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# Freshwater Resilience

## An appropriate lens for charting and tracking sustainable development in the Anthropocene

Water Resilience
World Water Week
31 Aug 2017

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Photo: Yann Arthus-Bertrand

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Sustainability Science for Biosphere Stewardship
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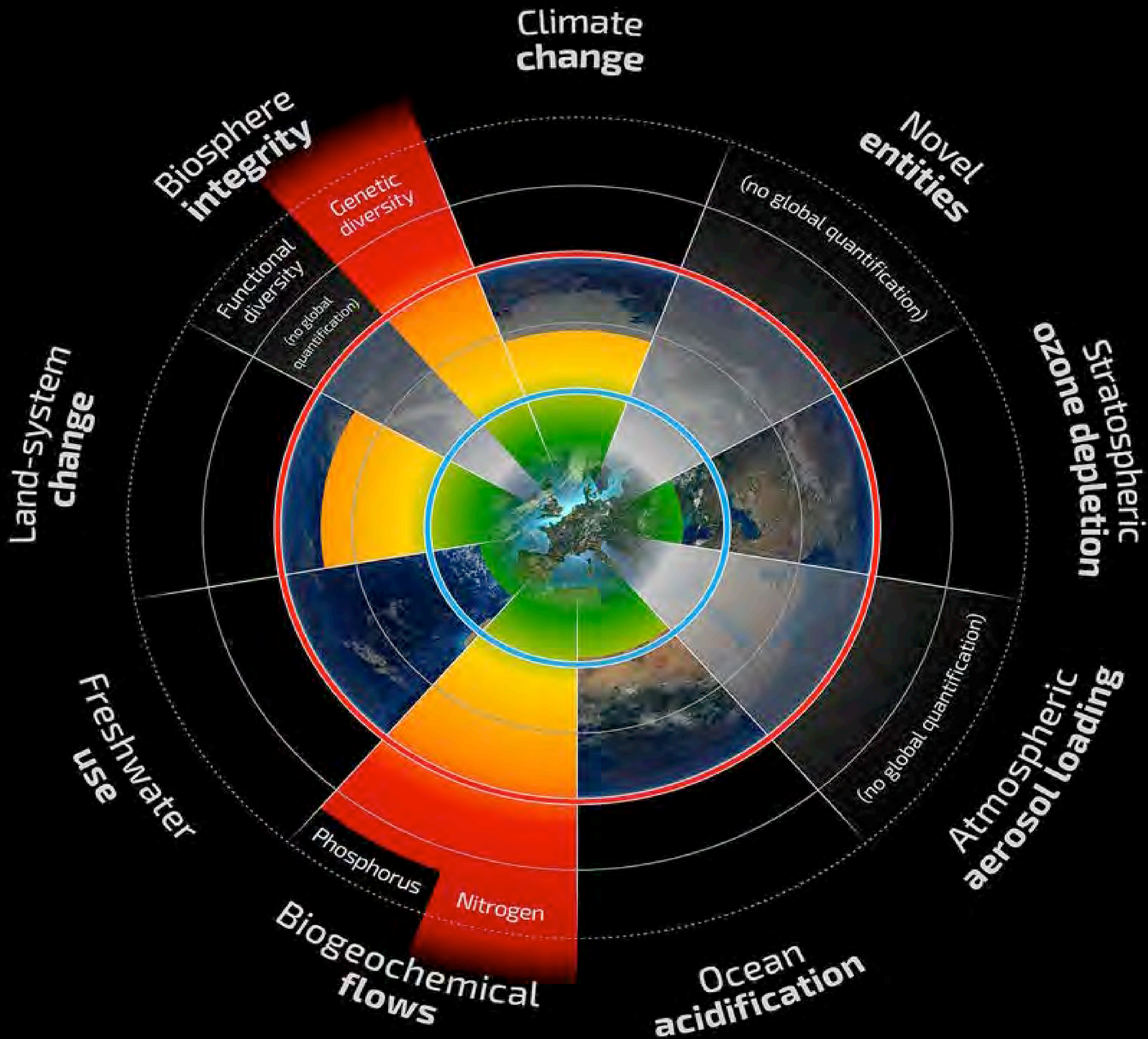
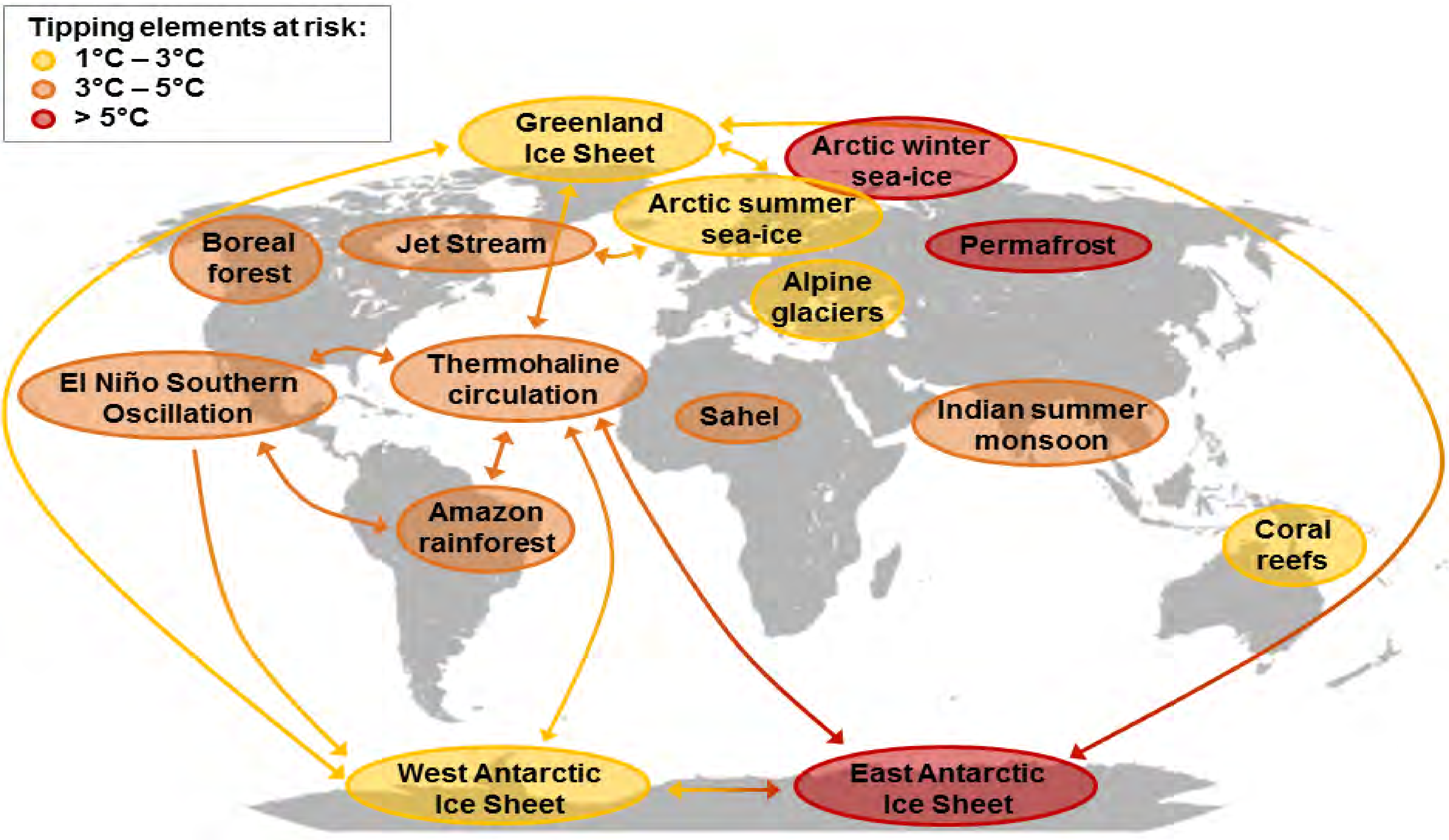


