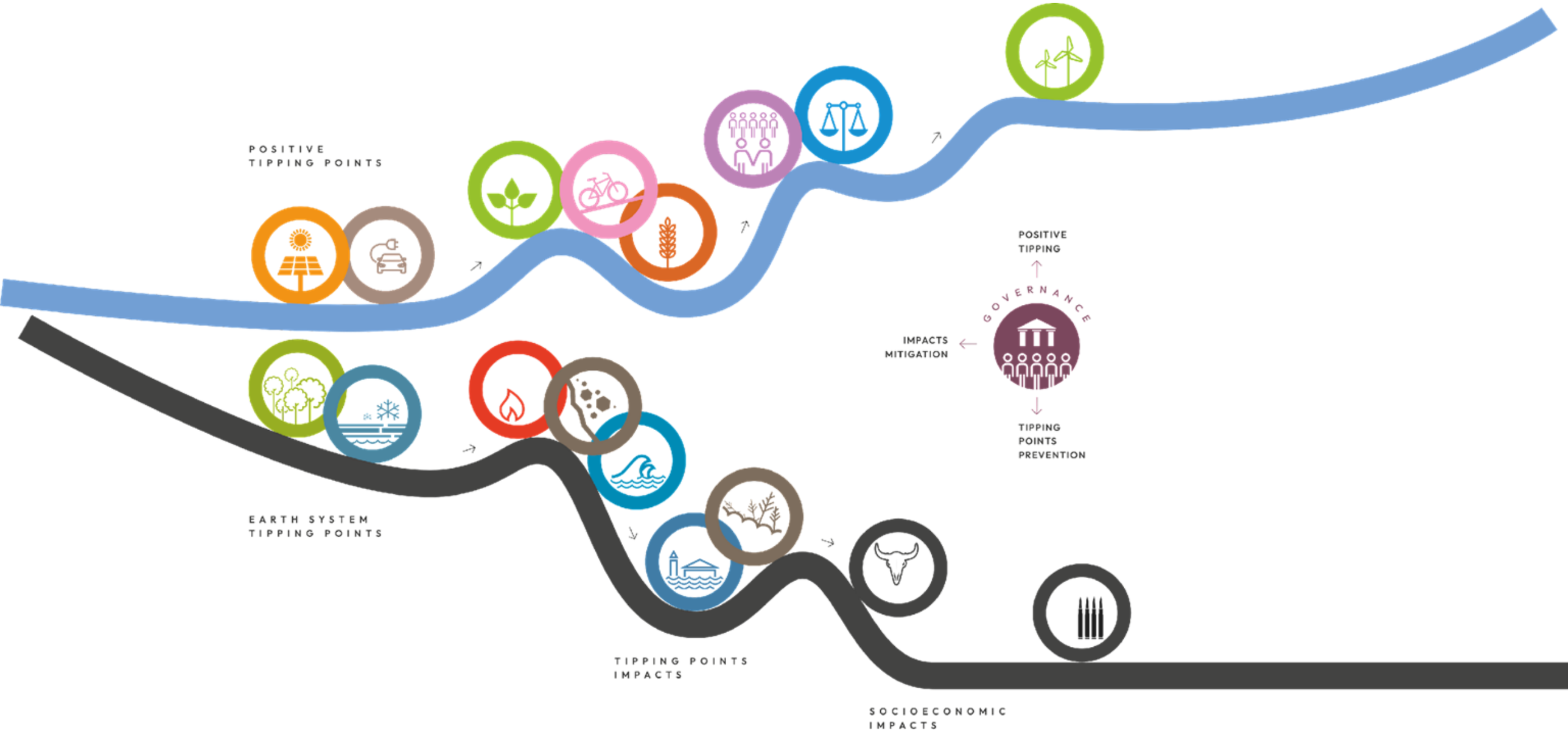

There is an urgent need to revise current global governance institutions, especially for climate mitigation, adaptation and loss and damage, to address the severe risks of Earth system tipping points

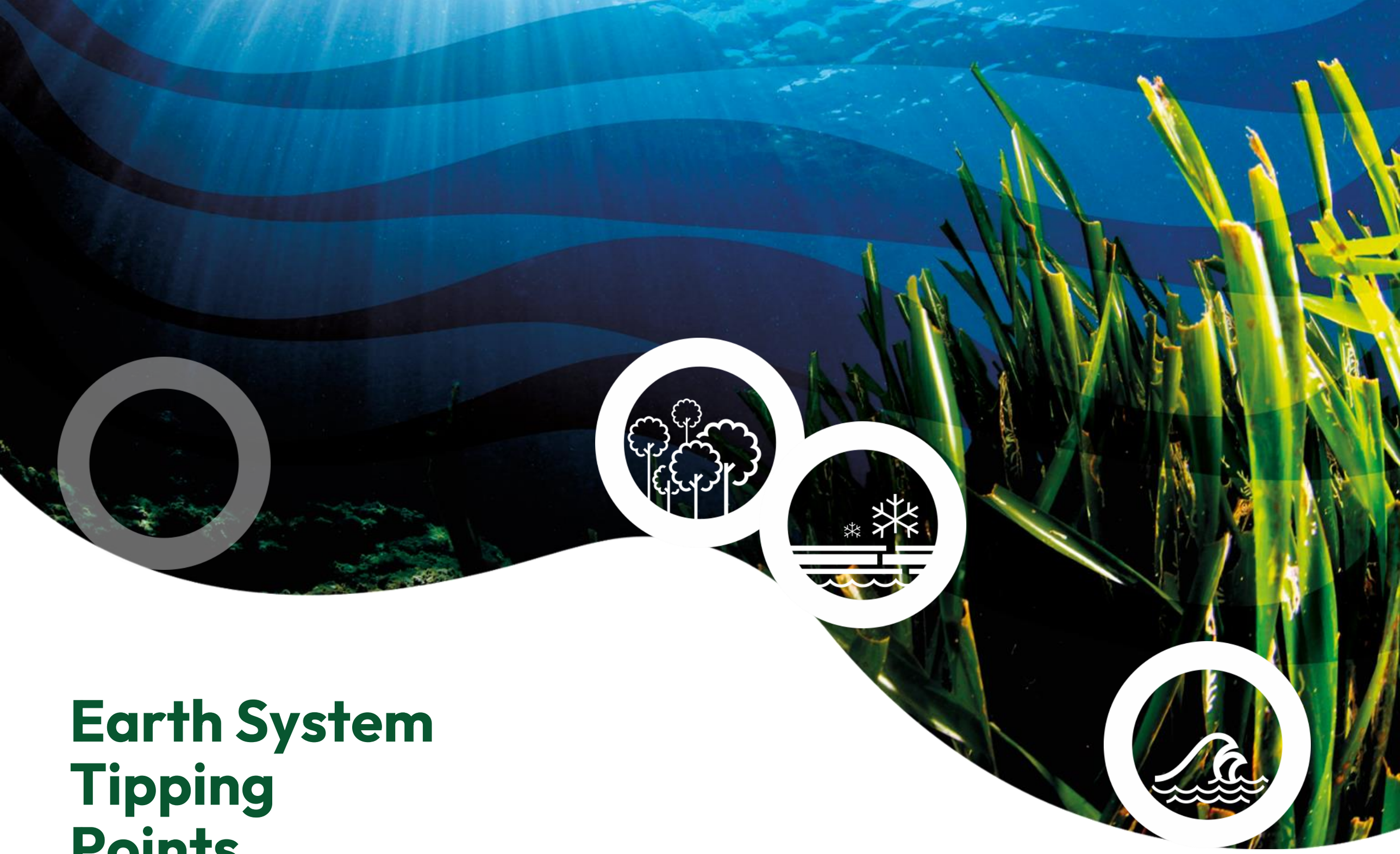
Positive tipping points offer the prospect that coordinated, strategic interventions can lead to disproportionately large and rapid beneficial results that mitigate existential climate risk and help redirect humanity along more sustainable pathways.

Key Recommendations

1. Phase out fossil fuels and land use emissions now
2. Strengthen adaptation and loss-and-damage governance
3. Include tipping points in NDCs and the Global Stocktake
4. Coordinate policy efforts to trigger positive tipping points
5. Convene a global summit on tipping points
6. Deepen knowledge of tipping points and its translation into action

No ‘business as usual’





Earth System Tipping Points

Led by David I. Armstrong McKay & Sina Loriani

Chapter leads: Ricarda Winkelmann, Norman J. Steinert, David I. Armstrong McKay, Boris Sakschewski, Rosa Roman-Cuesta, Sina Loriani, Nico Wunderling, Anna von der Heydt, Chris A. Boulton, Joshua E. Buxton

Report context

Section 1

Earth system tipping points (ESTPs)

1.1 Introduction

1.2 Tipping points in the cryosphere

1.3 Tipping points in the biosphere

1.4 Tipping points in ocean & atmospheric circulations

1.5 Climate tipping points interactions and cascades

1.6 Early warning Signals of ESTPs

1.7 Synthesis

Section 2

Impacts of Earth system tipping points

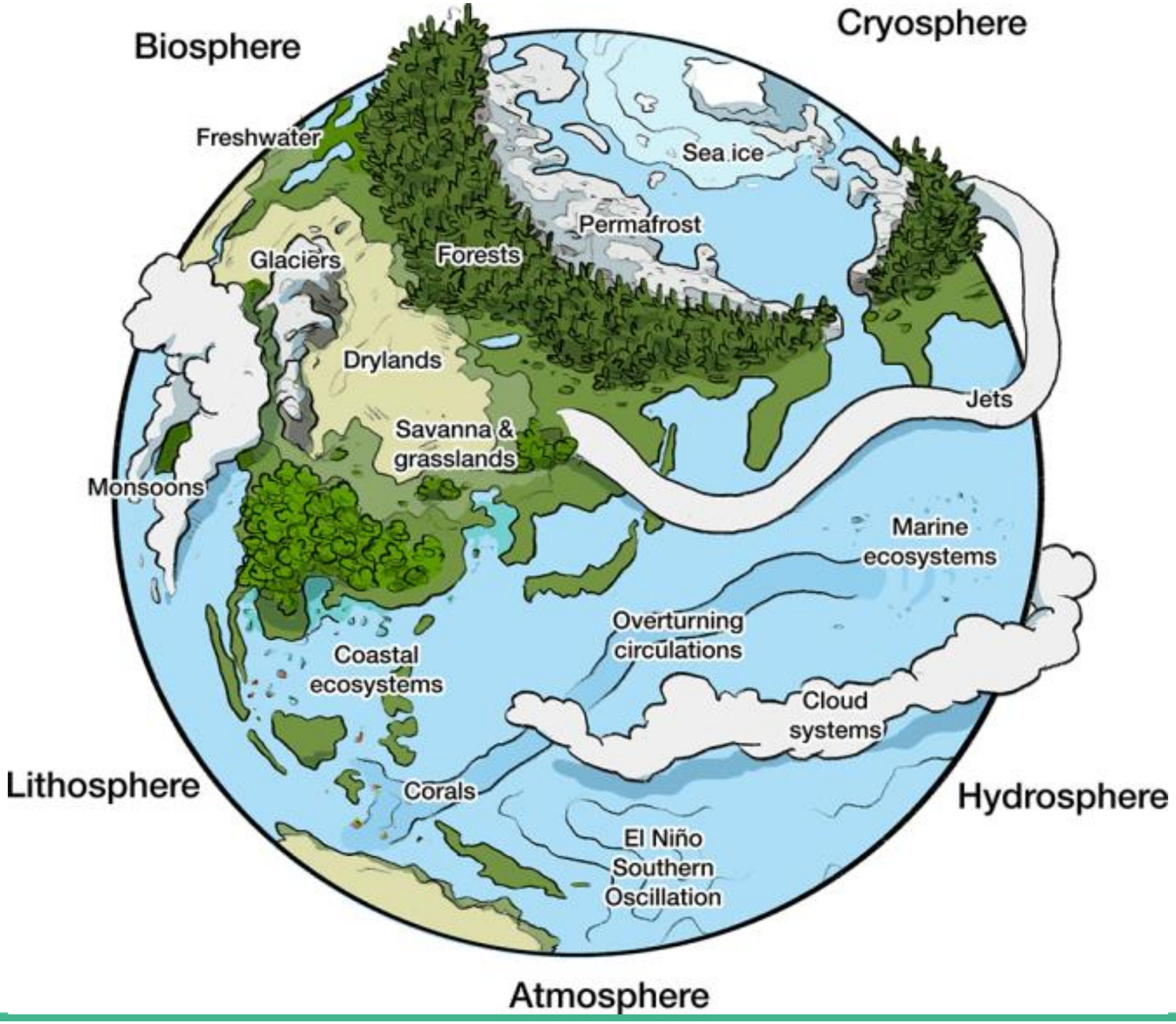
Section 3

Governance of Earth system TPs

Section 4

Positive Tipping Points (PTPs)

