Presentation from

2015 World Water Week in Stockholm

www.worldwaterweek.org

SIWI

Green Water Solutions Key for Sustainable Development

Malin Falkenmark Seminar
World Water Week
23rd August 2015

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Stockholm Resilience Centre

Photo: Yann Arthus-Bertrand

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Sustainability Science for Biosphere Stewardship
Stockholm University

A PARTNER WITH
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The Royal Swedish Academy of Sciences
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MISTRA
The Swedish Foundation for Strategic Environmental Research

ANALYSIS

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Solutions for a cultivated planet

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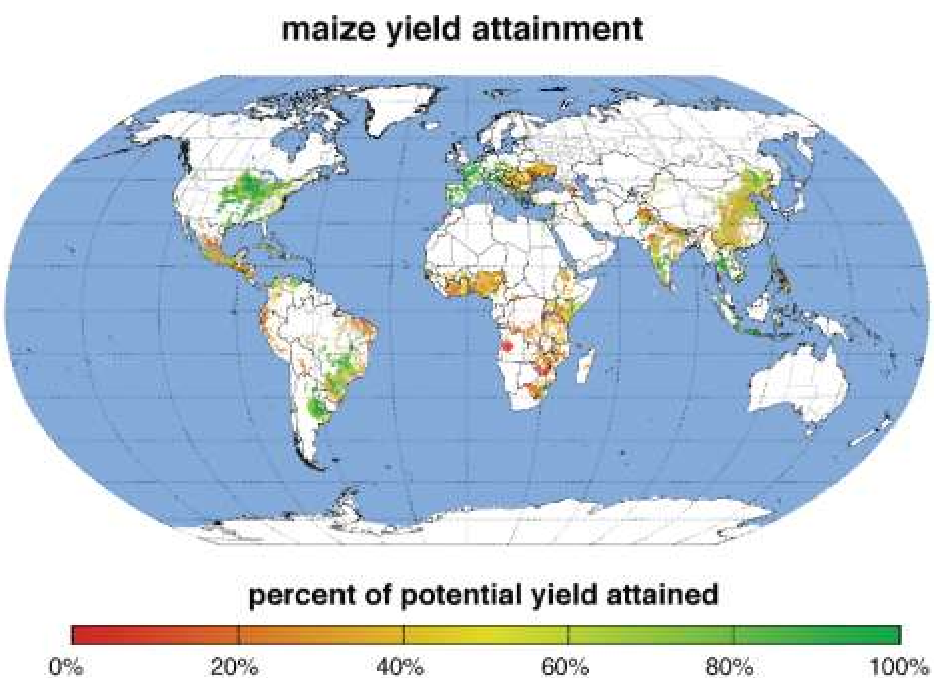
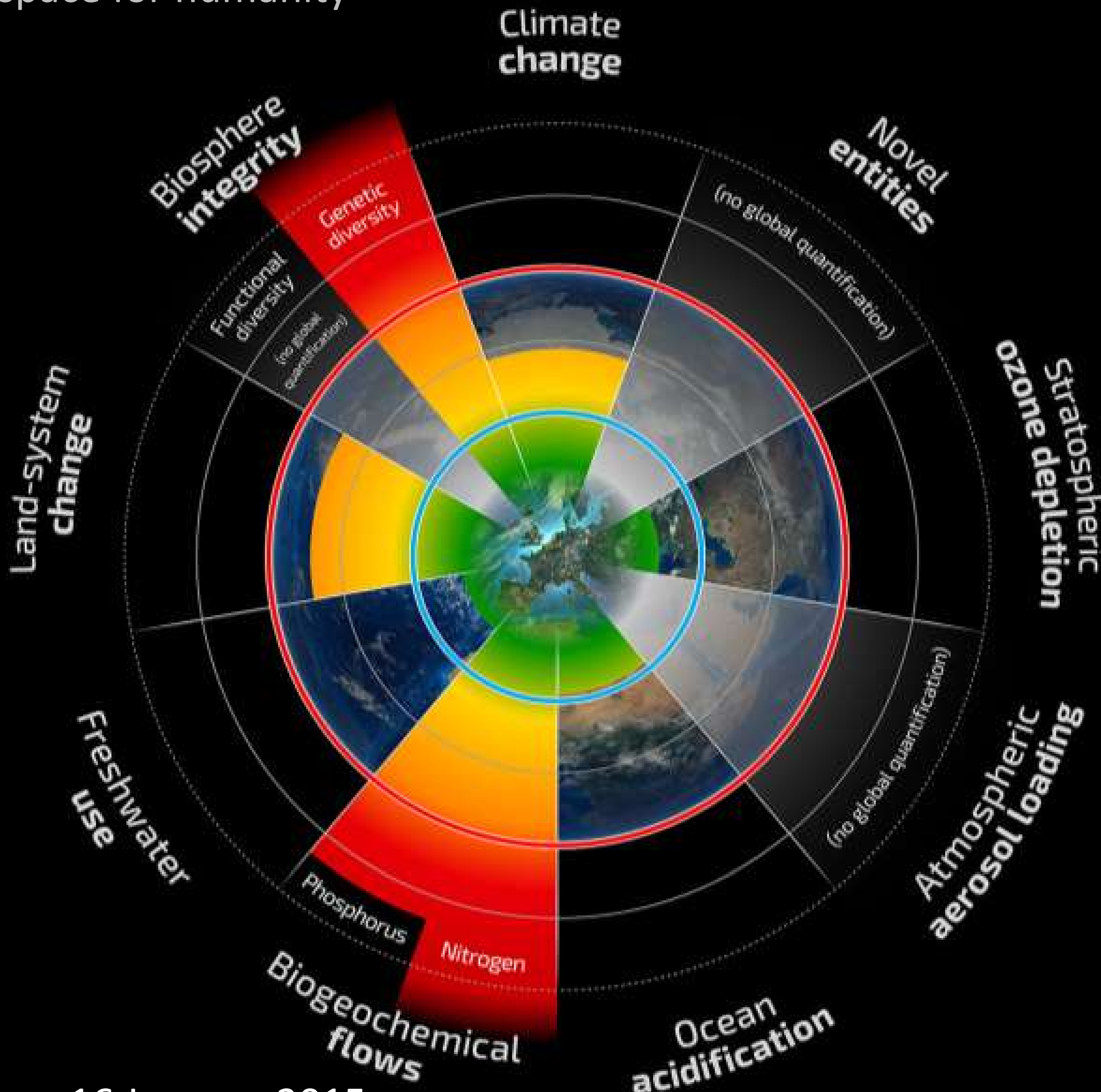