Climate change
Novel entities
(no global quantification)
Stratospheric ozone depletion
Atmospheric aerosol loading
(no global quantification)
Ocean acidification
Biogeochemical flows
Phosphorus
Nitrogen
Freshwater use
Land-system change
Biosphere integrity
Genetic diversity
Functional diversity
(no global quantification)

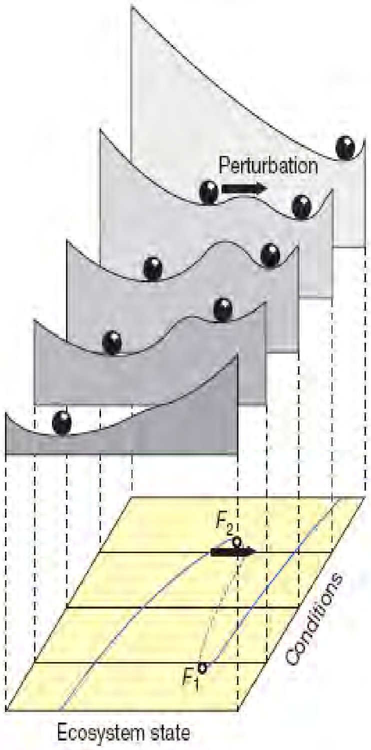


Tipping elements at risk:
1°C – 3°C
3°C – 5°C
> 5°C
Greenland Ice Sheet
Arctic winter sea-ice
Arctic summer sea-ice
Permafrost
Boreal forest
Jet Stream
Alpine glaciers
Thermohaline circulation
El Niño Southern Oscillation
Sahel
Indian summer monsoon
Amazon rainforest
Coral reefs
West Antarctic Ice Sheet
East Antarctic Ice Sheet

# RESILIENCE

Resilience is the capacity of a system to continually change and adapt yet remain within critical thresholds.


- ***Persistance*** - capacity of a SES to continually change and adapt yet remain within critical thresholds.
- ***Adaptability*** - capacity to adjust responses to changing external drivers and internal processes and thereby allow for development along the current trajectory (stability domain).
- ***Transformability*** - capacity to cross thresholds into new development trajectories.
- interrelate *across multiple scales*.





Folke, C., R. Biggs, A. V. Norström, B. Reyers, and J. Rockström. 2016. Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society* 21(3):41. http://dx.doi.org/10.5751/ES-08748-210341

*Synthesis*

**Social-ecological resilience and biosphere-based sustainability science**

Carl Folke[1,2], Reinette Biggs[1,3], Albert V. Norström[1], Belinda Reyers[1] and Johan Rockström[1]