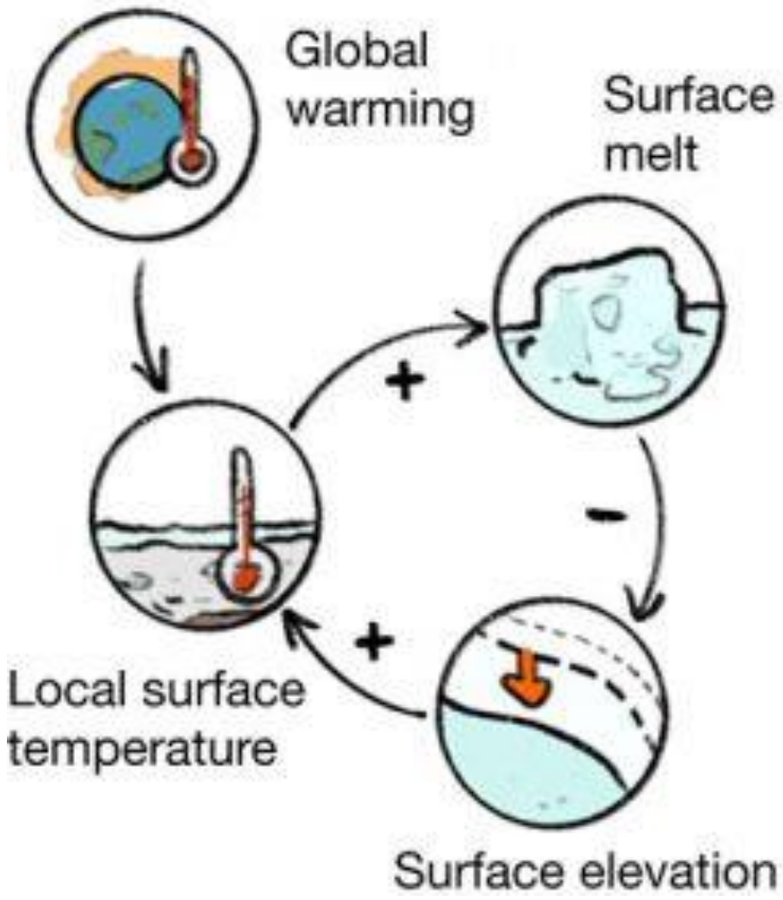
The Earth system is under pressure

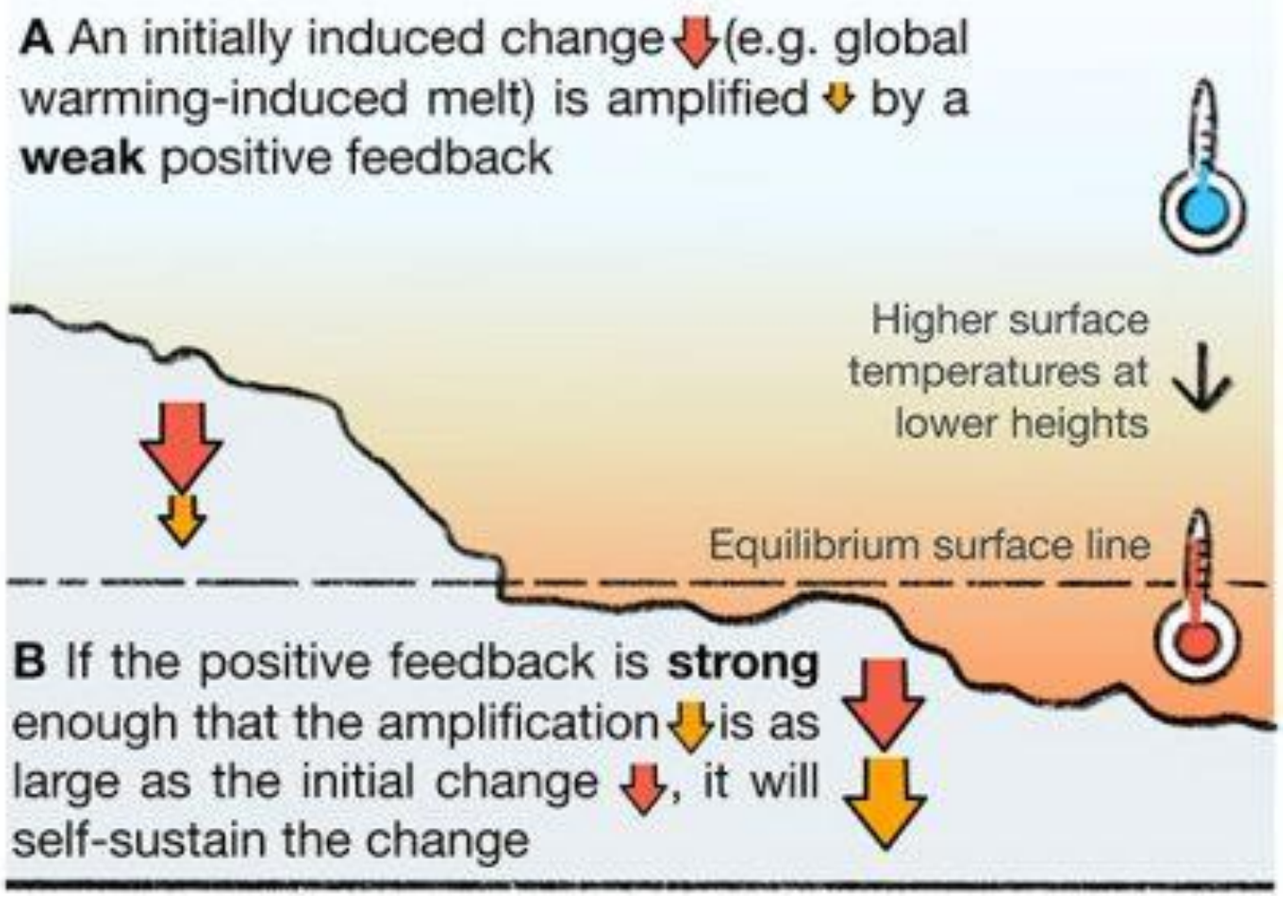


Earth system tipping points are possible

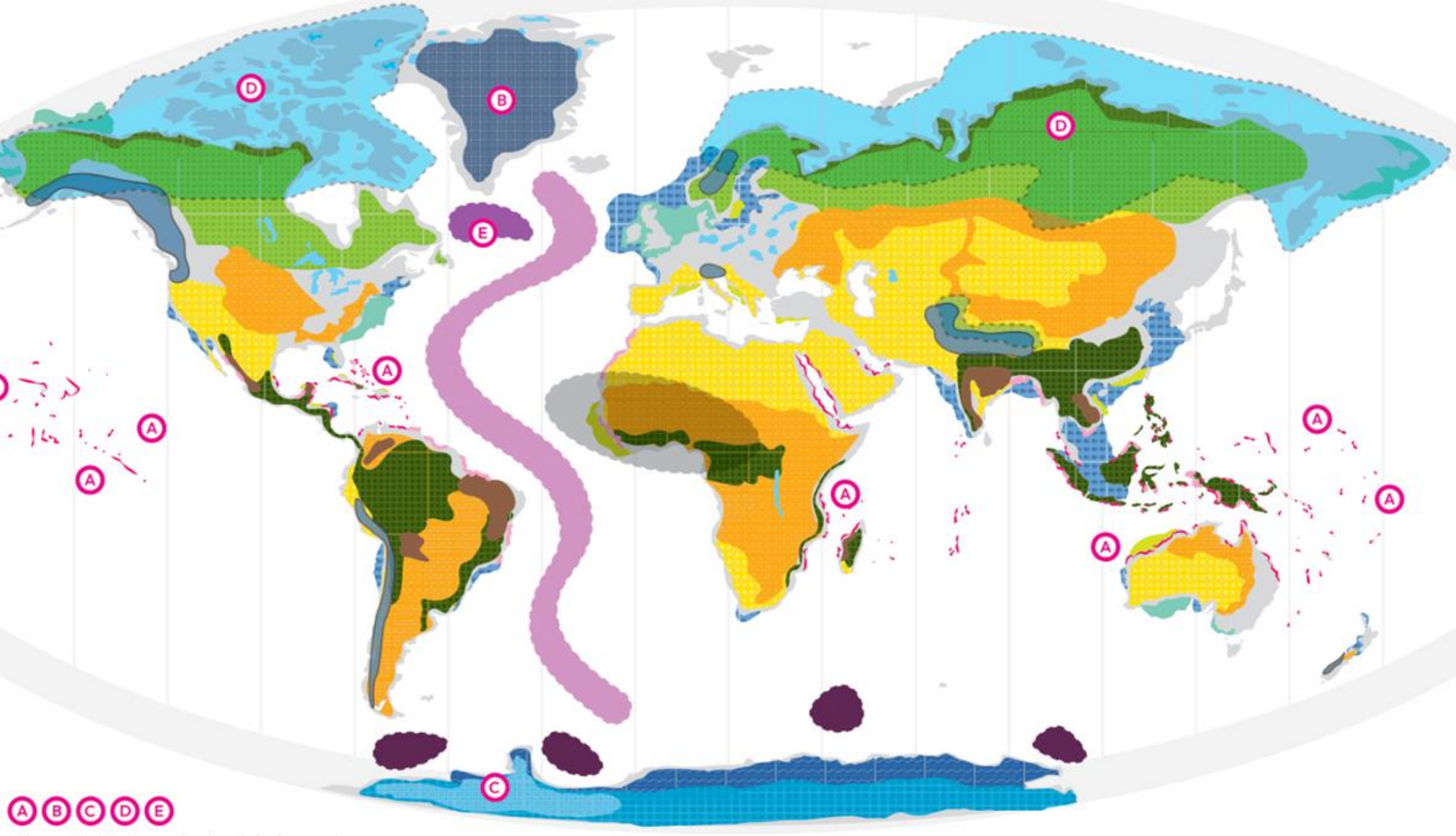
Our Earth system tipping point (ESTP) definition

Tipping points occur when change in a *tipping system* (also known as a *tipping element*) becomes *self-sustaining* once a *forcing threshold* is passed, leading to a qualitative *state change* (e.g. an ecological *regime shift*) driven by one or more *positive/amplifying feedback loops*.

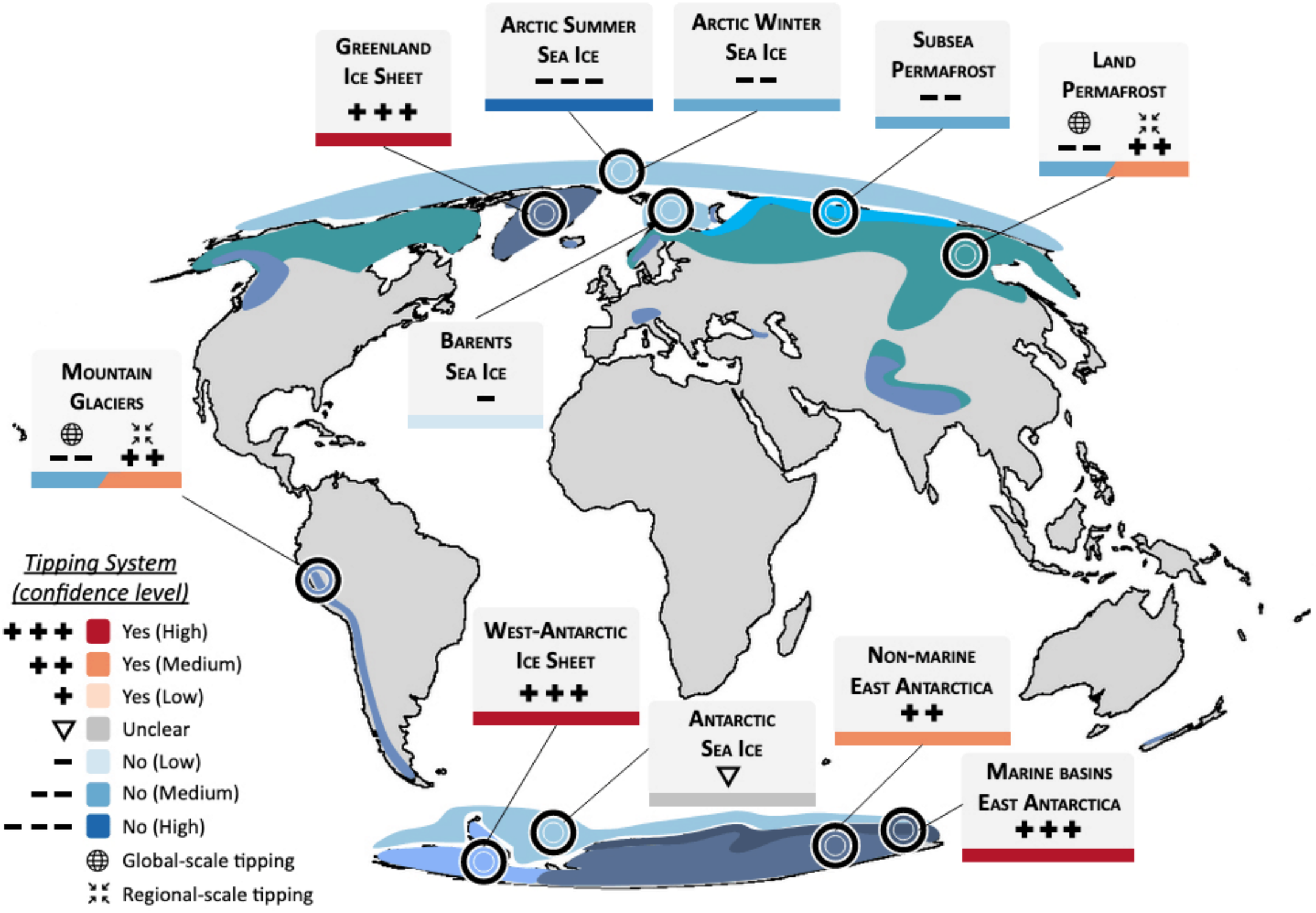




We identify over 25 ESTPs from scientific literature

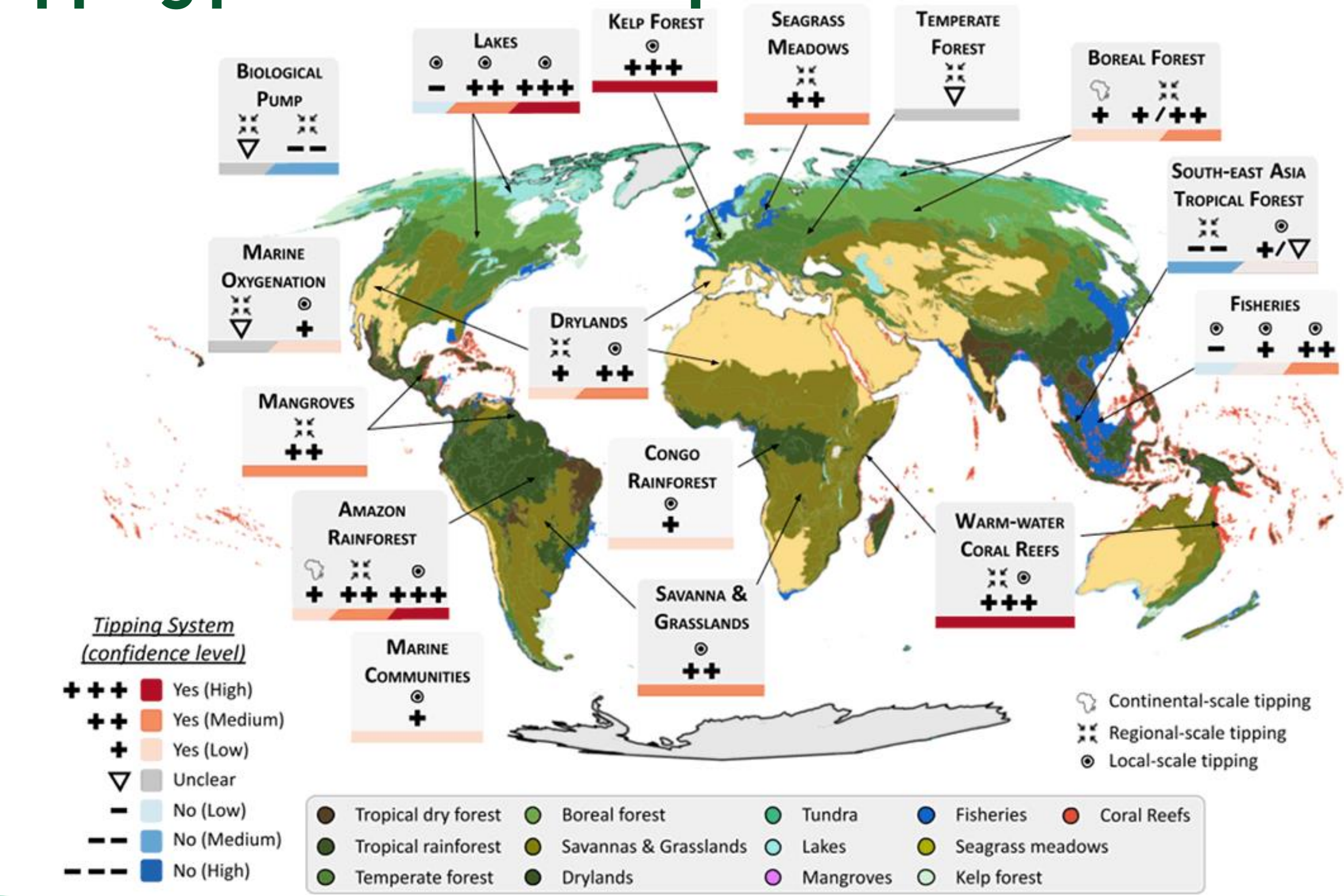


Tipping points in the cryosphere



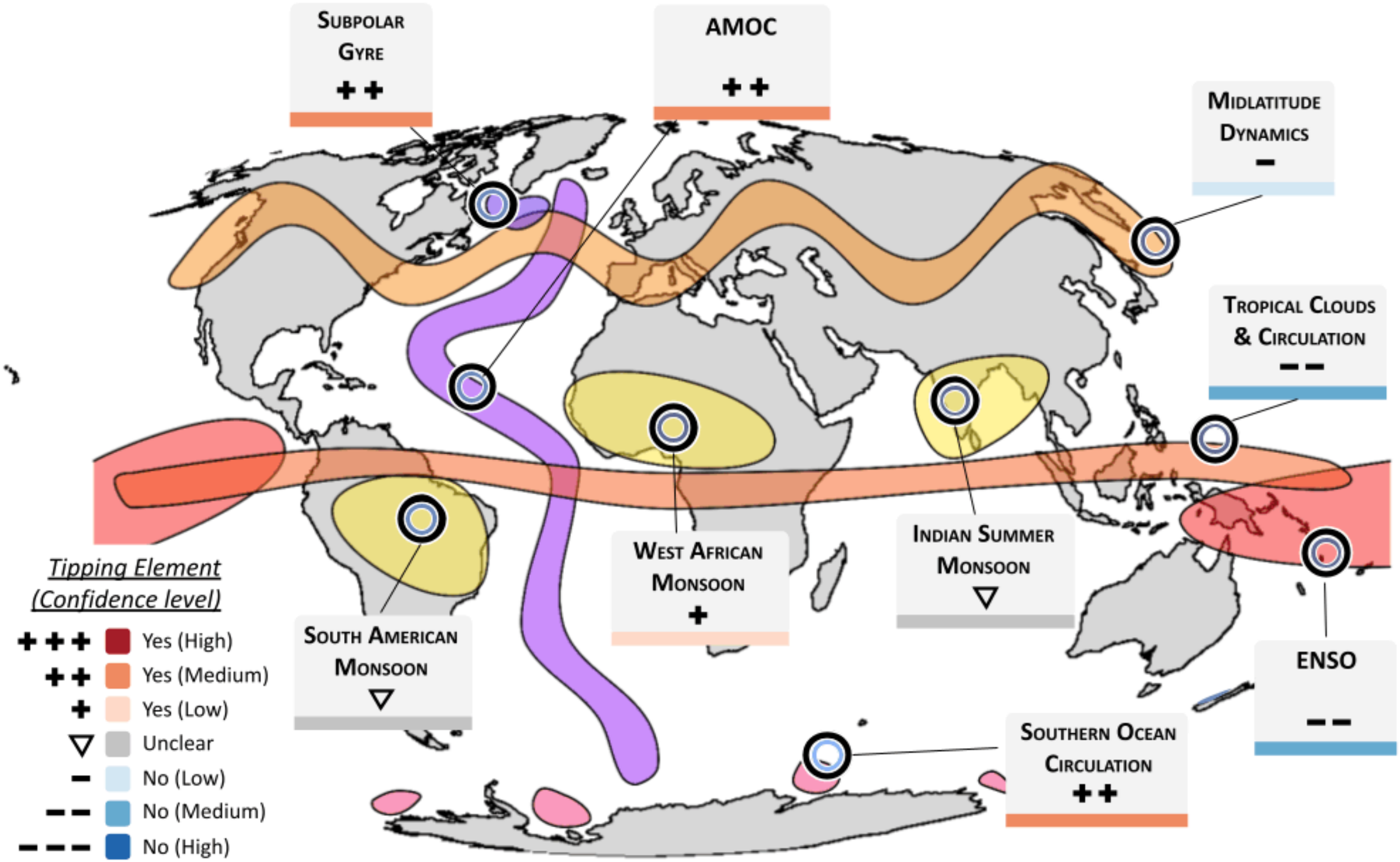
Ricarda Winkelmann, Norman J. Steinert, David I. Armstrong McKay, Victor Brovkin, Andreas Kääb, Dirk Notz, Yevgeny Aksenov, Sandra Arndt, Sebastian Bathiany, Eleanor Burke, Julius Garbe, Ed Gasson, Heiko Goelzer, Gustaf Hugelius, Ann Kristin Klose, Petra Langebroek, Ben Marzeion, Fabien Maussion, Jan Nitzbon, Alex Robinson, Stefanie Rynders, Ivan Sudakow