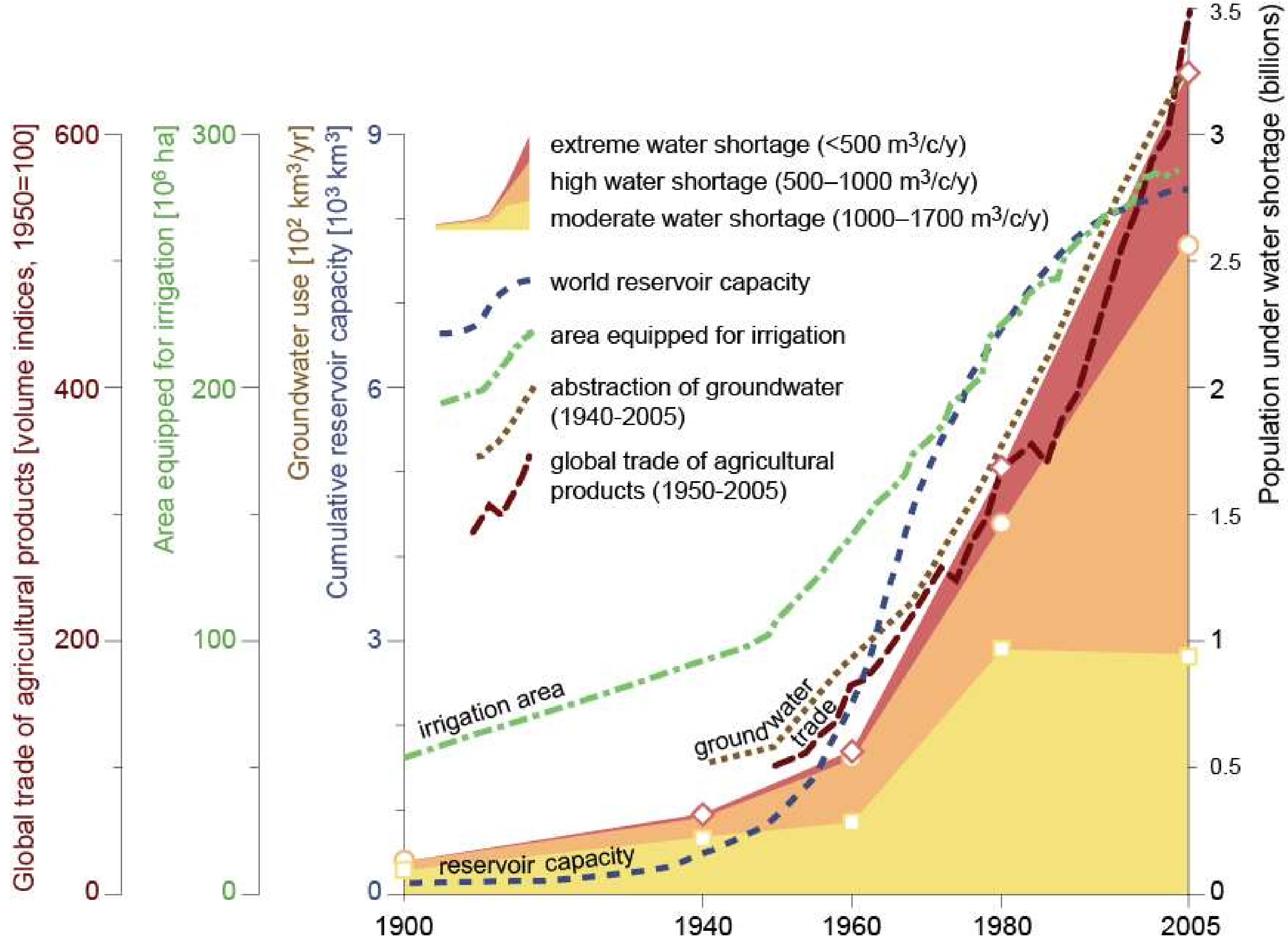
Planetary Boundaries

A safe operating space for humanity



Steffen *et al* Science 16 January 2015

Earth System Process	Control Variables	Planetary Boundary (zone of uncertainty)	Current Value of Control Variables
Climate change	Atmospheric CO_2 concentration, ppm	350 ppm CO_2 (350–450 ppm)	396.5 ppm CO_2
	Energy imbalance at top-of-atmosphere, W/m^2	Energy imbalance: +1.0 W m^{-2} (+1.0–1.5 W m^{-2})	2.3 W m^{-2} (1.1–3.3 W m^{-2})
Biosphere integrity	Genetic diversity: Extinction rate	Genetic: < 10 E/MSY (10–100 E/MSY) but with an aspirational goal of ca. 1 E/MSY (the background rate of extinction loss). E/MSY = number of extinctions each year per million species	100–1,000 E/MSY
	Functional diversity: Biodiversity Intactness Index (BII) Note: These are interim control variables until more appropriate ones are developed	Functional: Maintain BII at 90% (90–30%) or above, assessed geographically by biomes/ large regional areas (for example, southern Africa), major marine ecosystems (for example, coral reefs) or by large functional groups	84.4%, applied to southern Africa only
Novel entities	No control variable currently defined	No boundary currently identified, but see boundary for stratospheric ozone for an example of a boundary related to a novel entity (CFCs)	
Stratospheric ozone depletion	Stratospheric O_3 concentration, DU	<5% reduction from pre-industrial level of 290 DU (5%–10%), assessed by latitude	Only transgressed over Antarctica in Austral spring (~200 DU)