**Principles for Building Resilience**

Sustaining ecosystem services in social-ecological systems

CAMBRIDGE

**Reinette (Oonsie) Biggs, Maja Schlüter, Michael Schoon (Eds)**

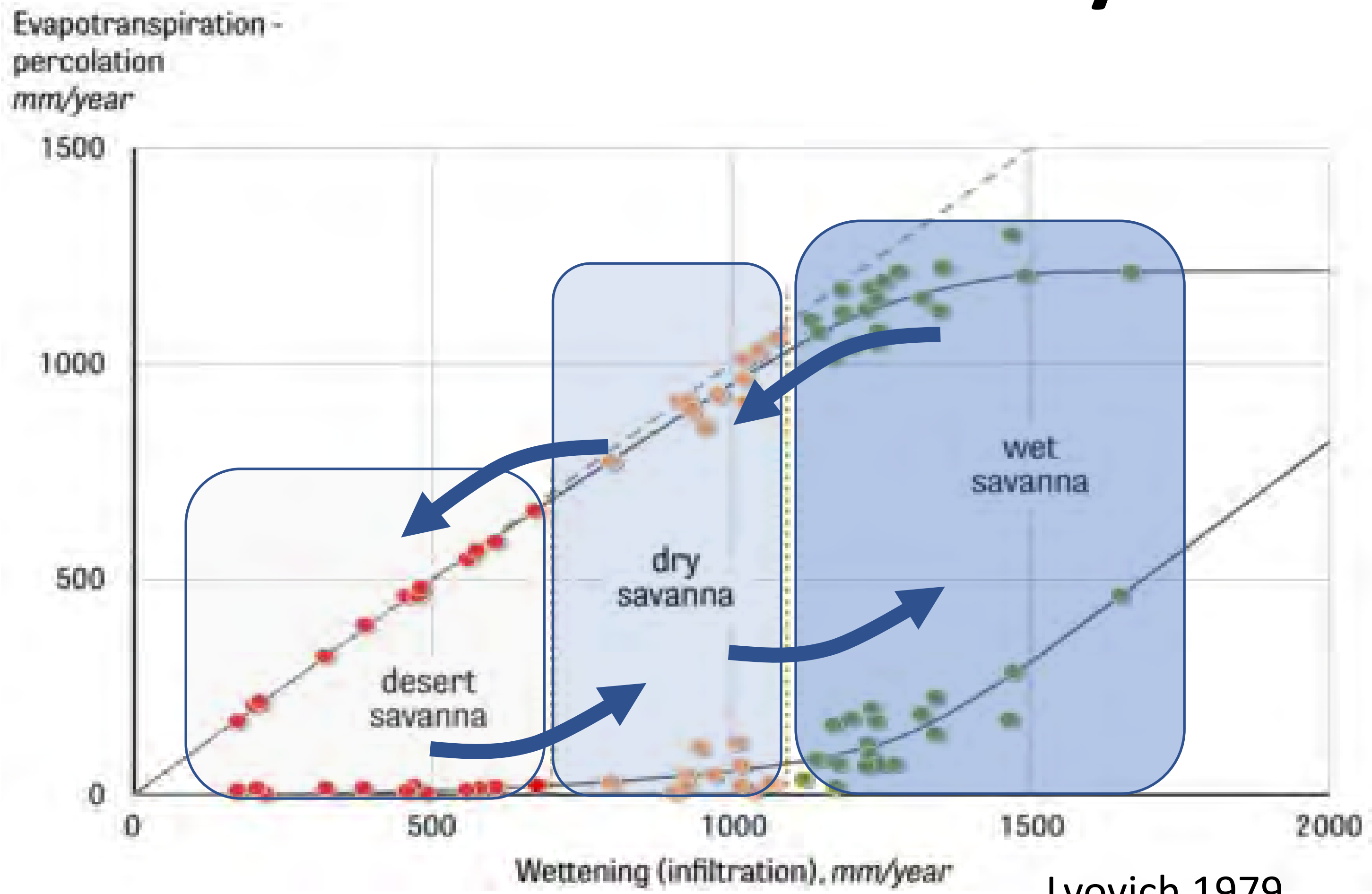
Erin Bohensky, Georgina Cundill, Vasilis Dakos, Karen Kotschy, Anne Leitch, Allyson Quinlan, Marty Anderies, Derek Armitage, Jacopo Baggio, Elena Bennett, Duan Biggs, Örjan Bodin, Katrina Brown, Shauna BurnSilver, Tim Daw, Nathan Engle, Louisa Evans, Christo Fabricius, Carl Folke, Victor Galaz, Line Gordon, Chanda Meek, Garry Peterson, Ciara Raudsepp-Hearne, Martin Robards, Lisen Schultz, Brian Walker, Paul West

# Water Resilience

The role of water in determining the state of social-ecological systems, in generating critical ecosystem functions and services, in building capacity to deal with shocks and stress (persist), adapt to changing conditions, and transform in situations of crisis

| 3 Features of Water Resilience | |
|---|---|
| Water as Control Variable | - Water self-regulating rainfall<br>- Water for Ecosystem Functions – e.g., biomass growth/biodiversity |
| Water as State Variable | - Degree of green water wetness in landscapes to uphold system<br>- Minimum blue EWF to sustain habitats<br>- Minimum blue water for society |
| Water as Driving Variable | - Water as trigger of social shocks (floods, droughts)<br>- Water as driver of conflict |

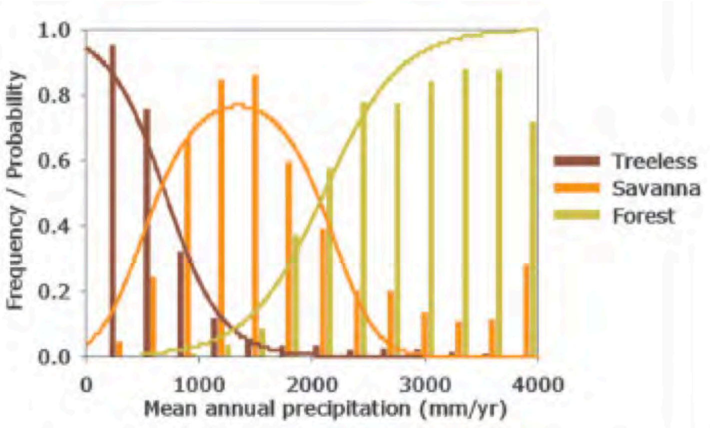
# The role of water in regulating biome stability