Tipping points in the biosphere



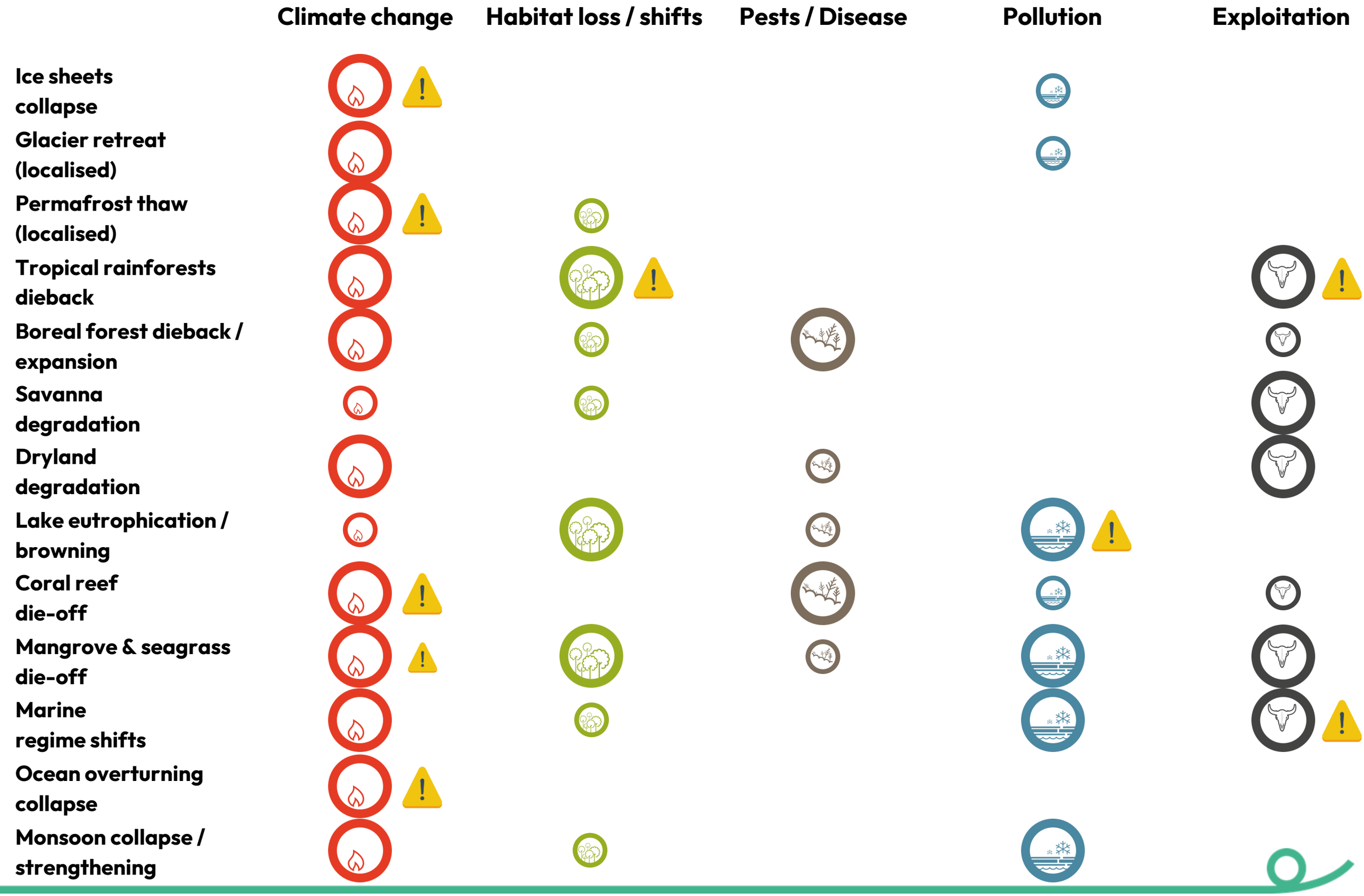
David I. Armstrong McKay, Boris Sakschewski, Rosa M. Roman-Cuesta*, Vasilis Dakos, Bernardo M. Flores, Dag O. Hessen, Marina Hirota, Sonia Kéfi, David Obura, Christopher P.O. Reyer, Carla Staver, Dominik Thom, Beniamino Abis, Cibele Amaral, Tom Andersen, Sebastian Bathiany, Gregory Beaugrand, Thorsten Blenckner, Victor Brovkin, Miguel Berdugo, Manuel Delgado-Baquerizo, Kyle G. Dexter, Markus Drüke, Norman C. Duke, Daniel Friess, Jorge A. Herrera Silveira, Alina Bill-Weilandt, Emilio Guirado, Milena Holmgren, Sarian Kosten, Catherine Lovelock, Angeles G. Mayor, Daniel J. Mayor, Melanie McField, Mariana Meerhoff, Israel Muñiz Castillo, Susa Niiranen, Steve Paton, Paul Pearce-Kelly, Yolanda Pueyo Estaún, Juan Rocha, Giovanni Romagnoni, Jose A. Sanabria-Fernandez, Camilla Sguotti, Bryan M. Spears, Arie Staal, Nicola Stevens, Geraint A. Tarling, Andy Wiltshire

Tipping points in ocean & atmospheric circulations

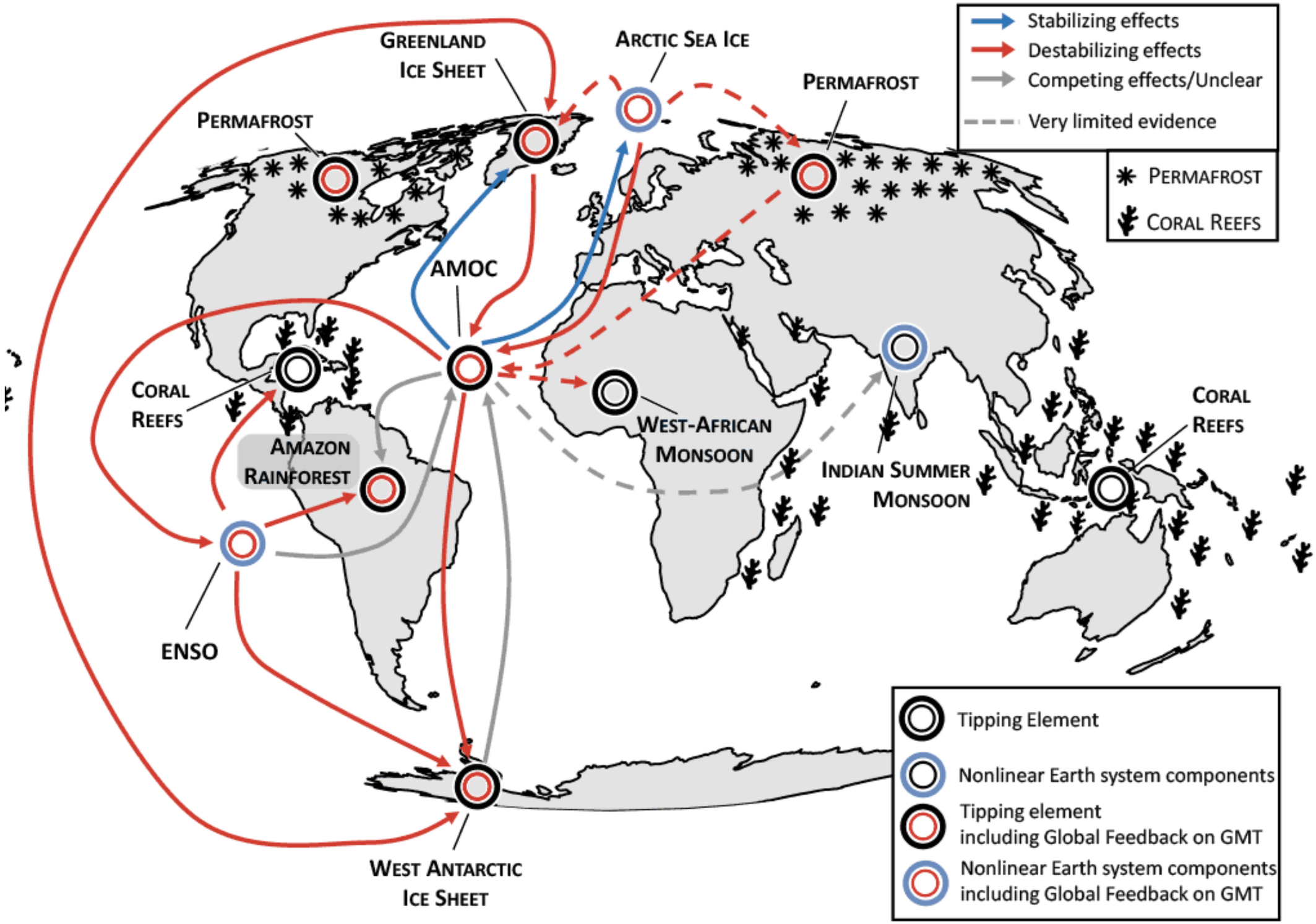


Sina Loriani, Yevgeny Aksenov, Henk Dijkstra, Matt England, Alexey Fedorov, Gabriele Messori, Francesco Pausata, JB Sallée, Bablu Sinha, Steven Sherwood, Thejna Tharammal, David I. Armstrong McKay, Govindasamy Bala, Andreas Born, Sybren Drijfhout, Laura Jackson, Kai Kornhuber, Cristiano M. Chiessi, Stefanie Rynders, Didier Swingedouw

ESTPs are being destabilised, & some may be close

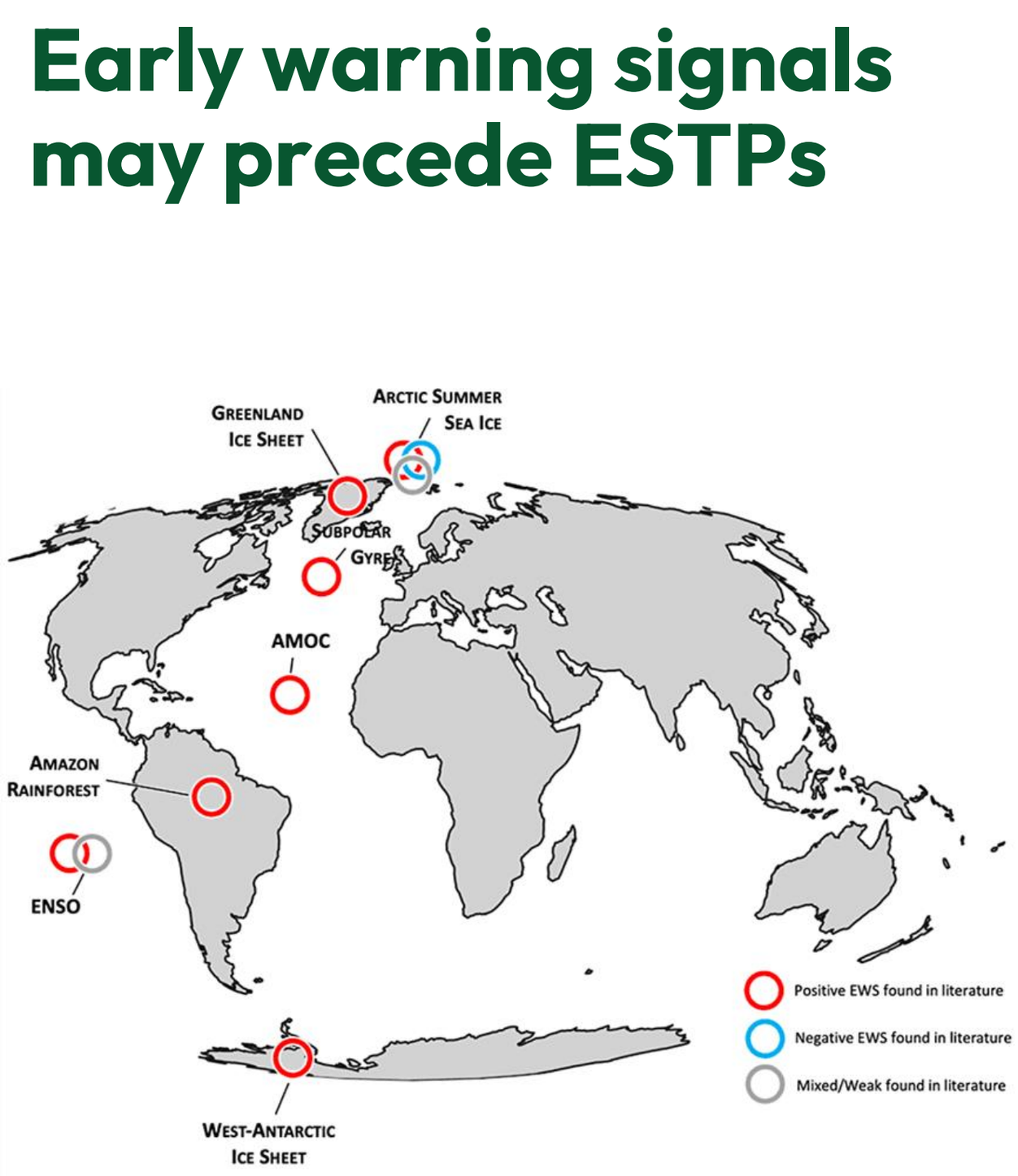


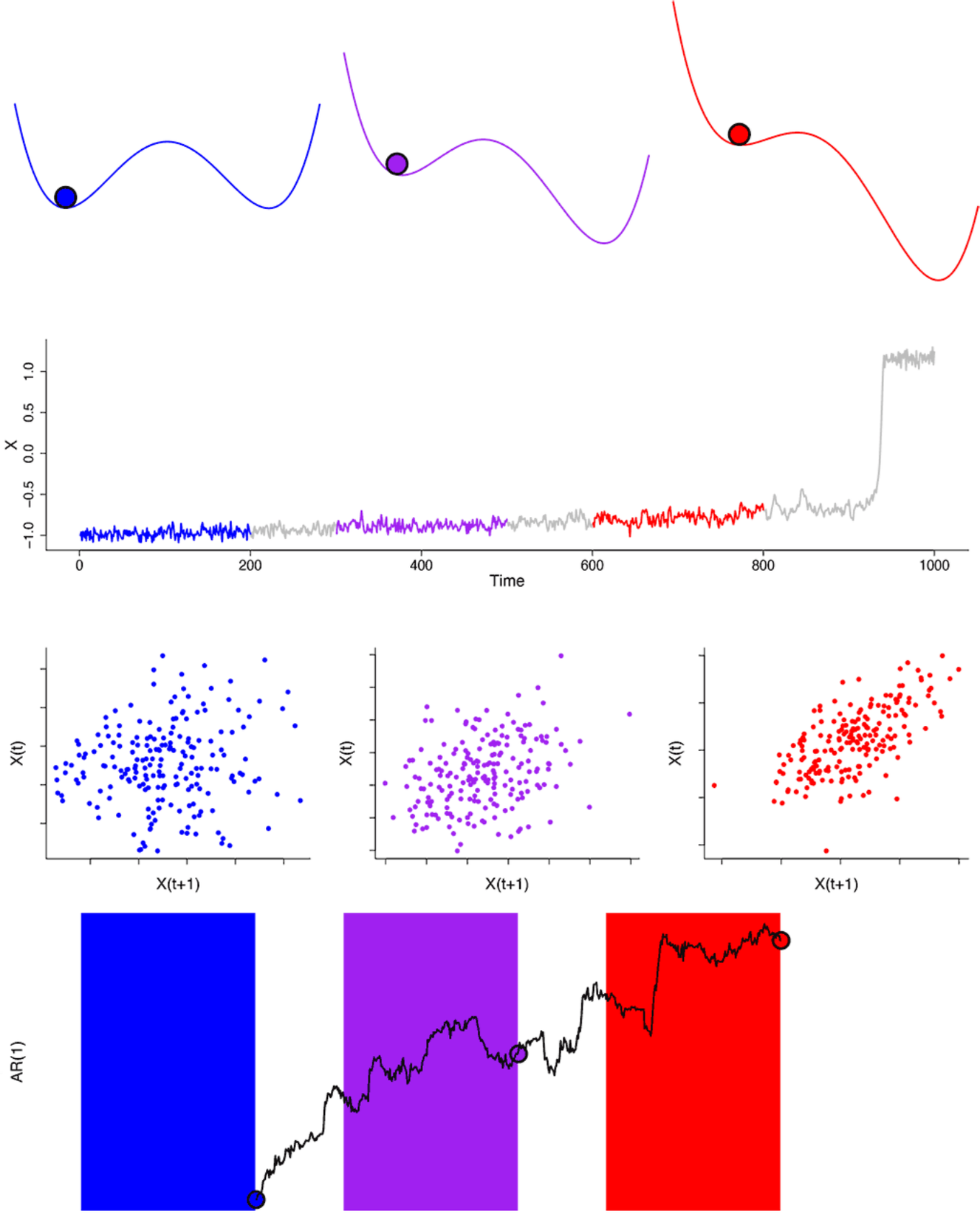
Interactions tend to destabilise ESTPs



Nico Wunderling, Anna von der Heydt, Yevgeny Aksenov, Stephen Barker, Robbin Bastiaansen, Victor Brovkin, Maura Brunetti, Victor Couplet, Thomas Kleinen, Caroline H. Lear, Johannes Lohmann, Rosa M. Roman-Cuesta, Sacha Sinet, Didier Swingedouw, Ricarda Winkelmann, Pallavi Anand, Jonathan Barichivich, Sebastian Bathiany, Mara Baudena, John T. Bruun, Cristiano M. Chiessi, Helen K. Coxall, David Docquier, Jonathan F. Donges, Swinda K. J. Falkena, Ann Kristin Klose, David Obura, Juan Rocha, Stefanie Rynders, Norman J. Steinert, Matteo Willeit

Early warning signals may precede ESTPs





Chris A. Boulton, Joshua E. Buxton, Beatriz Arellano-Nava, Sebastian Battiany, Lana Blaschke, Niklas Boers, Vasilis Dakos, Daniel Dylewsky, Sonia Kefi, Carlos Lopez-Martinez, Isobel Parry, Paul Ritchie, Bregje van der Bolt, Larissa van der Laan, Els Weinans

S1 Recommendations

- **Prevent destabilisation of the Earth's tipping systems** through urgent and ambitious elimination of greenhouse gas emissions and reduction of other pressures such as deforestation, black carbon emissions and nutrient pollution
- **Reduce deep uncertainties,** for example related to key processes and feedbacks like marine ice cliff instabilities, ecosystem responses to increasing extreme events and fine-scale ocean mixing, through further co-designed research and model intercomparison
- **Improve risk assessments of potential tipping cascades** through improved models, model intercomparison, palaeoclimate research, and expert elicitation
- **Support development of novel and improved early warning techniques** (e.g. machine learning) to detect declining resilience and other potential signs of tipping. Expand remote sensing capabilities and palaeorecords, foster international data sharing and collaboration, and improve observational coverage in Africa and Asia