Ocean acidification	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	≥80% of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (≥80%– ≥70%)	~84% of the pre-industrial aragonite saturation state
Biogeochemical flows: (P and N cycles)	P cycle — Global: P flow from freshwater systems into the ocean	Global: 11 Mt P yr^{-1} (11–100 Mt P yr-1)	22 Mt P yr^{-1}
	P cycle — Regional: P flow from fertilizers to erodible soils	Regional: 3.72 Mt yr^{-1} mined and applied to erodible (agricultural) soils (3.72–4.84 Mt yr^{-1}). Boundary is a global average but regional distribution is critical for impacts.	~14 Mt P yr^{-1}
	N cycle — Global: Industrial and intentional biological fixation of N	44.0 Mt N yr^{-1} (44.0–62.0 Mt N yr^{-1}). Boundary acts as a global "valve" limiting introduction of new reactive N to Earth system, but regional distribution of fertilizer N is critical for impacts.	~150 Mt N yr^{-1}
Land-system change	Global: area of forested land as % of original forest cover	Global: 75% (75–54%) Values are a weighted average of the three individual biome	62%
Freshwater use	Global: Maximum amount of consumptive blue water use (km^3yr^{-1})	Global: 4,000 km^3 yr^{-1} (4,000–6,000 km^3 yr^{-1})	~2,600 km^3 yr^{-1}
	Basin: Blue water withdrawal as % of mean monthly runoff	Basin: Maximum monthly withdrawal as a percentage of mean monthly runoff. For low-flow months: 25% (25–55%); for intermediate-flow months: 30% (30–60%); for high-flow months: 55% (55–85%)	
	Monsoon used as a case study	scattering) AOD over Indian subcontinent of 0.25 (0.25–0.50); absorbing (warming) AOD less than 10% of total AOD	