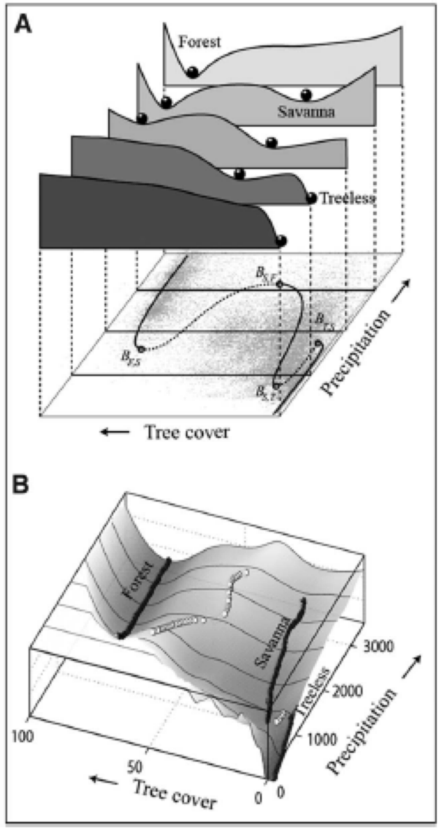


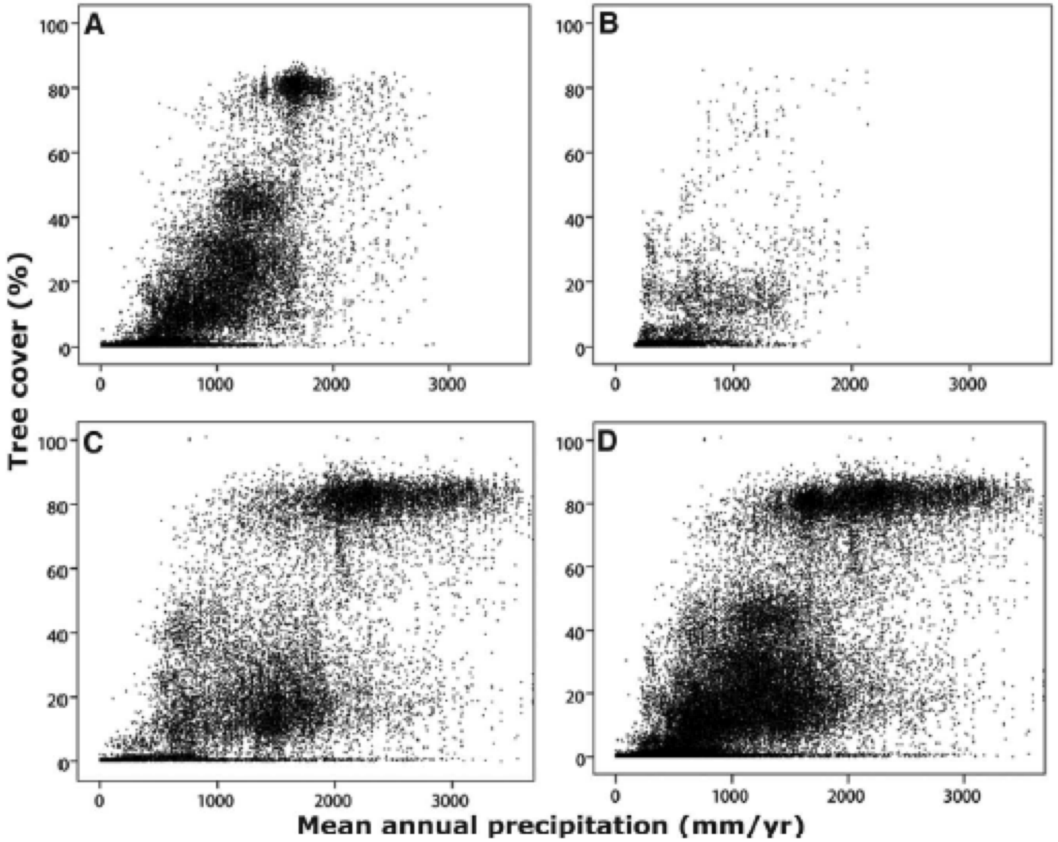

Lvovich 1979

# Global Resilience of Tropical Forest and Savanna to Critical Transitions

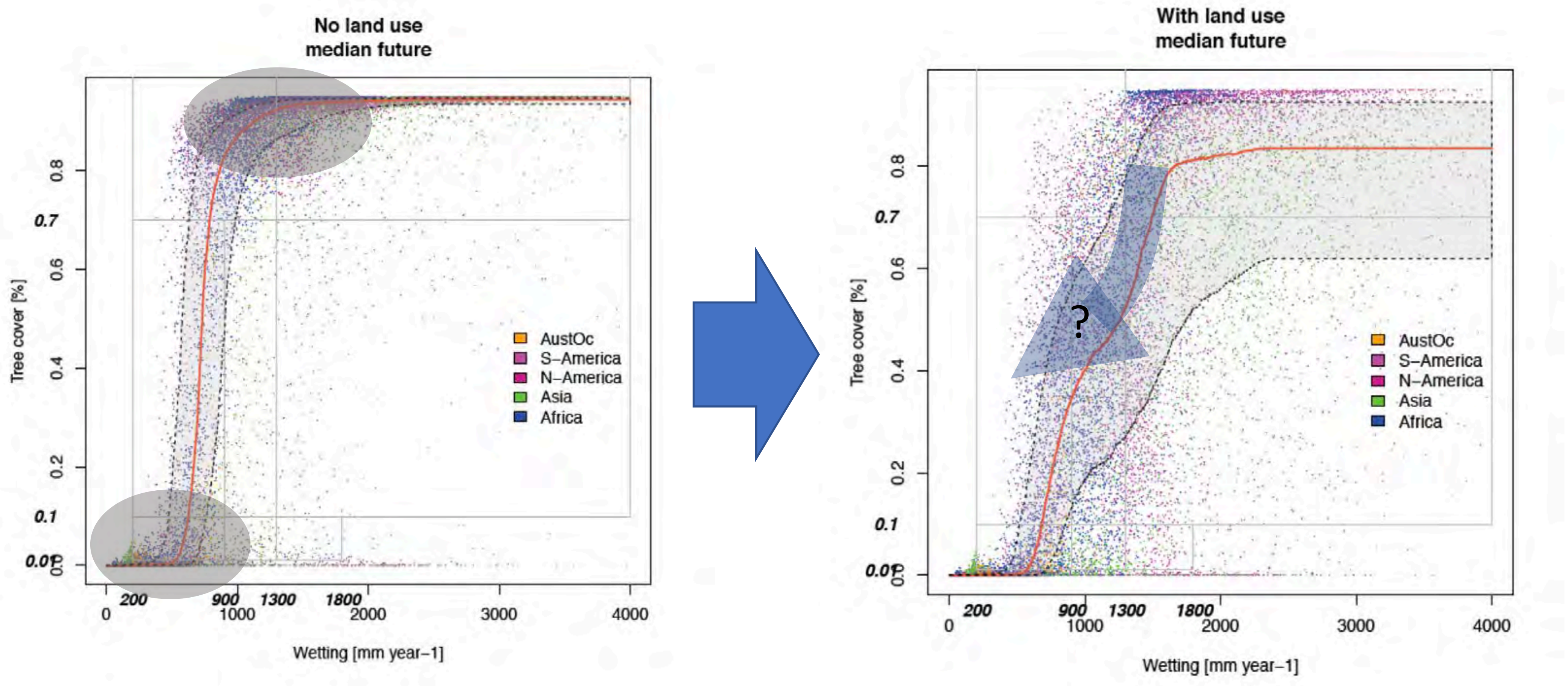
Marina Hirota,[1] Milena Holmgren,[2]* Egbert H. Van Nes,[1] Marten Scheffer[1]