Tipping Point impacts

Led by Jesse F. Abrams, Steven J. Lade, Jonathan F. Donges, Joshua E. Buxton

Chapter leads: Richard Betts, Viktoria Spaiser, Sirkku Juhola, Jana Sillmann, Juan Rocha, Krishna Krishnamurthy

Report context

Section 1 — Earth system tipping points

Section 2 — Impacts of tipping points on people

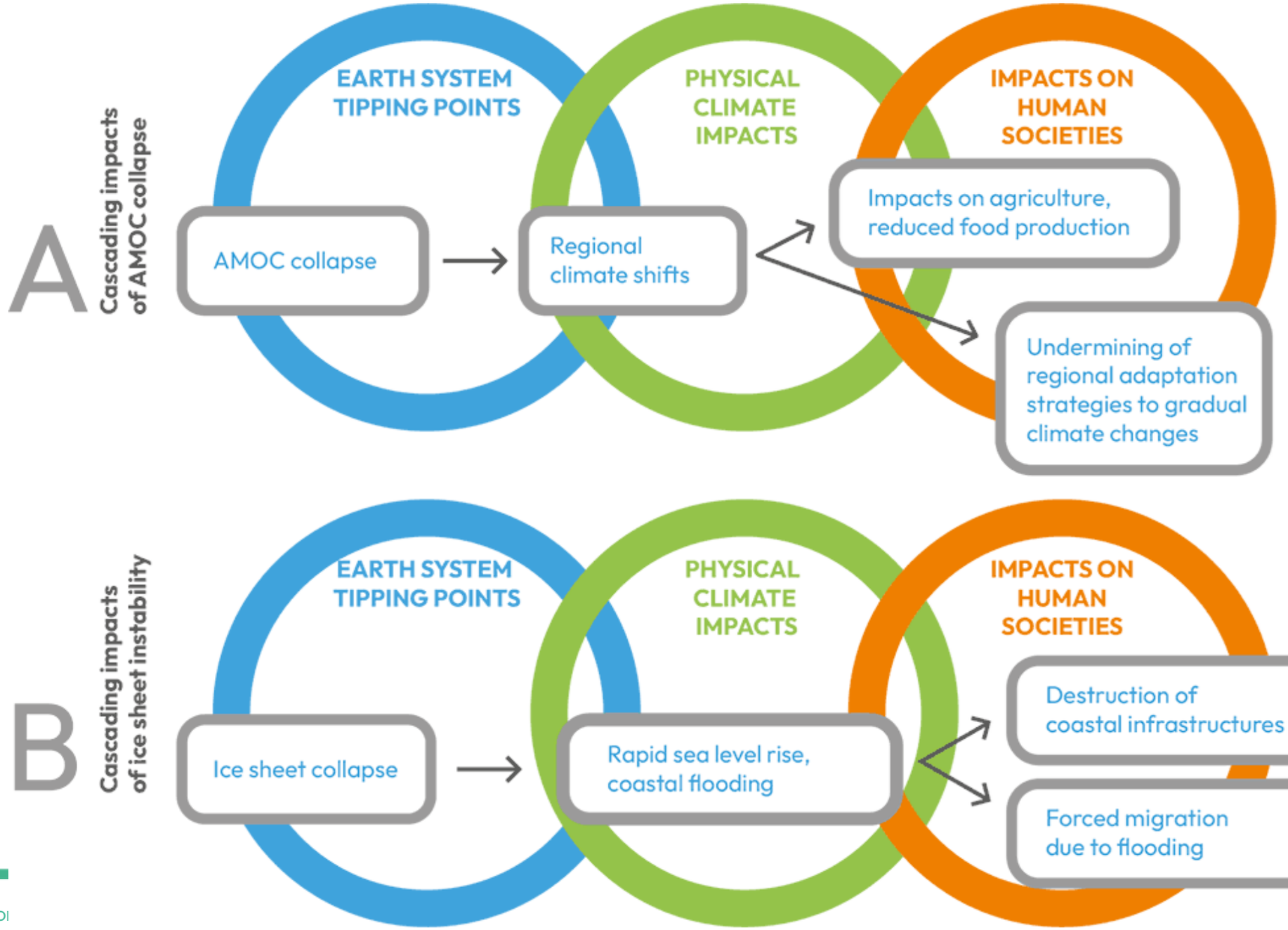
- 2.1 Introduction
- 2.2 Impacts on people of Earth system tipping points
- 2.3 Negative social tipping points
- 2.4 Cascades of tipping in impacts
- 2.5 Early warning signals

Section 3 — Governance

Section 4 — Positive tipping points

2.2 Impacts of ESTPs on people

- Little systematic assessment of tipping point impacts
- *Additional* to impacts without tipping
- Earth system tipping points can accelerate climate change



2.2 Tipping points and impact sectors

Earth system tipping points

- AMOC collapse
- Ice sheet collapse
- Amazon dieback
- Permafrost thawing
- Arctic sea ice loss

Impact sectors

- Water security
- Food security
- Energy security
- Health
- Biodiversity and ecosystem services
- Communities and economies

2.2 Amazon dieback

Earth system tipping points

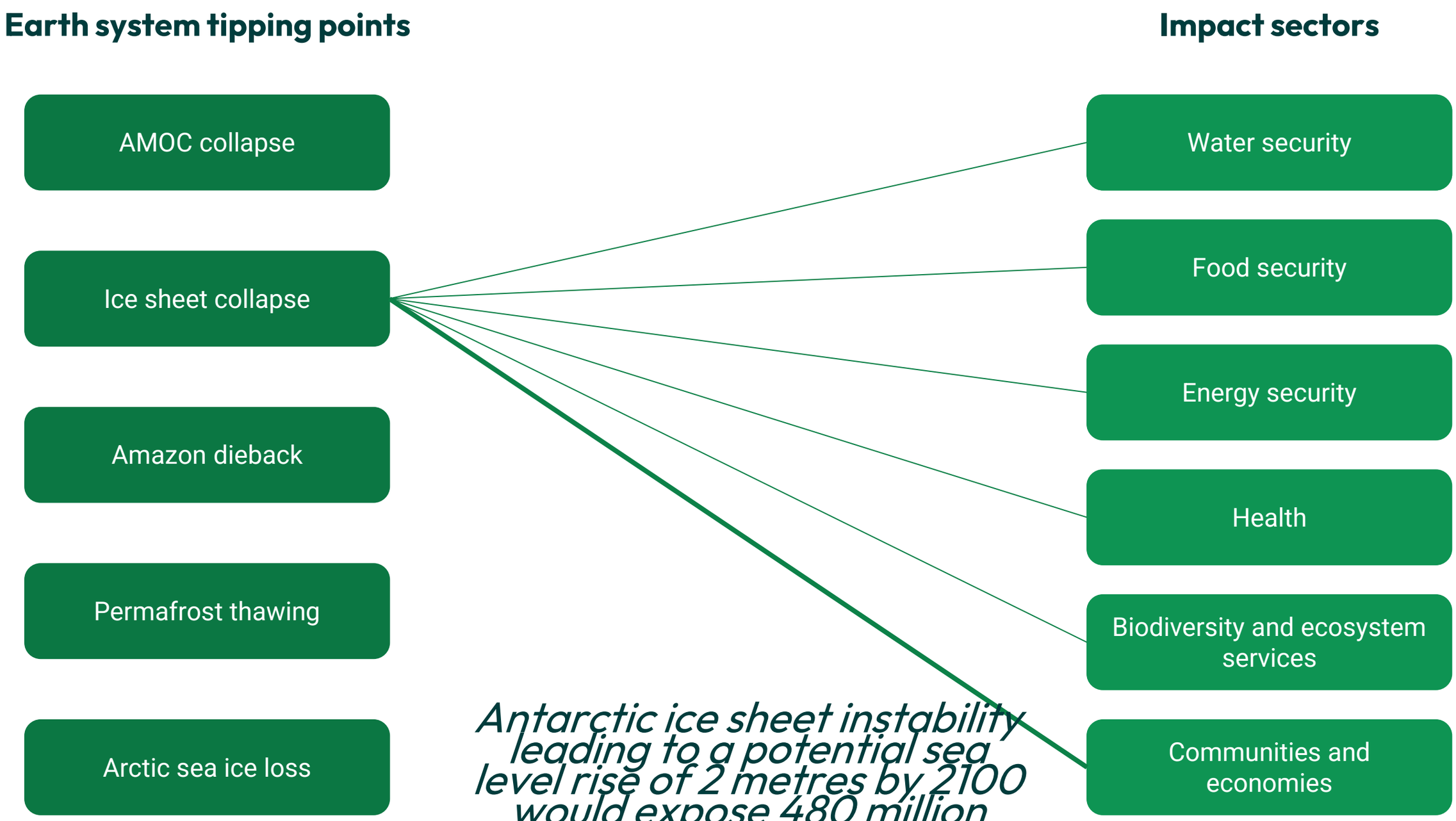
- AMOC collapse
- Ice sheet collapse
- Amazon dieback
- Permafrost thawing
- Arctic sea ice loss

Amazon dieback could put 6 million people at risk of extreme heat stress and cause US$1-3.5 trillion economic damages.

Impact sectors

- Water security
- Food security
- Energy security
- Health
- Biodiversity and ecosystem services
- Communities and economies

2.2 Antarctic ice sheet



Antarctic ice sheet instability leading to a potential sea level rise of 2 metres by 2100 would expose 480 million people to annual coastal flooding events.

2.2 Permafrost thaw

Earth system tipping points

- AMOC collapse
- Ice sheet collapse
- Amazon dieback
- Permafrost thawing
- Arctic sea ice loss

70% of current infrastructure in permafrost regions is in areas with high potential for thaw by 2050.

Impact sectors

- Water security
- Food security
- Energy security
- Health
- Biodiversity and ecosystem services
- Communities and economies

2.2 AMOC collapse

Earth system tipping points

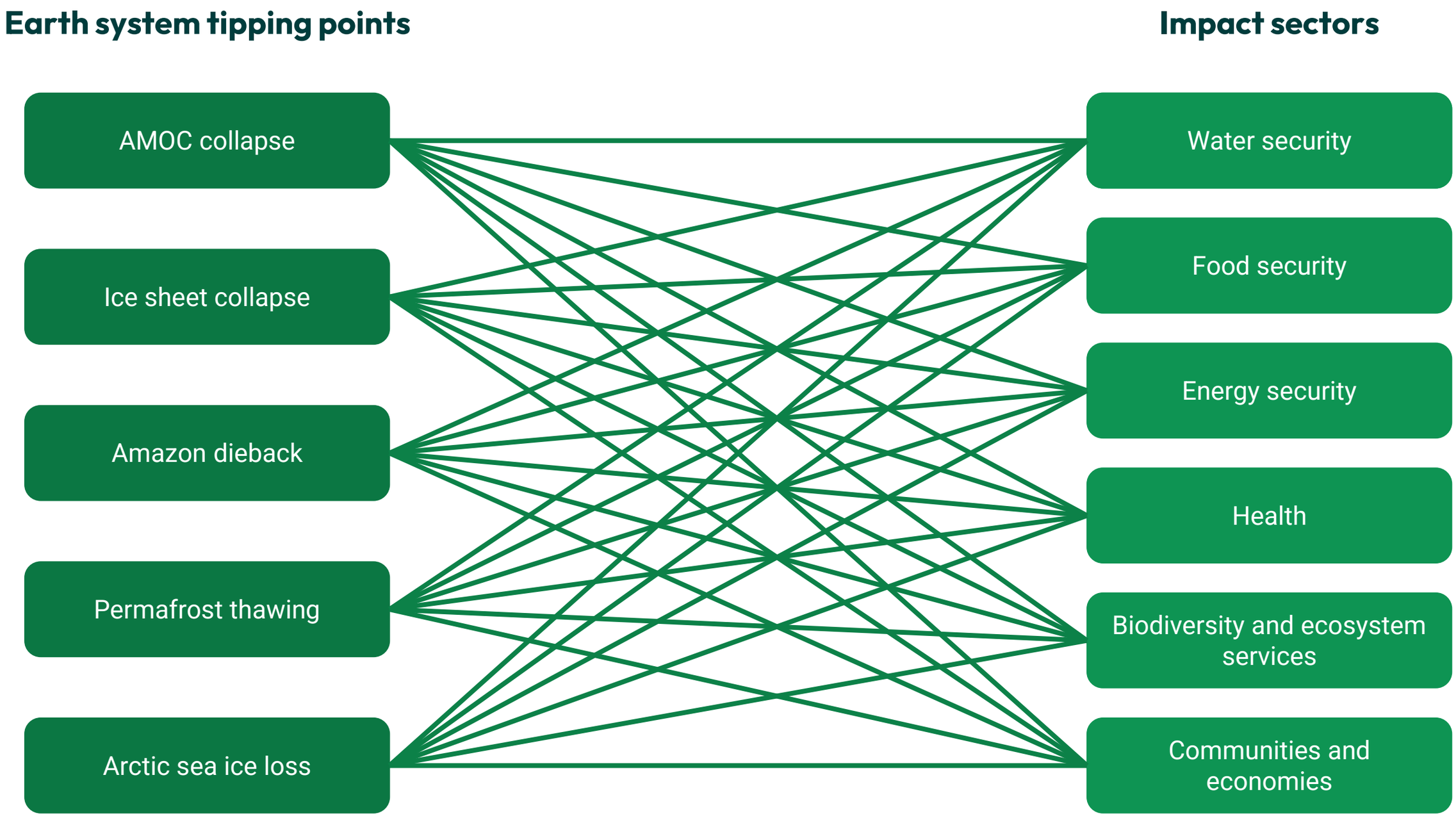
- AMOC collapse
- Ice sheet collapse
- Amazon dieback
- Permafrost thawing
- Arctic sea ice loss

An AMOC collapse would disrupt regional climates worldwide, substantially reducing vegetation and crop productivity across large areas of the world, with profound implications for food security.

Impact sectors

- Water security
- Food security
- Energy security
- Health
- Biodiversity and ecosystem services
- Communities and economies

Earth system tipping points have the potential for severe impacts on people and biodiversity.



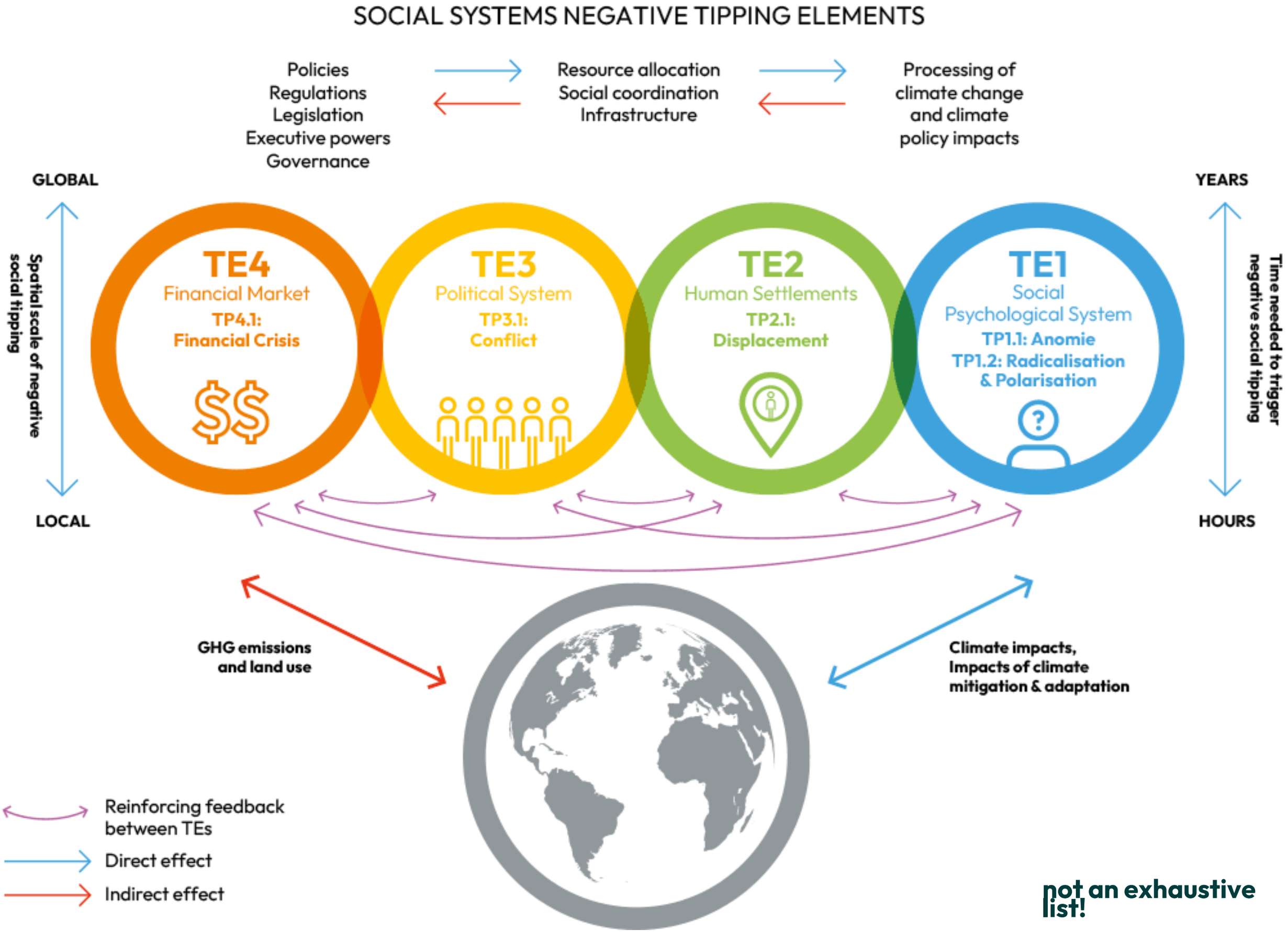
2.3 Negative social tipping points

Negative tipping points are social tipping points that are *predominantly harmful for humans and the natural systems we depend upon.*