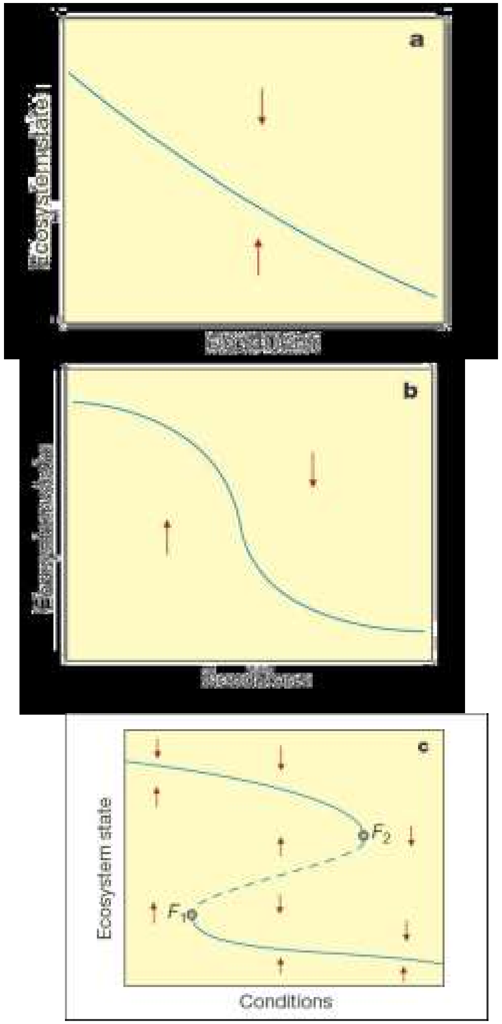


Kummu, Ward, de Moel, Varis 2010 Environmental Research Letters

CRITICAL TRANSITIONS

Critical transitions or regime shifts

Regime shifts are substantial, persistent, reorganizations in ecosystem structure and processes