# Water Induced Thresholds in Biomes



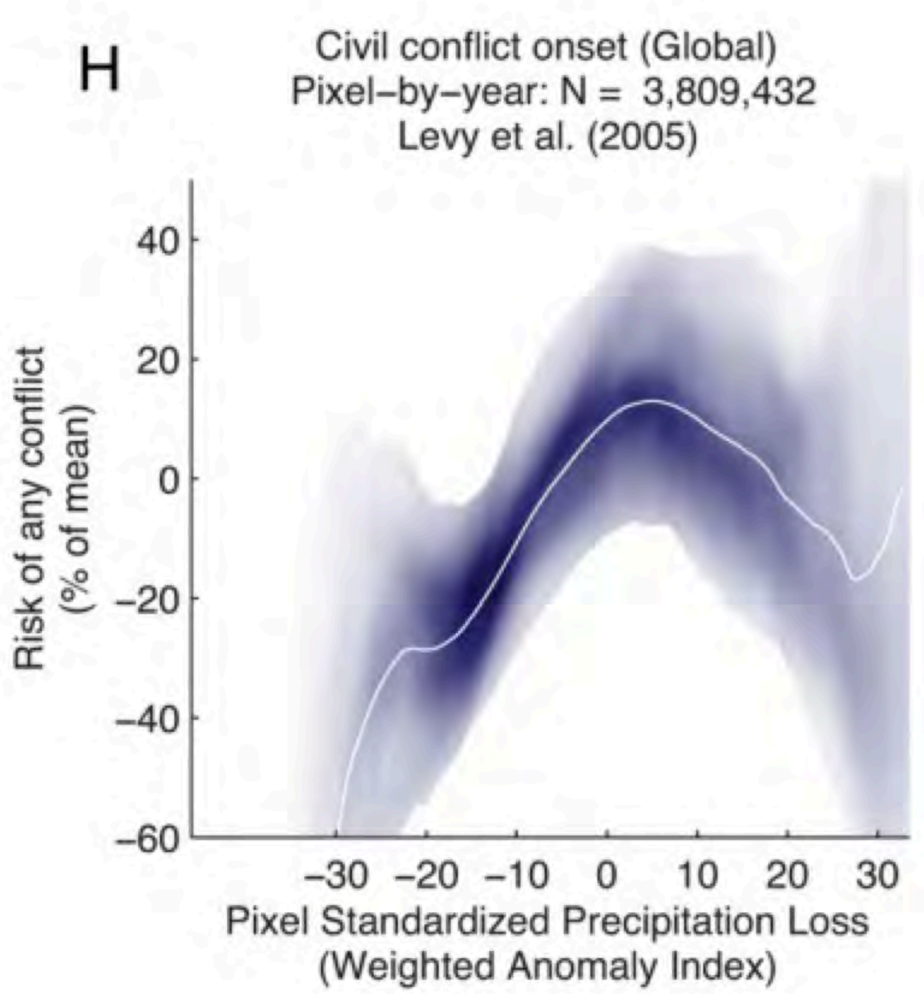

Rockstrom, Falkenmark, Fetzer, Blenckner, Folke, in progress

# Social Tipping Points when losing Water Resilience

## Global Environment Change  Human Conflict

Strong causal evidence linking climate events [extreme temperature and rainfall] to human conflict across all major regions fo the world

Global Warming 1 SD → 14 % increase in inter-group conflict
Global Warming 2-4 SD by 2050 → 28 – 56 % increase in conflict




**Quantifying the Influence of Climate on Human Conflict**

Solomon M. Hsiang,[1,2*†‡] Marshall Burke,[3†] Edward Miguel[2,4]


Rainwater
Human activities
Water partitioning
Ecosystem services
Water alterations
Aquatic feedback flows
Terrestrial feedback flows