- ‘Negative’ in the value-based sense (not mathematical)

- Caused by Earth system tipping point impacts or by non-tipping climate change

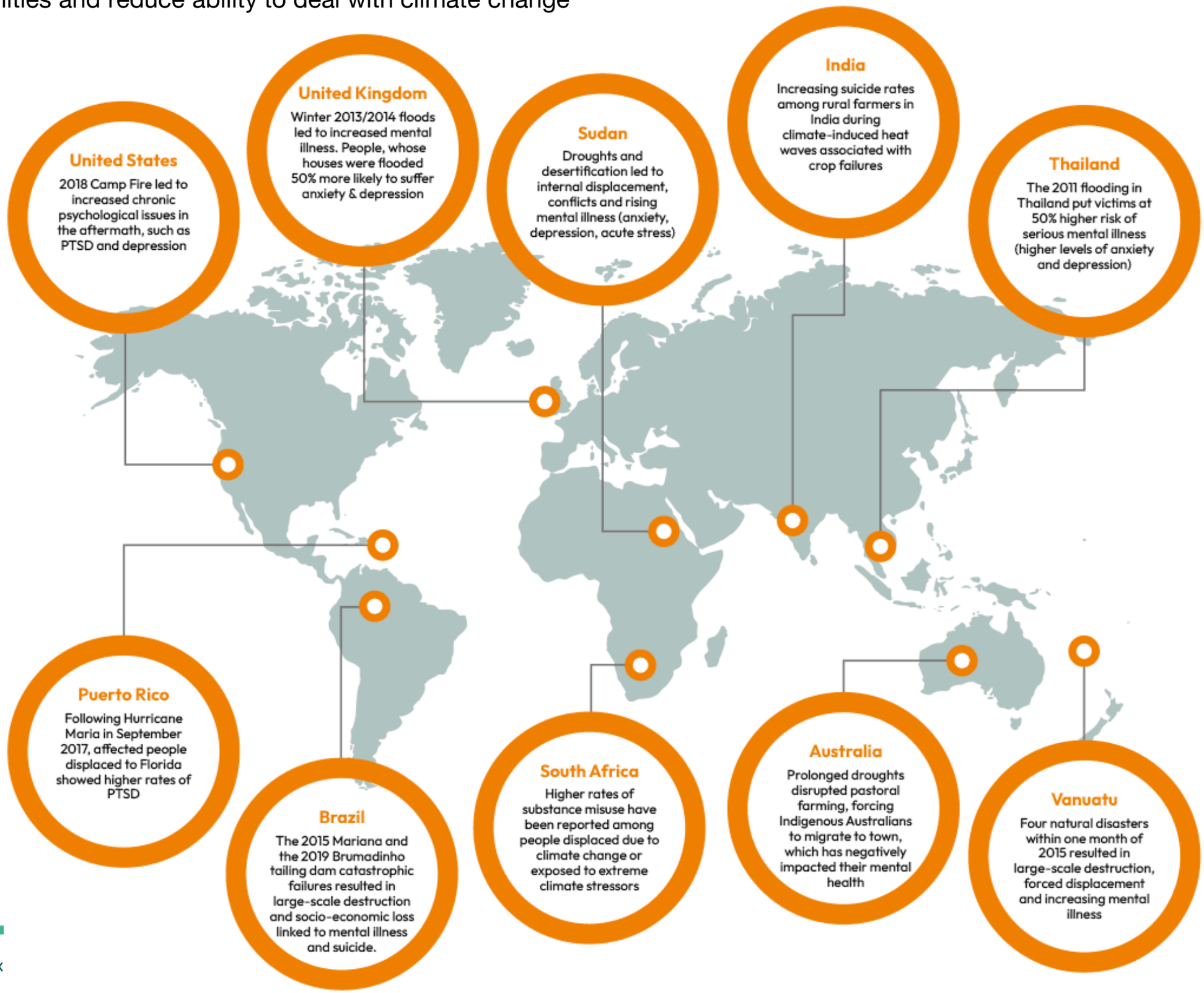
2.3 Negative social tipping points



2.3 Examples of anomie

Anomie: breakdown of social norms, social ties and social reality resulting in social disorder and deteriorating mental health

Numerous examples of anomie following environmental events - possible that this may become more widespread, abruptly effect communities and reduce ability to deal with climate change



2.4 Cascades of tipping in impacts

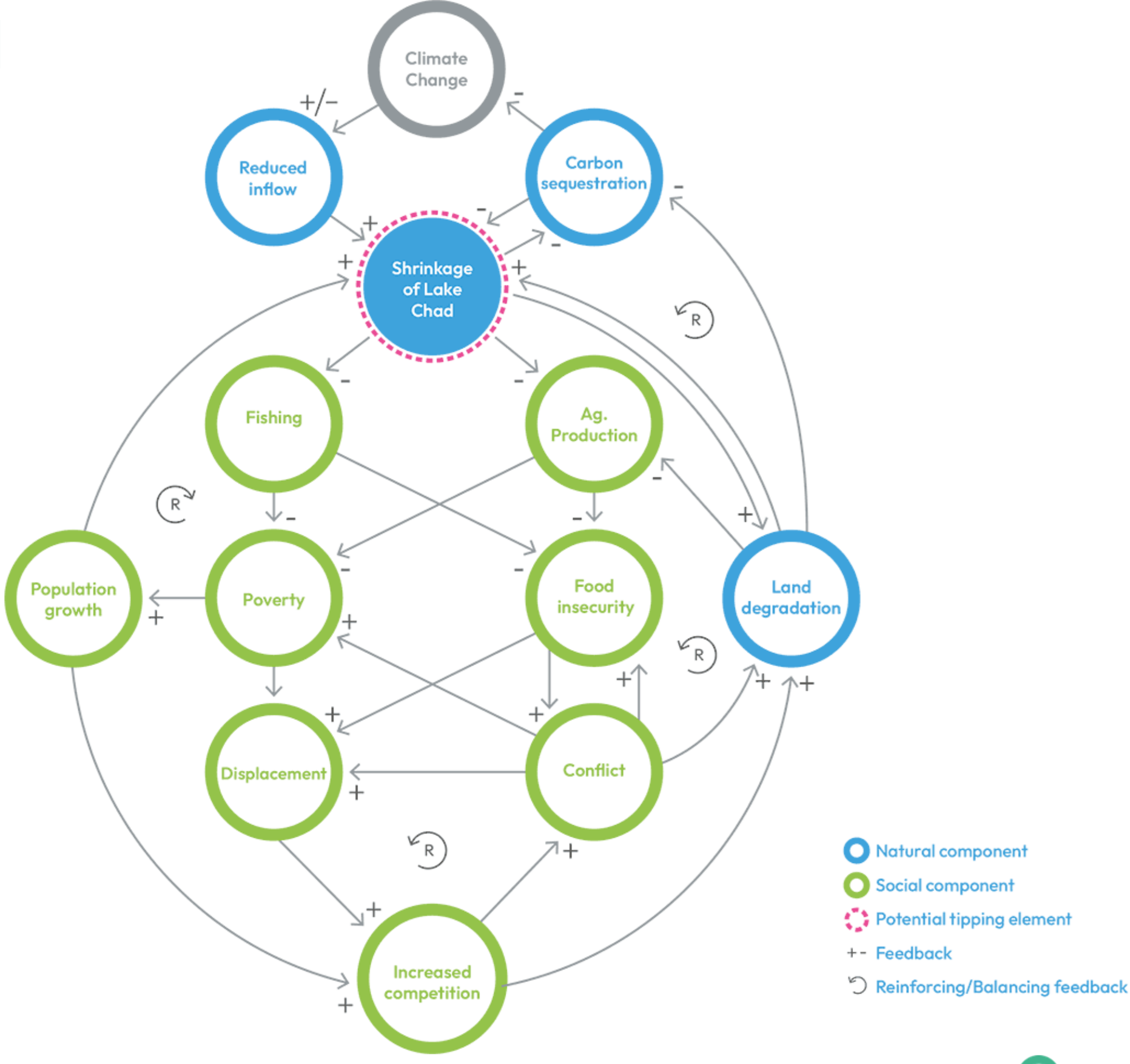
Systemic risk: the functioning of an entire system is compromised due to the interactions among its components

- exemplified by **cascades** that spread within and across systems and sectors
- via the movements of people, goods, capital and information within and across boundaries

Literature on this is underdeveloped.

2.4 Potential Examples

- Amazon
- Coral reefs
- Forced migration
- Arab Spring
- Lake Chad



2.5 Early warning signals

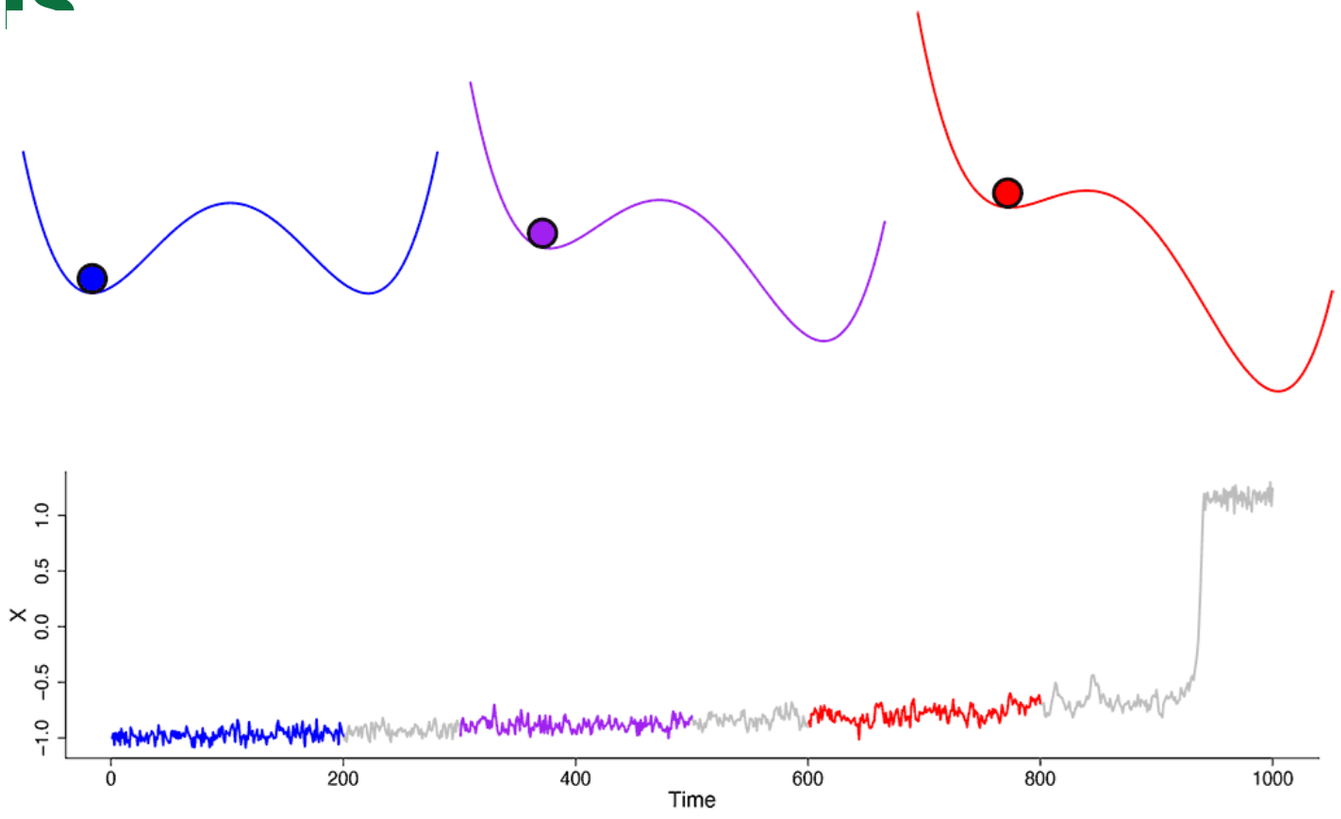
Application of **early warning signals** to interconnected social and environmental systems.

Limited research so far in this space.

One case study identifies trends in environmental data 3-6 months prior to food insecurity.

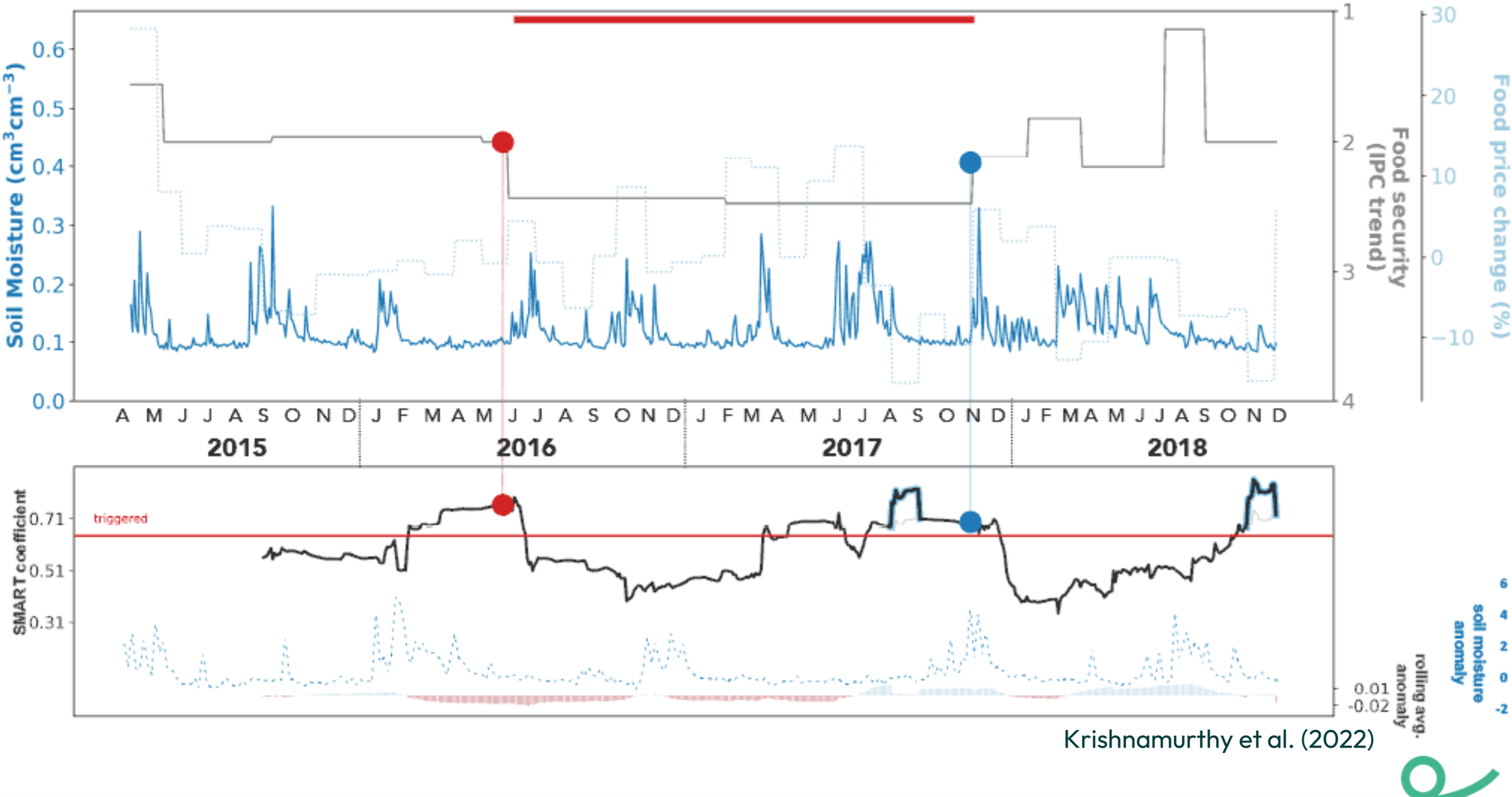
Further work required:

- to identify case studies and data to test these ideas
- to integrate this into decision-making systems



2.5 Early warning signals

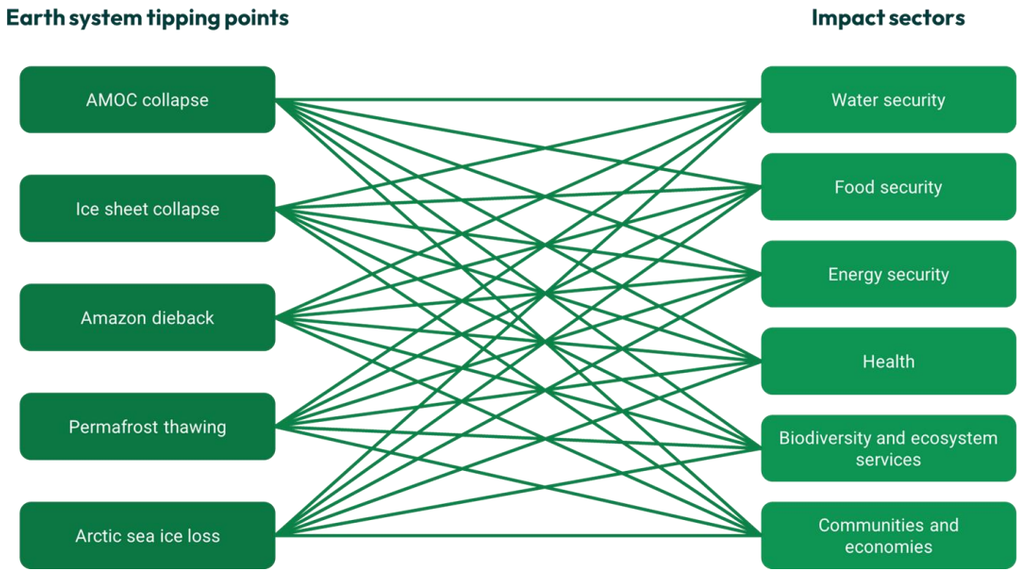
In north-east Kenya, soil moisture autocorrelation anticipated worsening of food security by 3-6 months



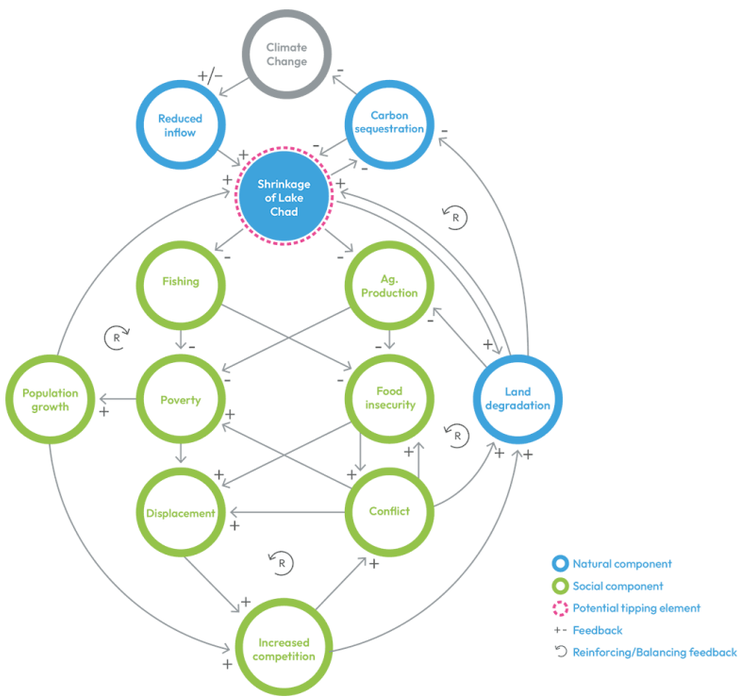
Krishnamurthy et al. (2022)

S2 Current state of knowledge

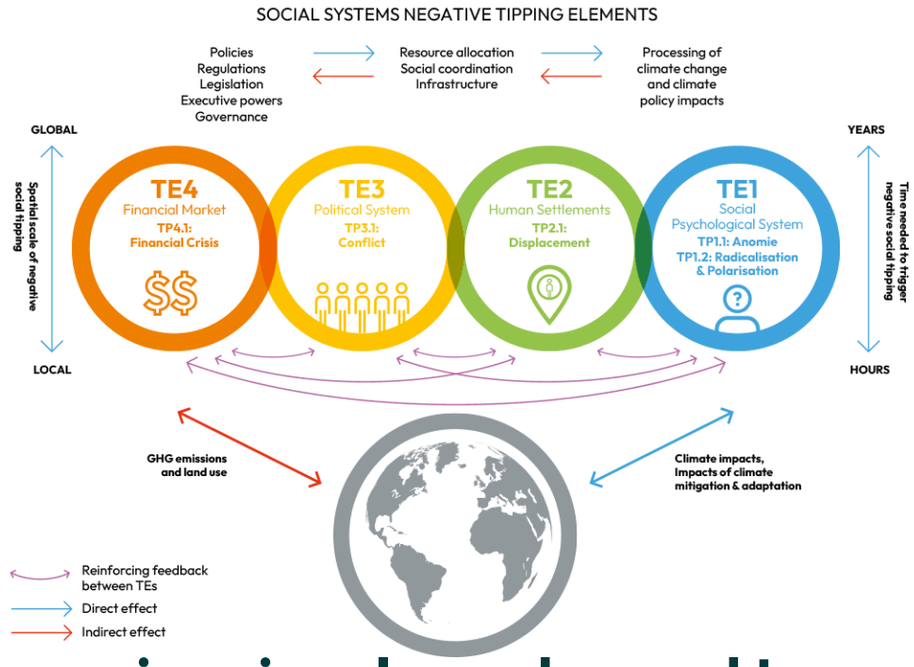
Earth system tipping points have the potential for severe impacts on people and biodiversity.



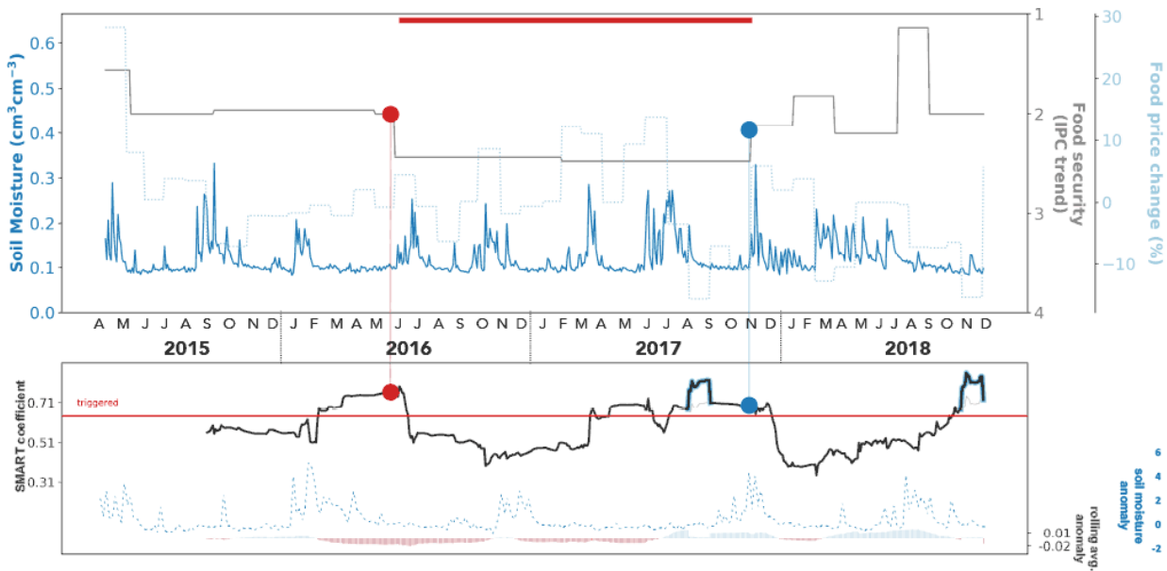
Negative social tipping points could cascade to create systemic risk.



Negative social tipping points triggered by climate change could have catastrophic impacts on human societies.



Early warning signals can be used to anticipate impact tipping points.



S2 Recommendations

- Risk assessments and adaptation plans should give deeper consideration to implications of Earth system tipping points

- Large knowledge gaps in the literature around tipping point impacts, such as regional impacts, and interlinkage between negative social and environmental tipping points

Governance of Earth system tipping points

Led by Manjana Milkoreit

Report context

Section 1

Earth system tipping points

Section 2

Impacts of Earth system tipping points

Section 3

Governance of Earth system TPs

3.1 Introduction

3.2 Prevention

3.3 Impact Governance

3.4 Knowledge & Science-Policy

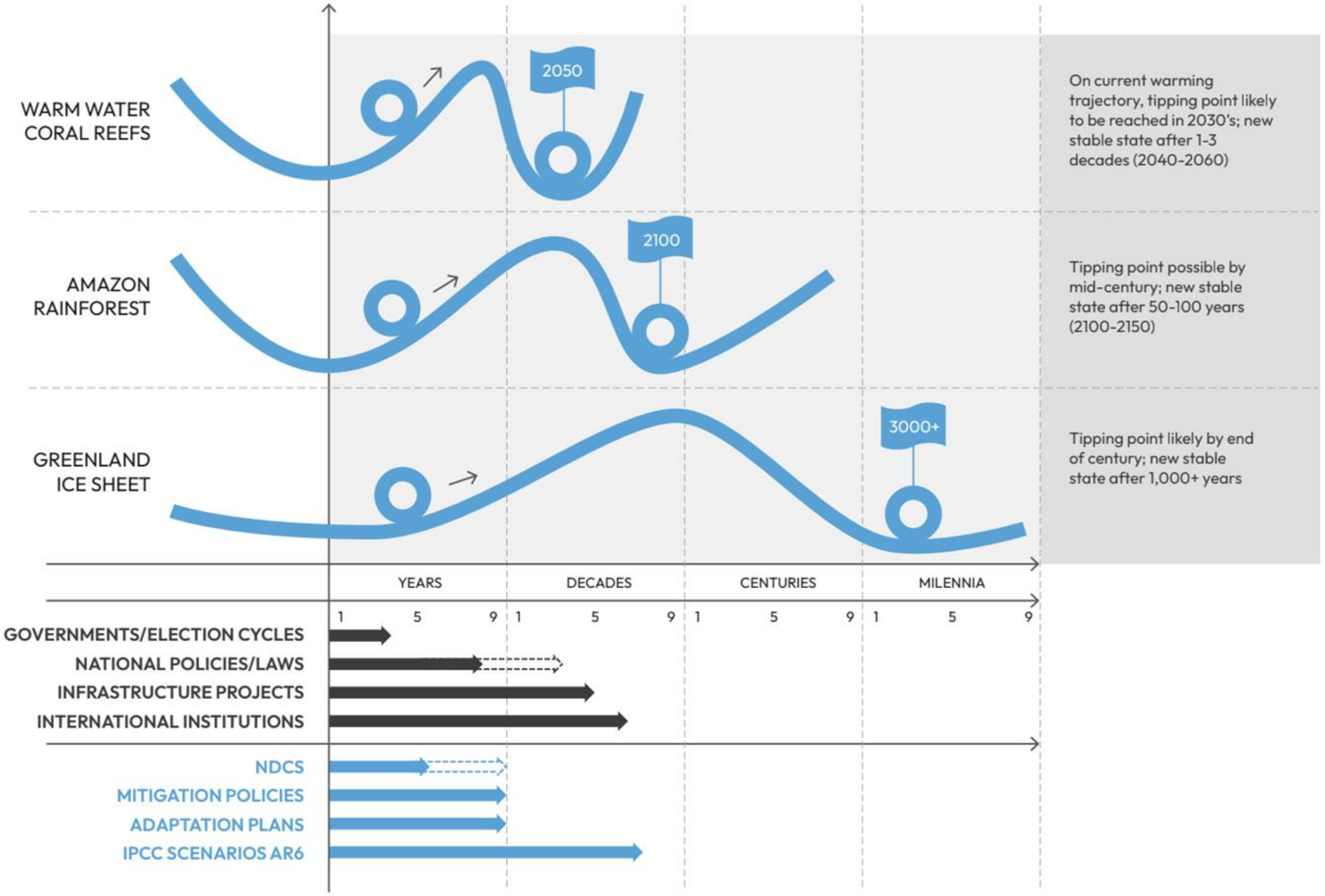
Section 4

Positive tipping points

S3 Key Messages

- Governance efforts to address the specific and severe threats of Earth system tipping points (ESTPs) are currently lacking and **urgently needed**.
- Existing global and national sustainability governance institutions should adopt responsibilities for the governance of ESTPs. Many of these need **significant adjustments and strengthening** in light of ESTPs.
- A future governance framework for ESTPs should **prioritise efforts to prevent tipping events**, while also minimising impact-related harms, fostering adaptation and resilience, and facilitating knowledge co-production.
- These objectives can only be reached together, through systemic changes that address the root causes of Earth system change with **transformations** to sustainable and just societies.
- In all domains of governance (prevention, impact governance, knowledge production), the **diversity of tipping processes** (their timing, drivers and impacts) need to be carefully considered.

3.1 Diversity and Intertemporality



S3 Recommendations

- Now is the time for governance actors, including UN bodies, international organisations, national governments and non-state actors, to engage in governance of Earth system tipping points.
- Countries need to reduce GHG emissions rapidly and dramatically in the near term and reach zero by mid-century to minimise the risk of transgressing tipping points.
- Parties to the Paris Agreement should include Earth system tipping points in future Global Stocktake processes and NDCs.
- Parties to the Paris Agreement should initiate an evaluation of the adequacy of current mechanisms for addressing climate change impacts (e.g. adaptation, loss and damage, finance) in light of the specific risks posed by Earth system tipping points.
- Countries within the geographic scope of a specific Earth system tipping element should consider the need for new initiatives for collective impact governance.
- International organisations, national governments and science funders should foster urgent international research collaboration, especially in the social sciences and humanities, by promoting open, trans and interdisciplinary, solutions-oriented, networked knowledge systems focusing on Earth system tipping points.

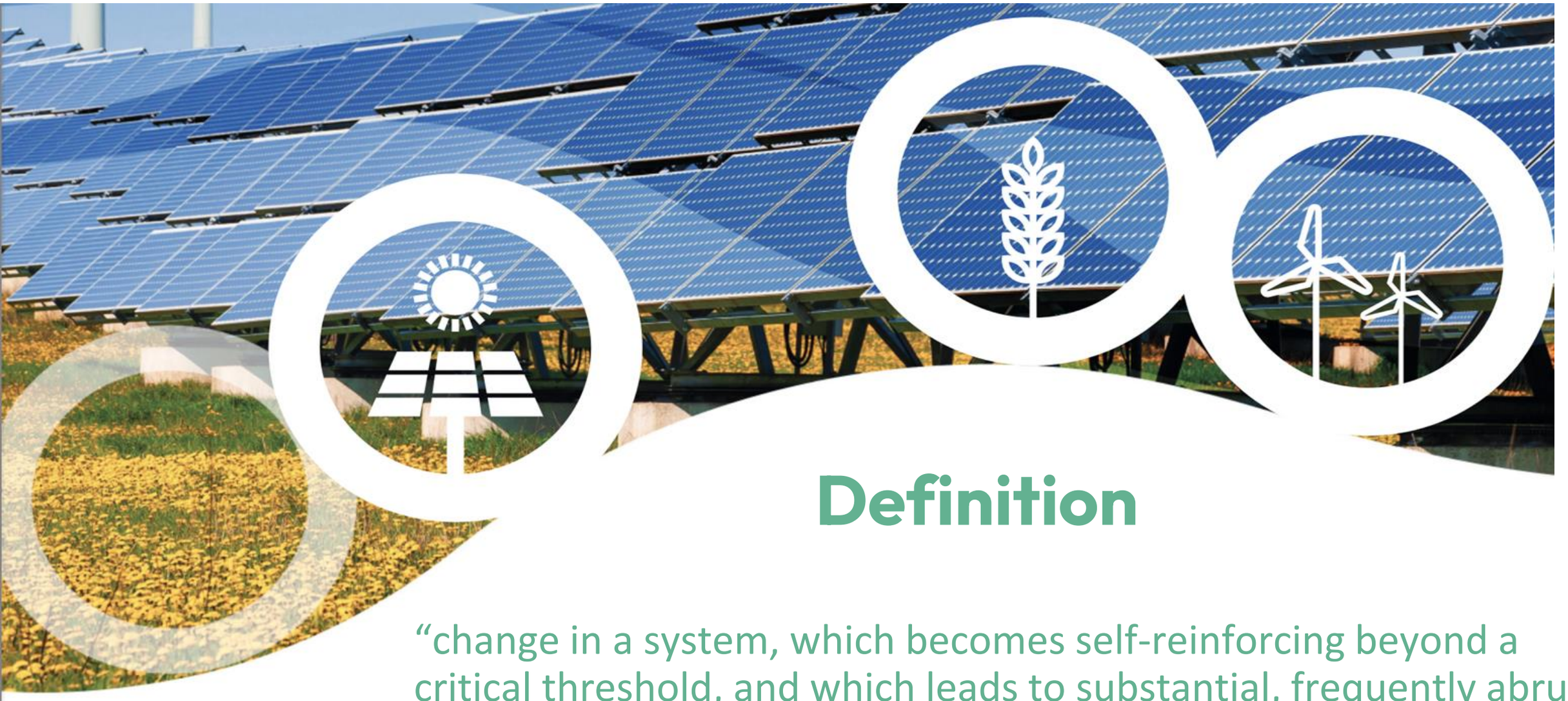
Positive tipping points in technology, economy and society

Led by Tom Powell, Steven R. Smith, Caroline Zimm and Emma Bailey

Chapter leads: Floor Alkemade, Luis Martinez, Lukas Fesenfeld, Viktoria Spaiser, Sara M. Constantino

Nadia Ameli, Joshua E. Buxton, Chris A. Boulton, Sibel Eker, Elena Verdolini, Laura Pereira

Positive Tipping Points



Definition

“change in a system, which becomes self-reinforcing beyond a critical threshold, and which leads to substantial, frequently abrupt and often irreversible impacts that are predominantly beneficial”

Report context

Section 1 — Earth system tipping points

Section 2 — Impacts of Earth system tipping points

Section 3 — Governance of Earth system TPs

Section 4

Positive Tipping Points (PTPs)

4.1 Introduction

4.2 Understanding and acting on PTPs

4.3 PTPs in energy, transport and food systems

4.4 Cross-cutting enablers of PTPs

4.5 Positive tipping cascades

4.6 Risks, equity and justice in PTP governance

S4 Key Messages

- Transformative and just positive tipping points can emerge with the **right enabling conditions, feedbacks and triggers.**
- Climate solutions focusing on fundamental **shifts in behaviours, values and institutions are as important as those that focus on technologies, materials and markets.**
- An **avoid-shift-improve logic** which rethinks our activities – whether they can be omitted, changed or undertaken more efficiently – can be used in many sectors to design interventions to manage holistic structural change.

Positive for whom?
Beneficial for whom?