# Water Resilience controls rainfall through moisture feedback from functioning forest landscapes



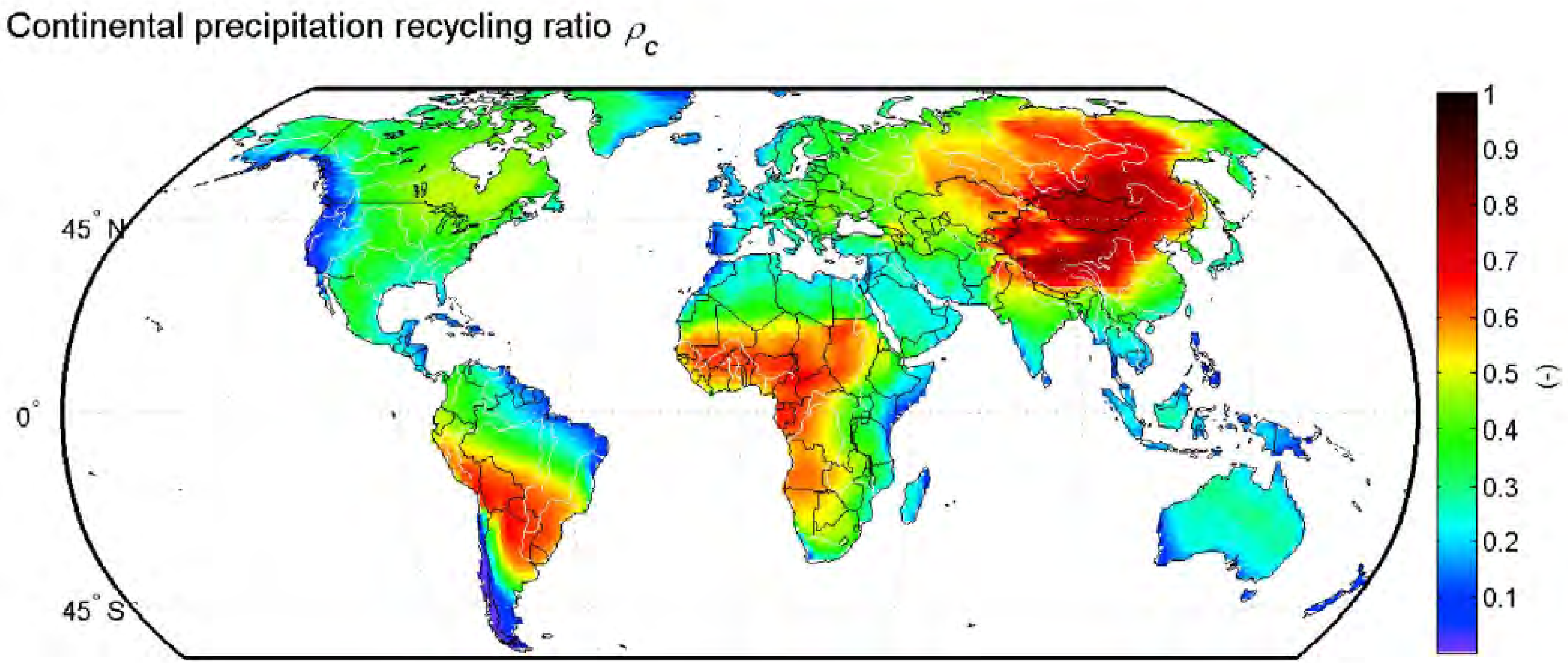
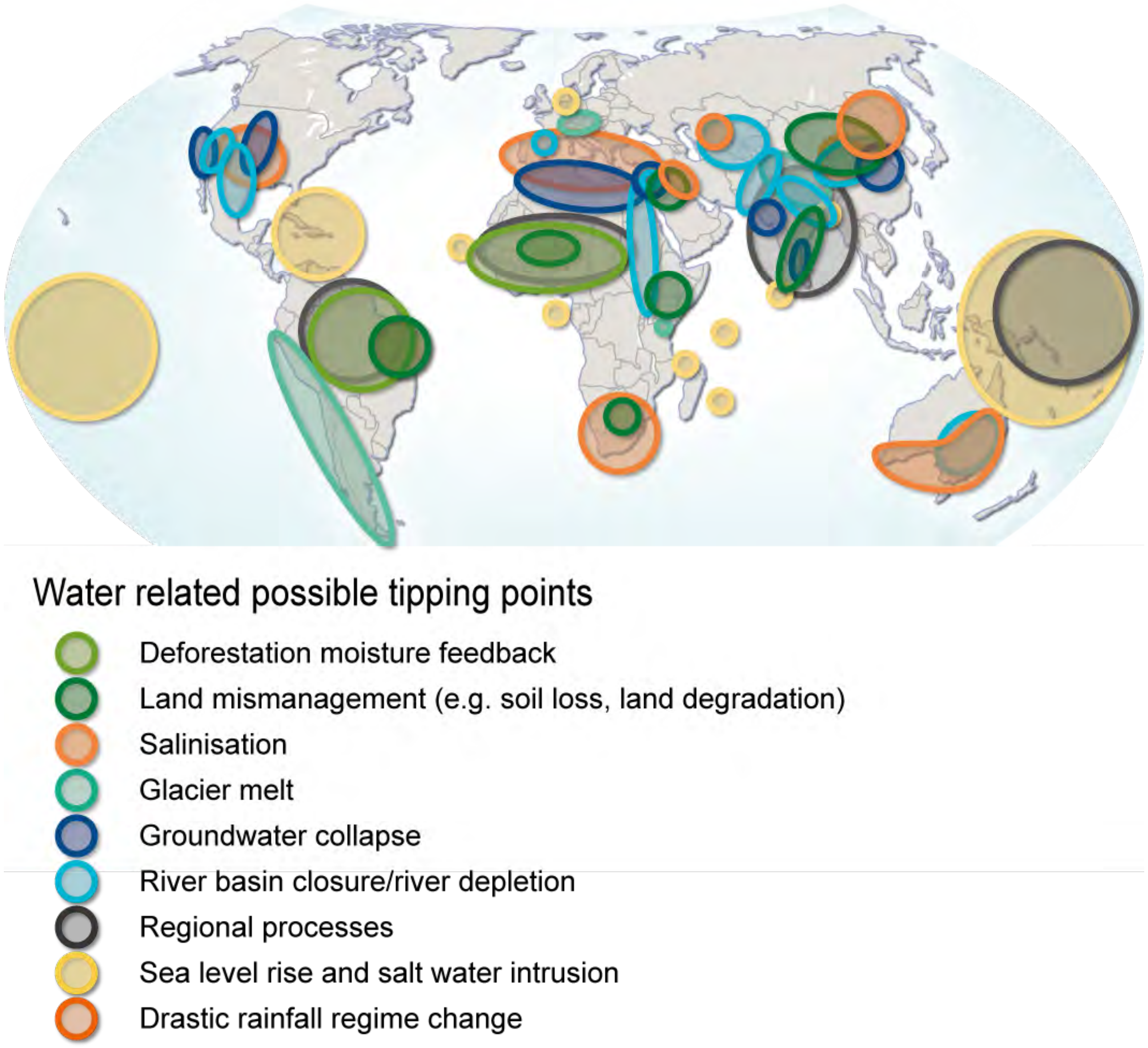
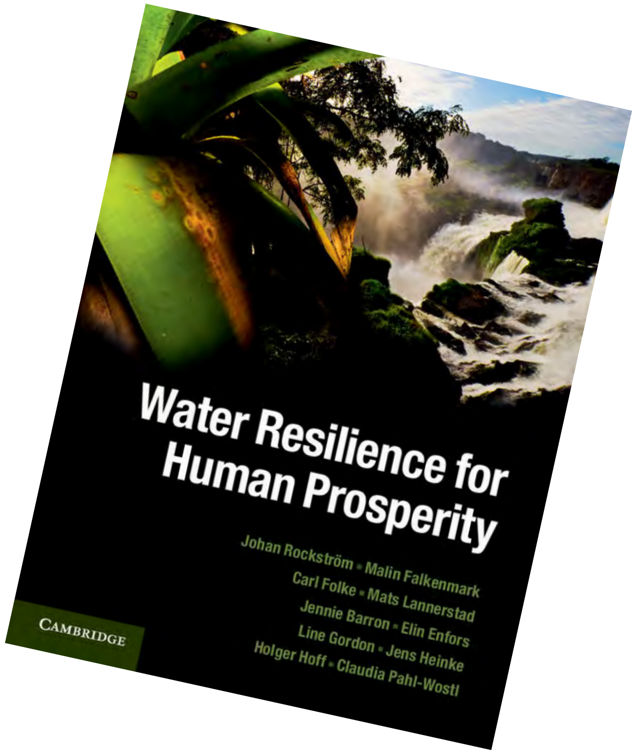