"collective, intentional transformation towards global sustainability"
(Lenton et al., 2022, p. 2)

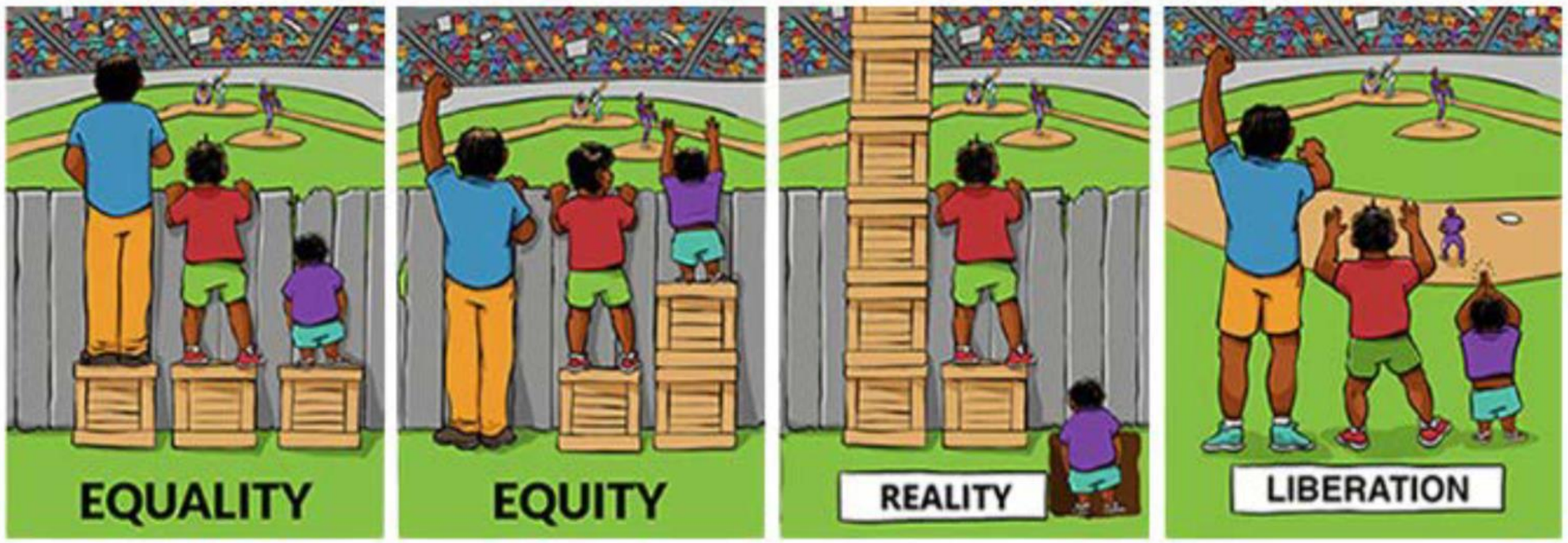


Image Credit: "Artist: Angus Maguire".

ESTPs and PTPs: similarities and differences

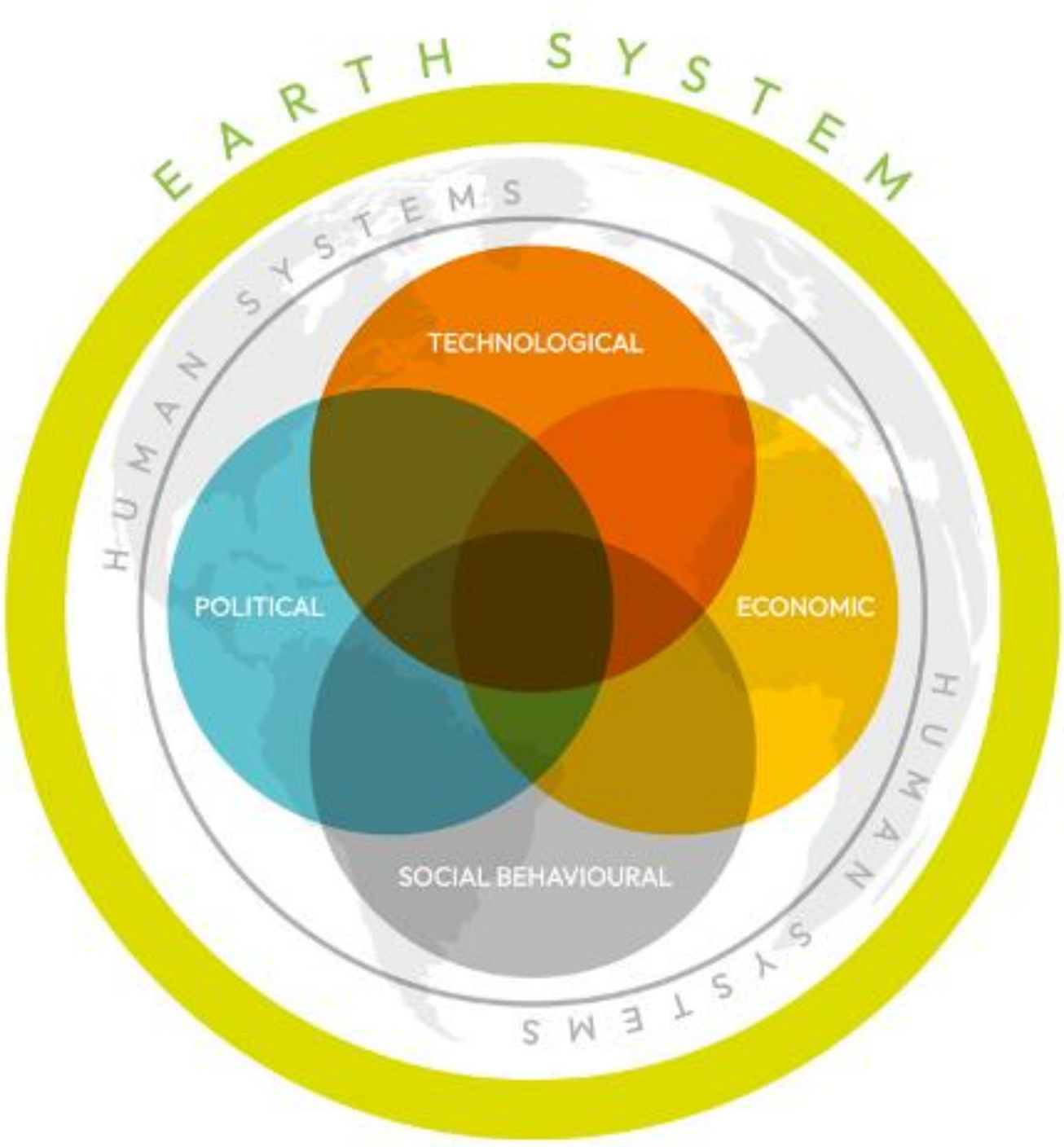
Similarities

- Tipping points, nonlinearity
- Alternative stable states
- Reinforcing (+) feedbacks
- Dampening (-) feedbacks
- Cascade effects
- Resilience / loss of resilience
- Path dependence

Differences

- Desirability
- Agency / Interventions
- Intention to support sustainability
- Temporal/spatial scales
- Different domains

Positive tipping point domains



Technological

e.g., innovation, R&D, automation and digitalisation

Economic

e.g., markets and finance

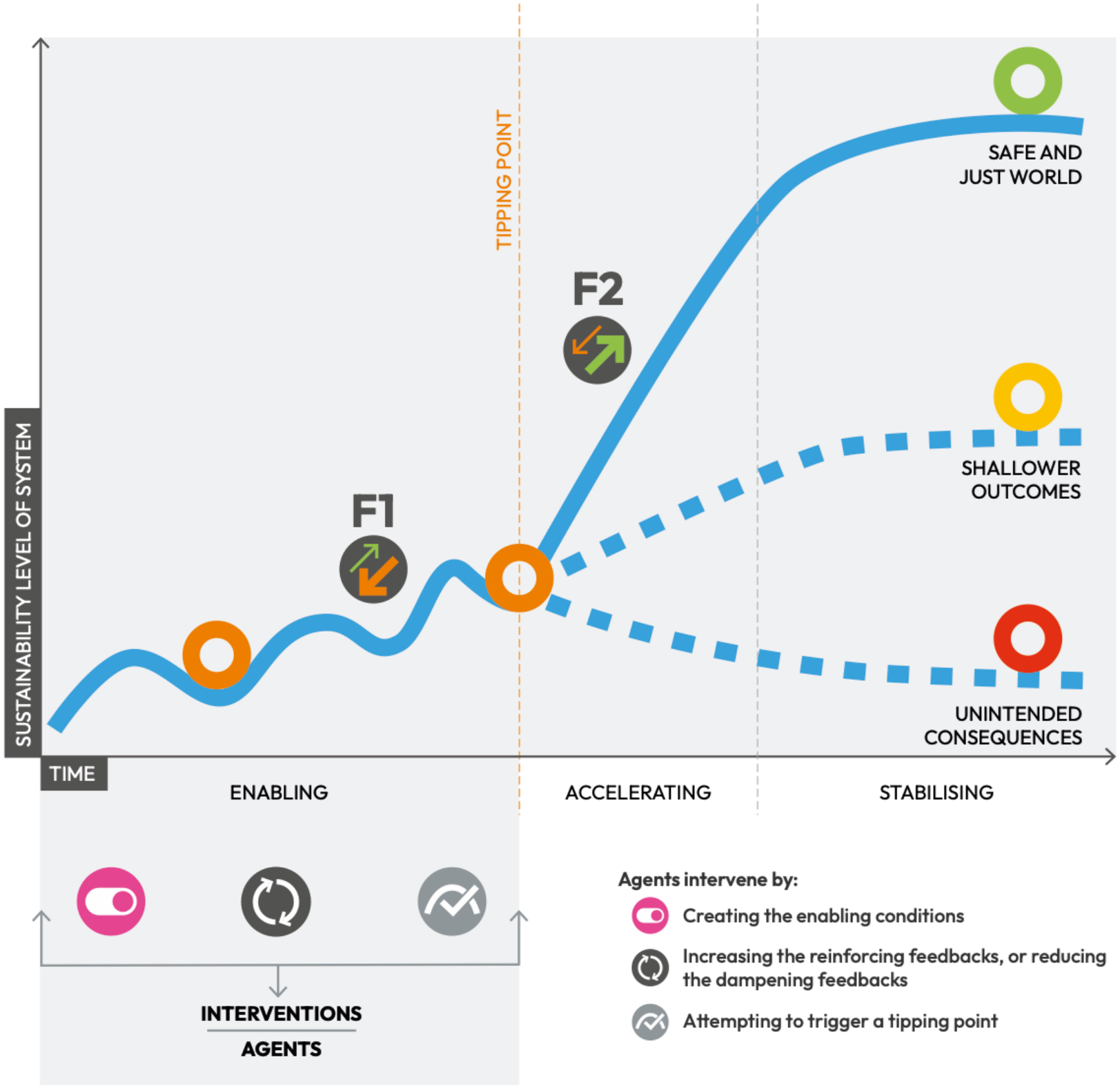
Social-Behavioural

e.g., social norms, lifestyles, values and cultures

Political

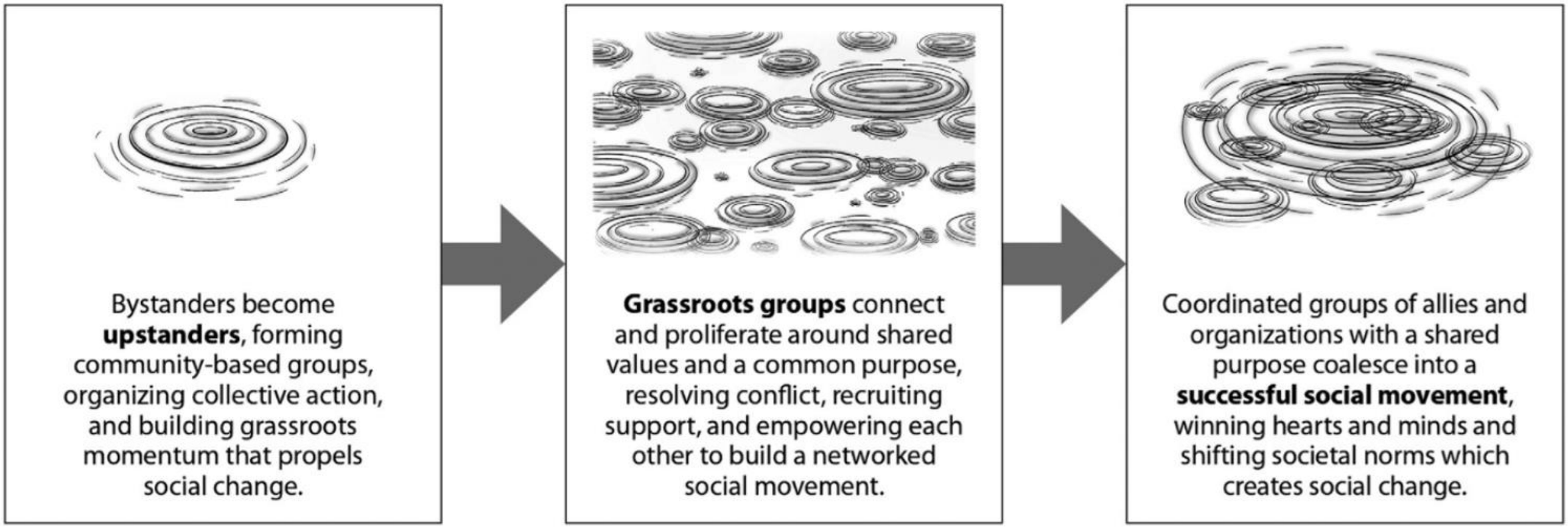
e.g., law, politics, policy, institutions and governance

Conceptual framework for PTP dynamics



4.5 Cross-cutting enablers of PTPs

1. Social-behavioural systems



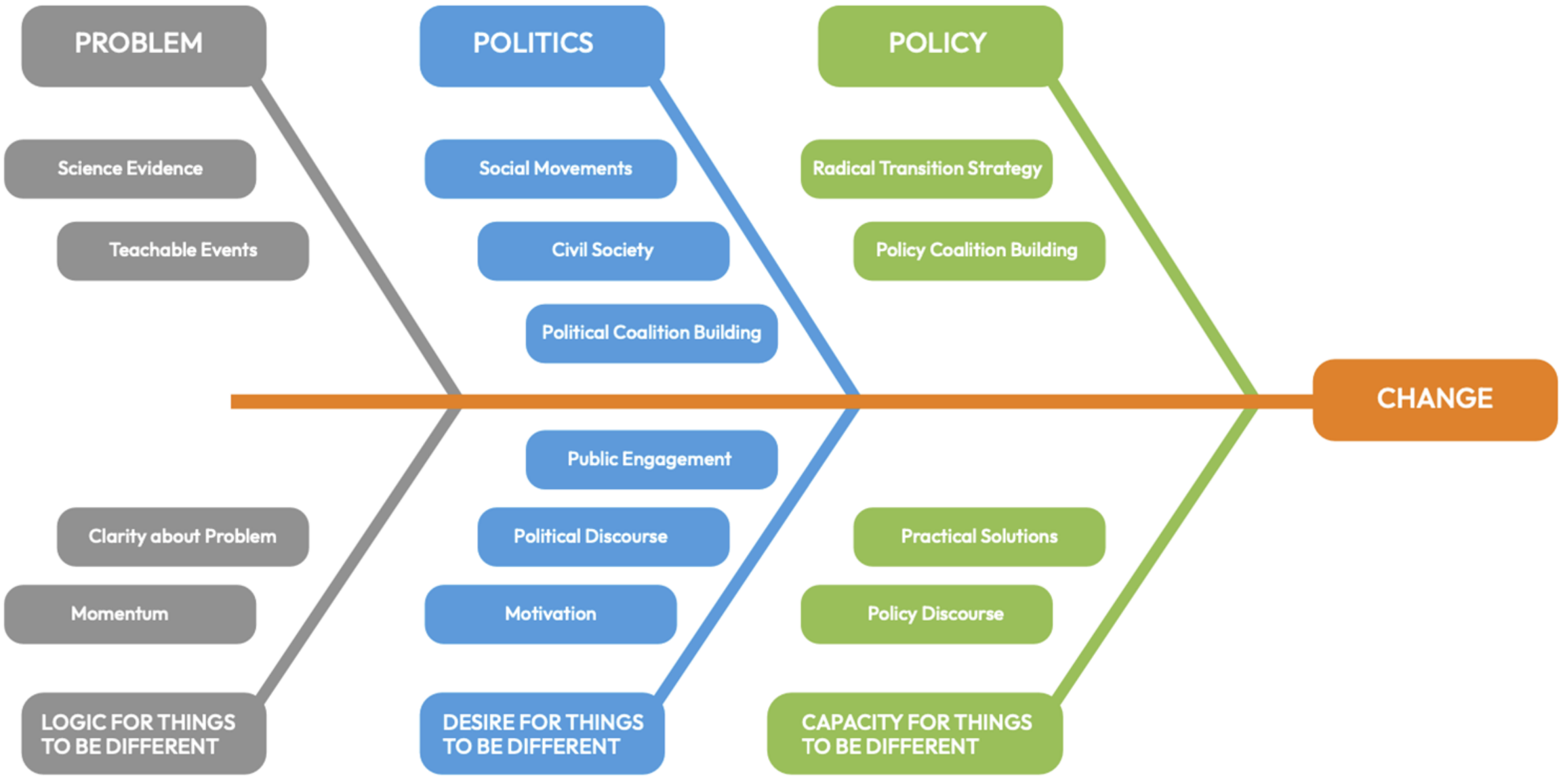
Bystanders become **upstanders**, forming community-based groups, organizing collective action, and building grassroots momentum that propels social change.

Grassroots groups connect and proliferate around shared values and a common purpose, resolving conflict, recruiting support, and empowering each other to build a networked social movement.

Coordinated groups of allies and organizations with a shared purpose coalesce into a **successful social movement**, winning hearts and minds and shifting societal norms which creates social change.