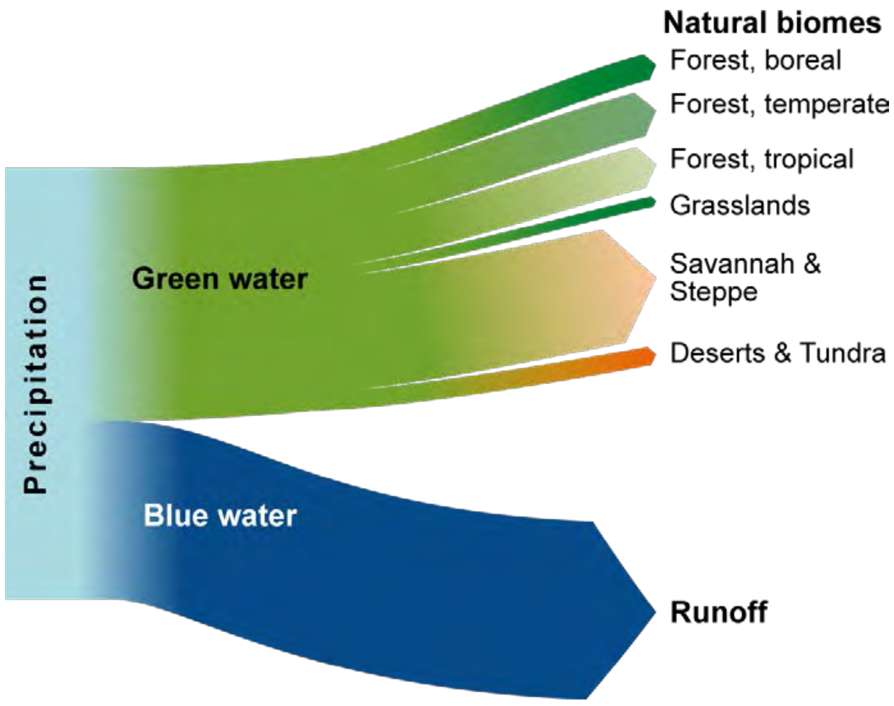

**Figure 3.** Average continental precipitation recycling ratio $\rho_c$ (1999–2008).

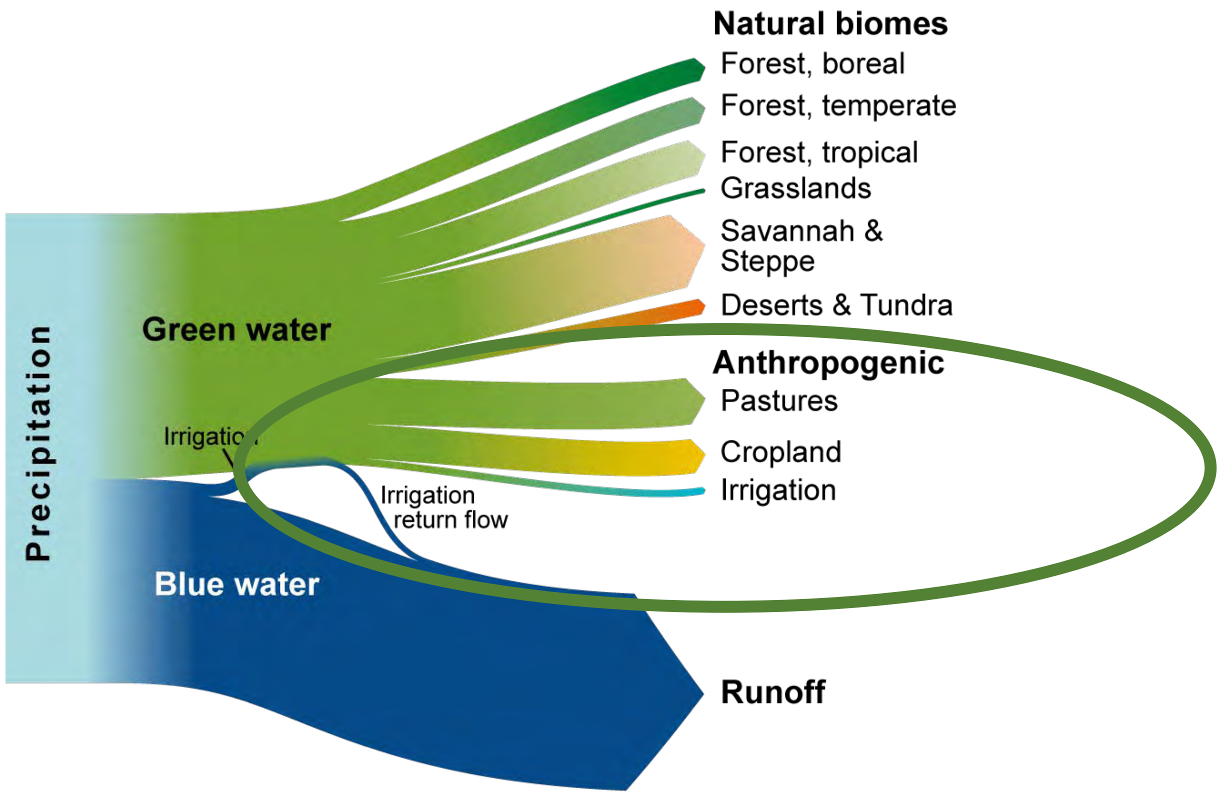
# Water related Tipping Elements in the Earth system



# Fundamental changes in global water appropriation



# Green Water

# The **Black Elephant** of the SDGs

COMMENT

RECRUITMENT Tips for hiring leaders emphasize emotional intelligence p.286 | PLANTS A symbiotic story of seeds and civilization p.288 | THEATRE The toll and the triumph of a life with OCD takes centre stage p.289 | OBITUARY Charles H. Townes, laser co-inventor, remembered p.292

BOBBY HAAS/NATIONAL GEOGRAPHIC CREATIVE

Terraced fields in the Simien Mountains, Ethiopia, help to conserve soil moisture.

## Increase water harvesting in Africa

Meeting global food needs requires strategies for storing rainwater and retaining soil moisture to bridge dry spells, urge **Johan Rockström** and **Malin Falkenmark**.

Concerned Scientists and Experts Declaration on Water, Hunger and Sustainable Development Goals

### Managing rain: the key to eradicating poverty and hunger

We scientists and experts, joining the 2014 World Water Week in Stockholm, are deeply concerned that sustainable management of rainwater in dry and vulnerable regions is missing in the goals and targets proposed by the UN Open Working Group (OWG) on Sustainable Development Goals (SDGs) on Poverty (Goal 1), Hunger (Goal 2) and Freshwater (Goal 6).

We commend the OWG for setting ambitious and aspirational global development goals of eradicating poverty and hunger and promoting equity, ensuring peace and transparent global governance, within the context of global sustainability for climate, oceans, and ecosystems.

Our concern arises from the failure to recognize the ominous congruence between, on the one hand, poverty, malnutrition, rapid population growth and economic reliance on agriculture, and the water challenges and predicament in semiarid tropical and subtropical climates on the other. These drylands are the most water vulnerable inhabited regions of the world, hosting the world's poorest countries.