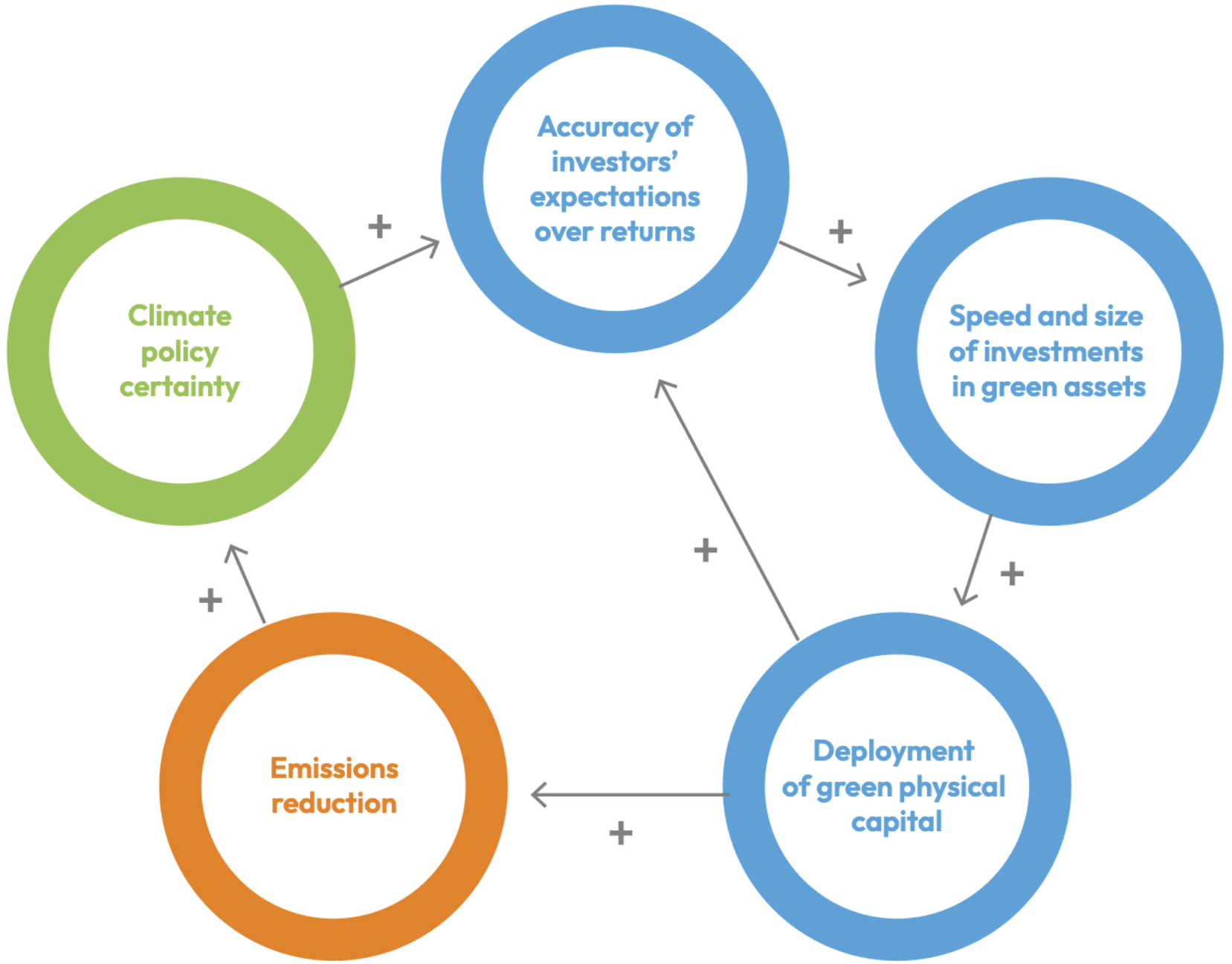
4.5 Cross-cutting enablers of PTPs

2. Political systems



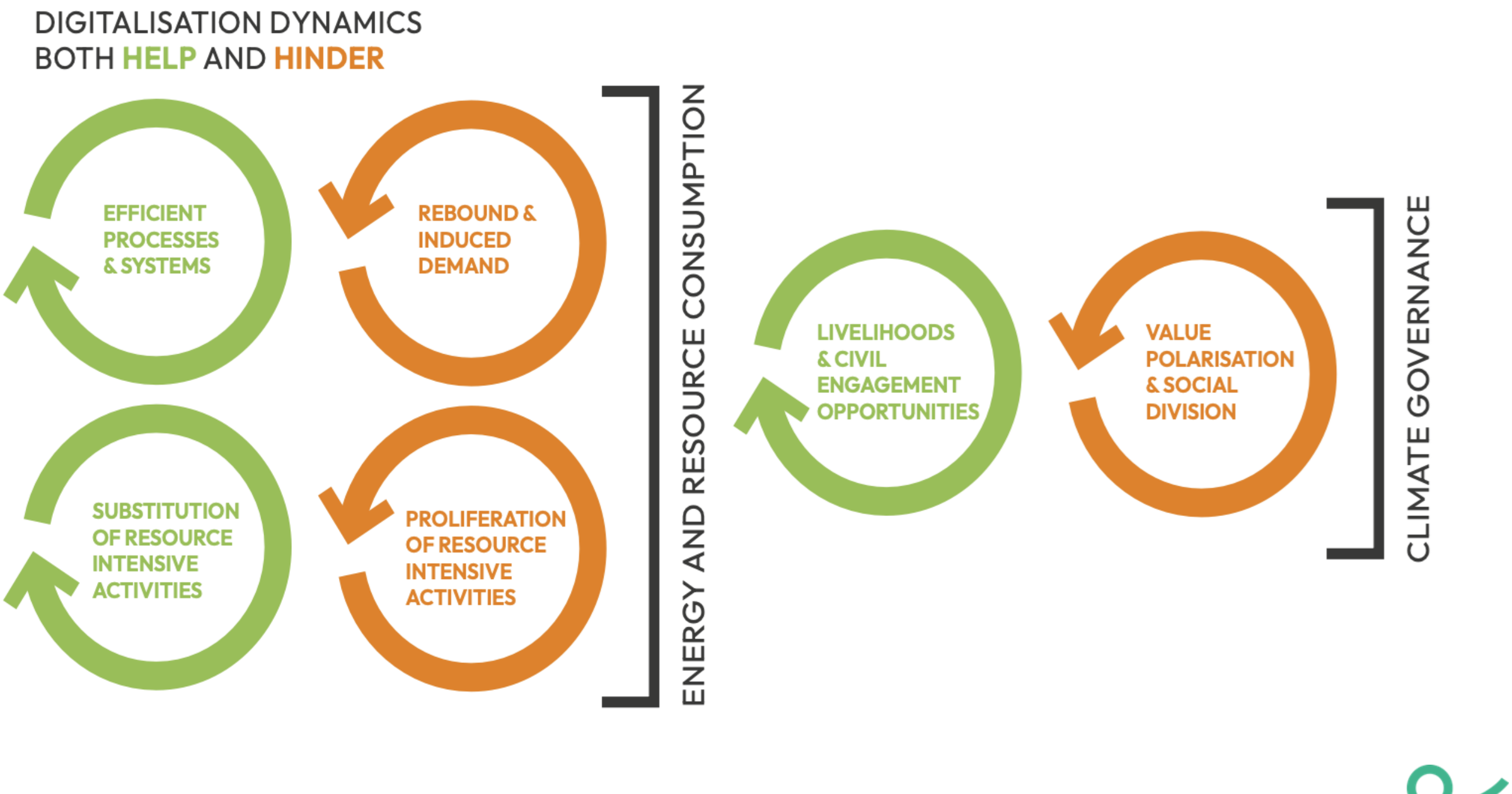
4.5 Cross-cutting enablers of PTPs

3. Financial systems



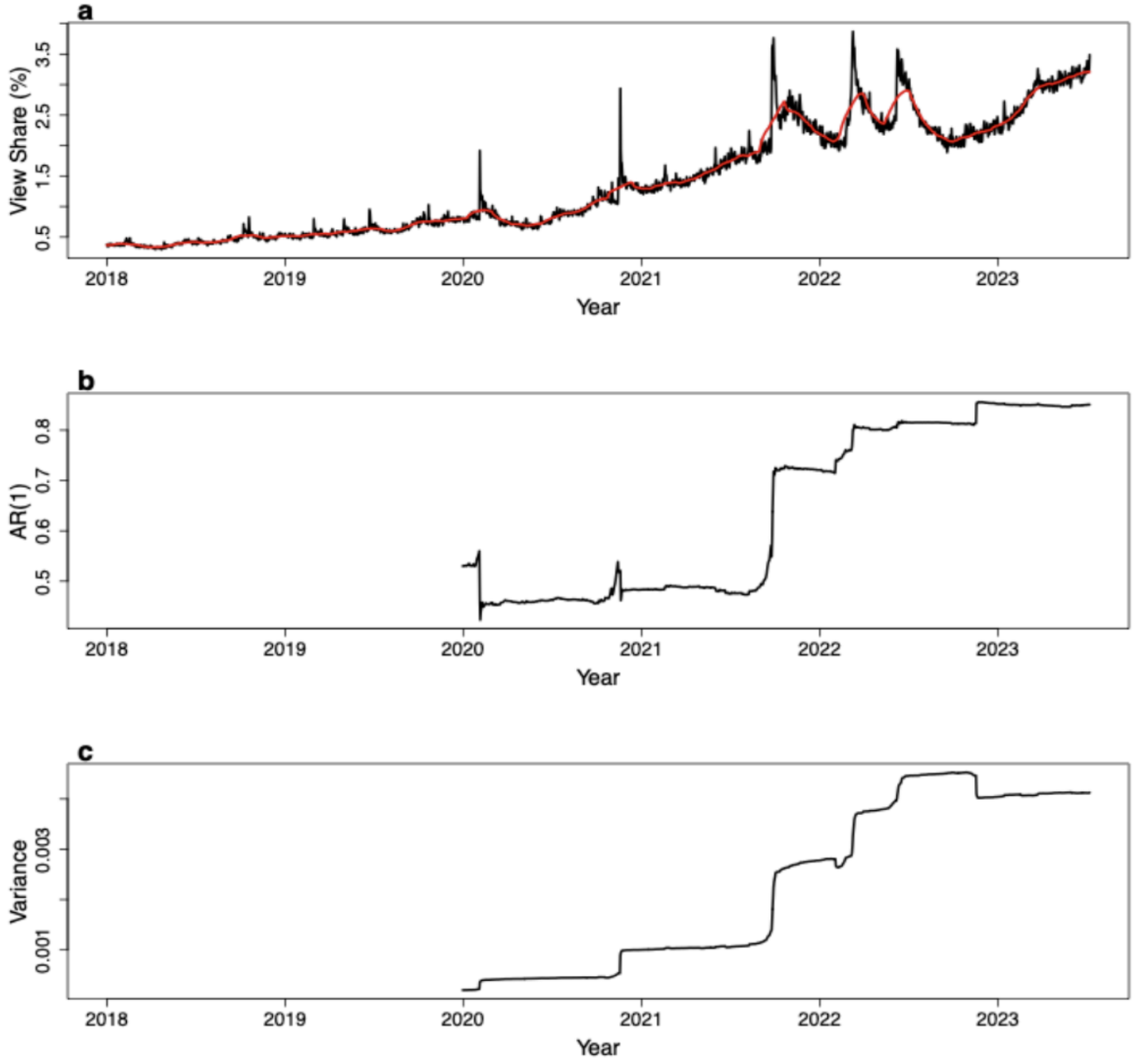
4.5 Cross-cutting enablers of PTPs

4. Digitalisation



4.5 Cross-cutting enablers of PTPs

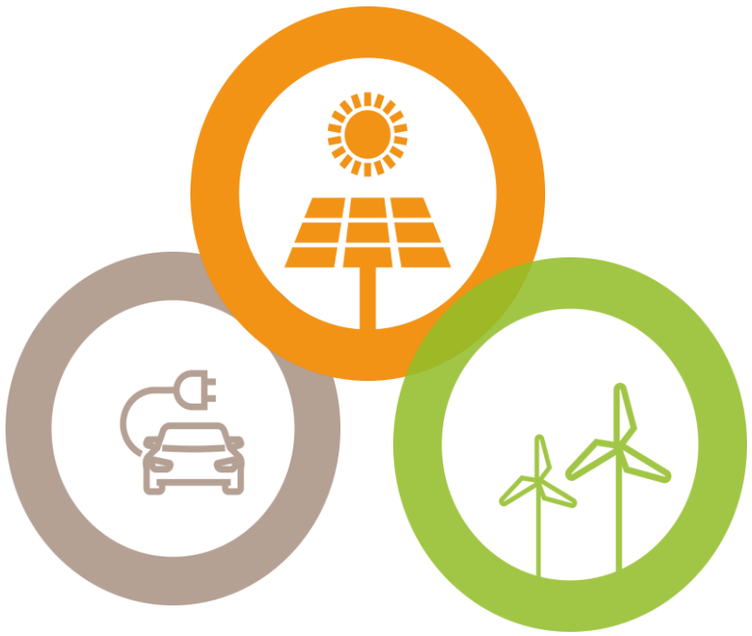
5. Detecting early opportunity indicators (EOIs)



4.3 Energy, mobility and transport systems

Positive tipping points are already happening:

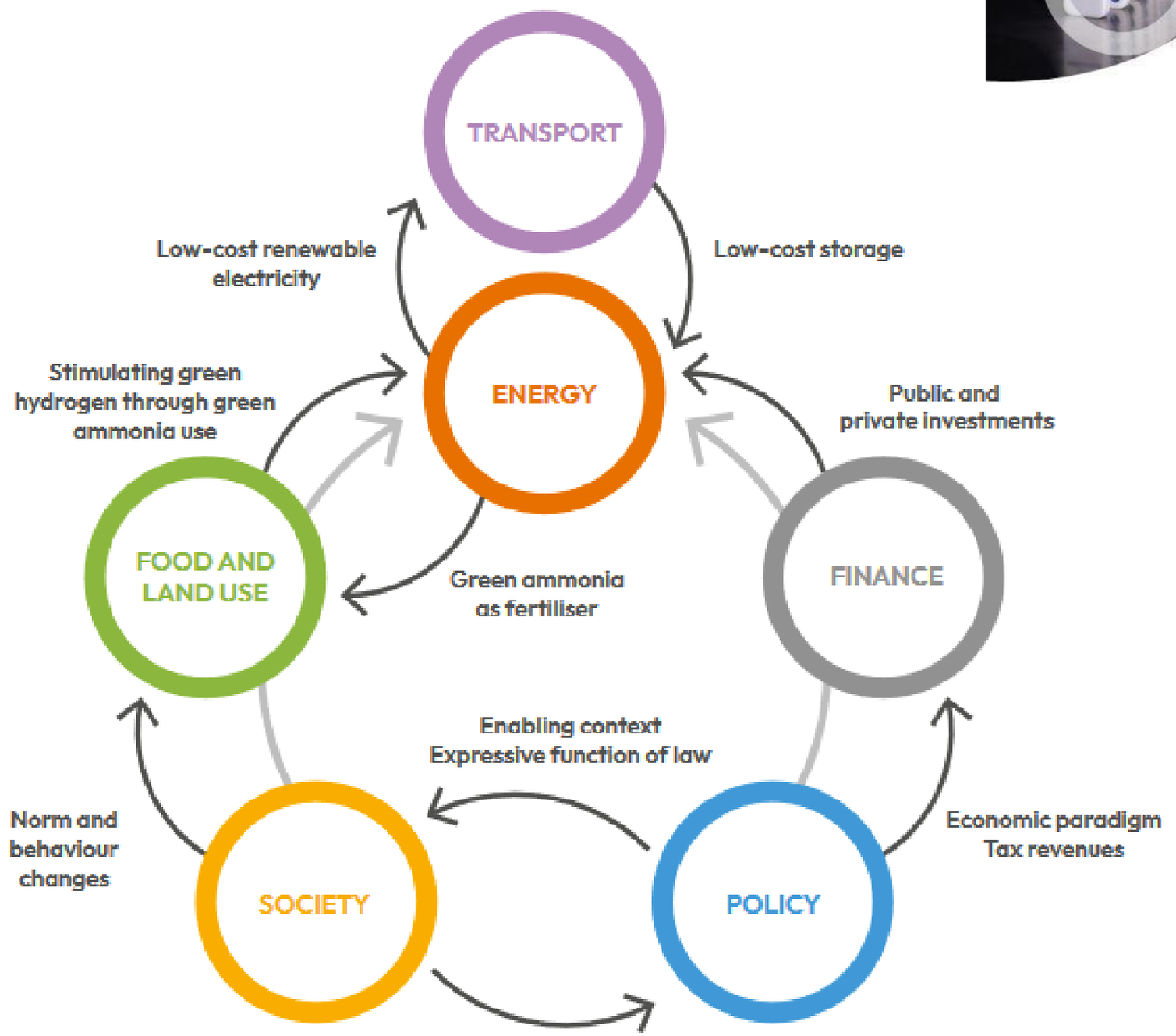
- The **power sector** in many countries recently passed a tipping point of cost parity for renewable generation. Over **80% of new electricity** generation in 2022 was solar and wind
- **Electric vehicles** show evidence of passing or approaching tipping points in major markets including China and Europe.



Positive tipping points need to be enabled:

- **Reducing energy demand** following AVOID-SHIFT-IMPROVE can accelerate decarbonising the energy system.
- There is an urgent need for tipping points in **transport demand** as it is continuing to increase with diverse negative impacts
- There are encouraging localised **examples of tipping points in urban mobility**, with a shift to more active transport modes.
- Positive tipping points have yet to occur at scale in **food systems:** Shifting to more plant-based diets, avoiding food loss and waste, improving farming practice have multiple benefits.

Positive Tipping Cascades



S4 Recommendations

- Positive tipping points theory, methods and applications will require a **comprehensive, systematic and transdisciplinary** programme of research and development.
- Decision makers need a **systems-thinking approach** and a coordinated strategy that encompasses all economic sectors, all departments of government, civil society (including public consultation), and both supply-side and demand-side interventions.
- A systems-thinking approach understands that the most effective way to catalyse global action may be via **small-group coalitions**. For example, a positive tipping point in green hydrogen could be achieved if the US, EU and India implemented blending mandates for green ammonia in fertiliser manufacturing.

THANK YOU!

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