This is a challenge of global importance. Drylands cover 41 percent of the world's land surface, host 44 percent of the world cultivated systems and are home to 2.1 billion people in nations with the world's highest population growth rates. Here, food production and human livelihoods rely on limited, highly variable, unreliable and unpredictable rain. When it rains, it often pours in intense convective storms that generate flash floods with eroding surface runoff, making fruitful rainfed agriculture and traditional irrigation extremely challenging. However, even in these areas there is generally enough rainfall and thus potential to drastically improve food production, if only we can guide more of the water to beneficial, productive uses.

By 2050, business-as-usual will mean 2 billion smallholder farmers, key managers and users of rainwater, eking out a living at the mercy of rainfall that is even less reliable than today due to climate change. Setting out to eradicate global poverty and hunger without addressing the productivity of rain is a serious and unacceptable omission. The proposed SDGs cannot be achieved without a strong focus on sustainable management of rainwater for resilient food production in tropical and subtropical drylands.

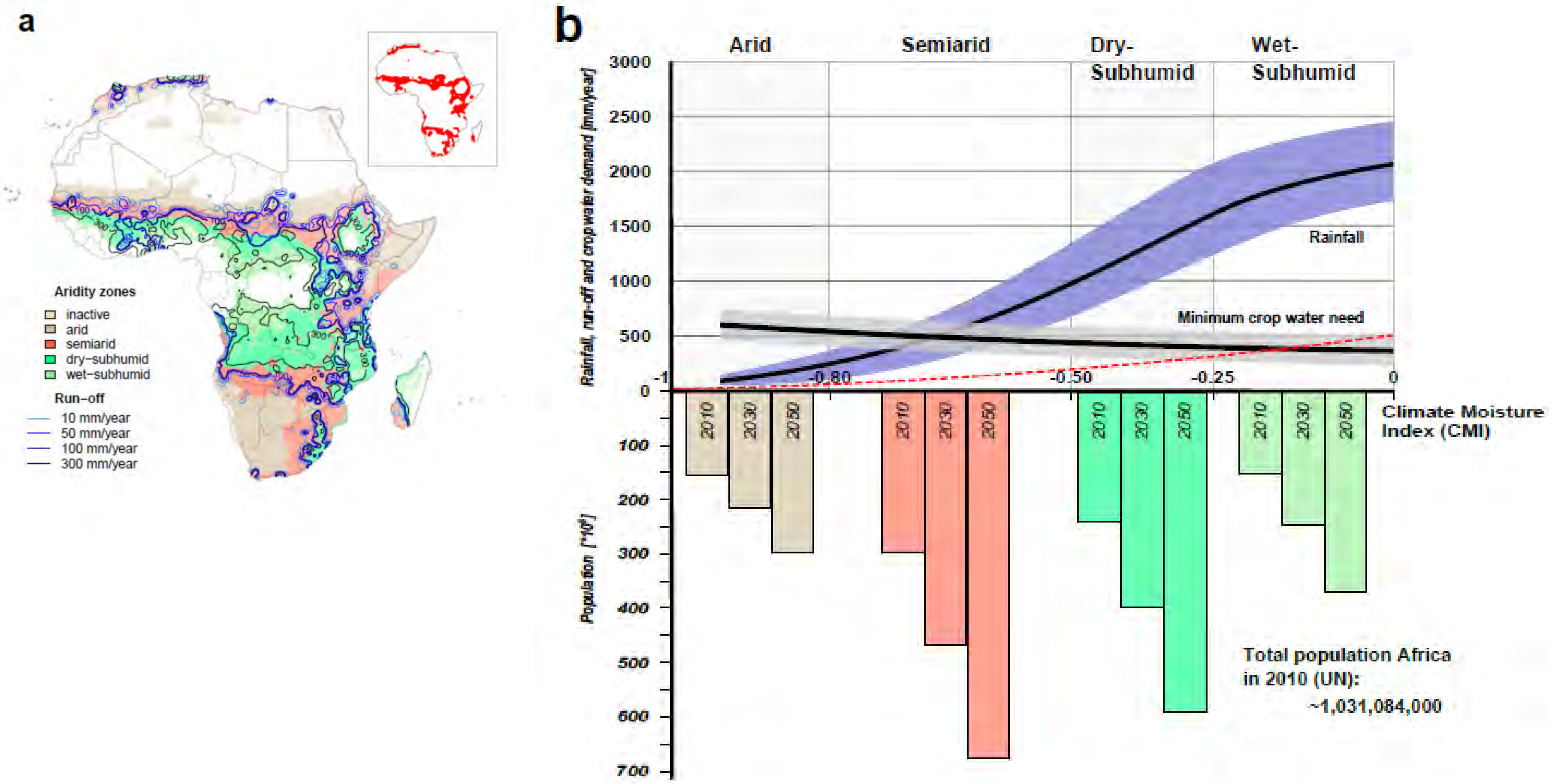
Sustainable development for the poorest dryland farmers depends on the ability to build resilience and raise agricultural production within the capacity of local and severely underutilised rainwater. Management practices and techniques, such as rainwater storage, efficient supplementary irrigation, and integrated management of water, land, crops and nutrients, can provide significant productivity gains and sustainable intensification of smallholder agriculture for livelihood improvements, community development and food security. This could also open the possibility for investments, stimulating further agricultural development, benefitting from experiences in mid- and high-income countries.

We therefore call upon the United Nations General Assembly to add in any Hunger Goal a target on sustainable and resilient rainwater management for improved food production, through the adoption of sustainable watershed management practices at all scales aiming for an increase of over 50% in the yield of food per unit of rainwater.

Stockholm 31 August 2014,

| | | |
|---|---|---|
| Malin Falkenmark, SIWI | Johan Rockström, SRC | Torgny Holmgren, SIWI |
| Mohamed Ait Kadi, GWP | Tony Allan, King's College | Naty Barak, NETAFIM |
| Jeremy Bird, IWMI | Fred Boltz, Rockefeller Foundation | Peter Gleick, Pacific Institute |
| David Grey, University of Oxford | Jerson Kelman, Federal University of Rio de Janeiro | Roberto Lenton, University of Nebraska |
| Julia Marton-Lefèvre, IUCN | Lisa Sennerby Forsse, SLU | |

# The Grand African Predicament




SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

# Water Resilience key lens for global sustainable development in the Anthropocene