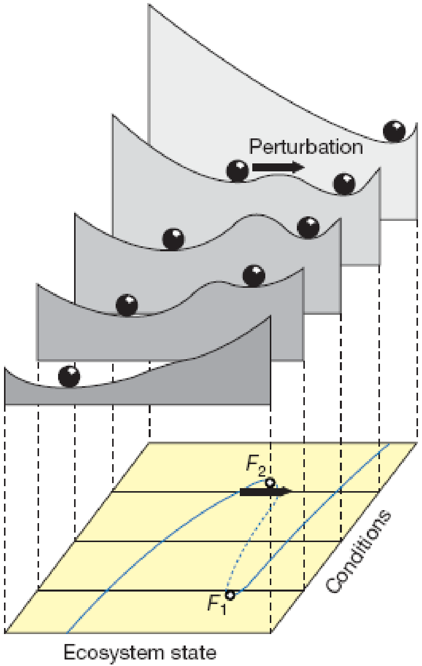


Parkland Savanna

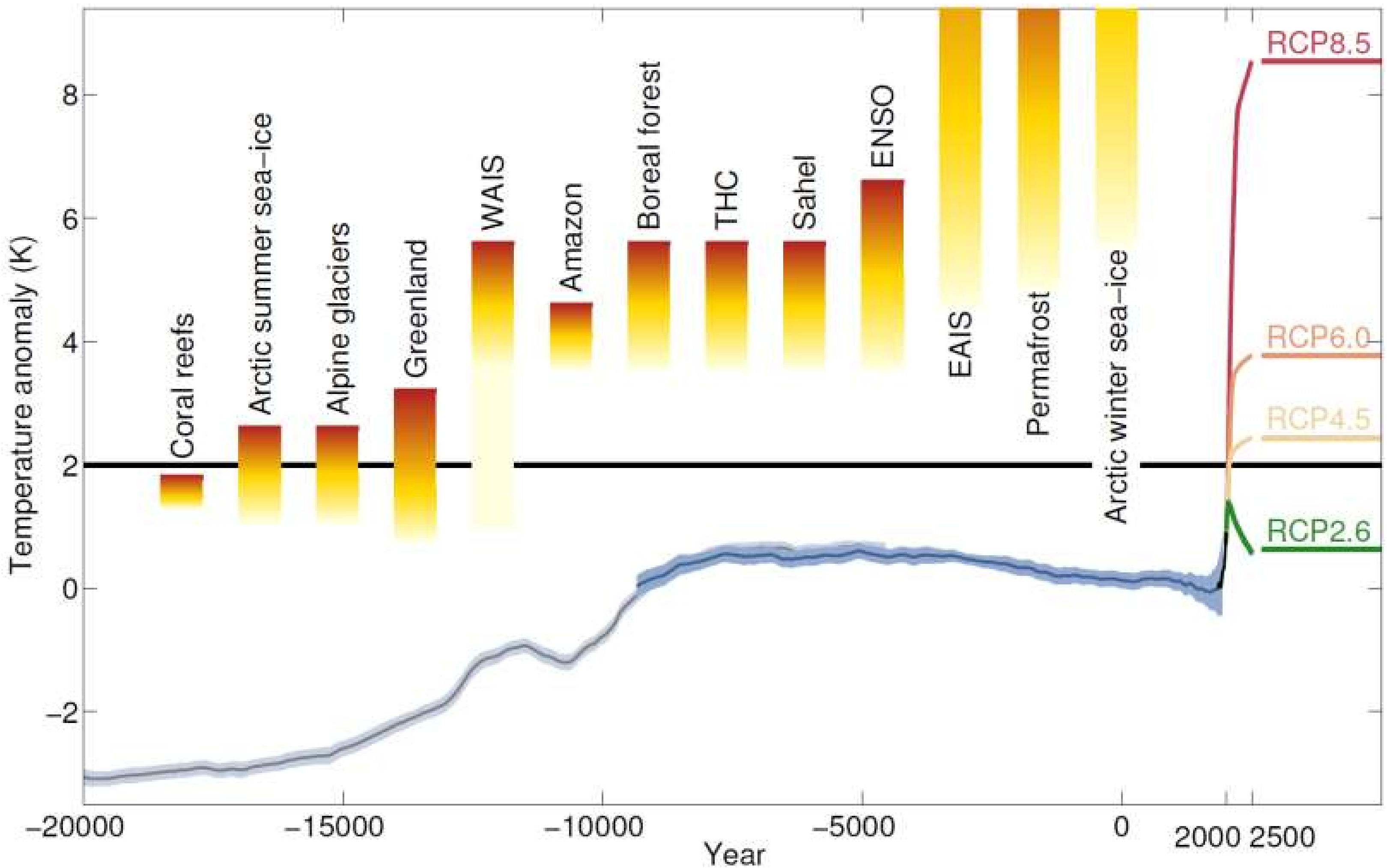
Bush steppe

Diverse Coral dominated

Algae Dominated Reef



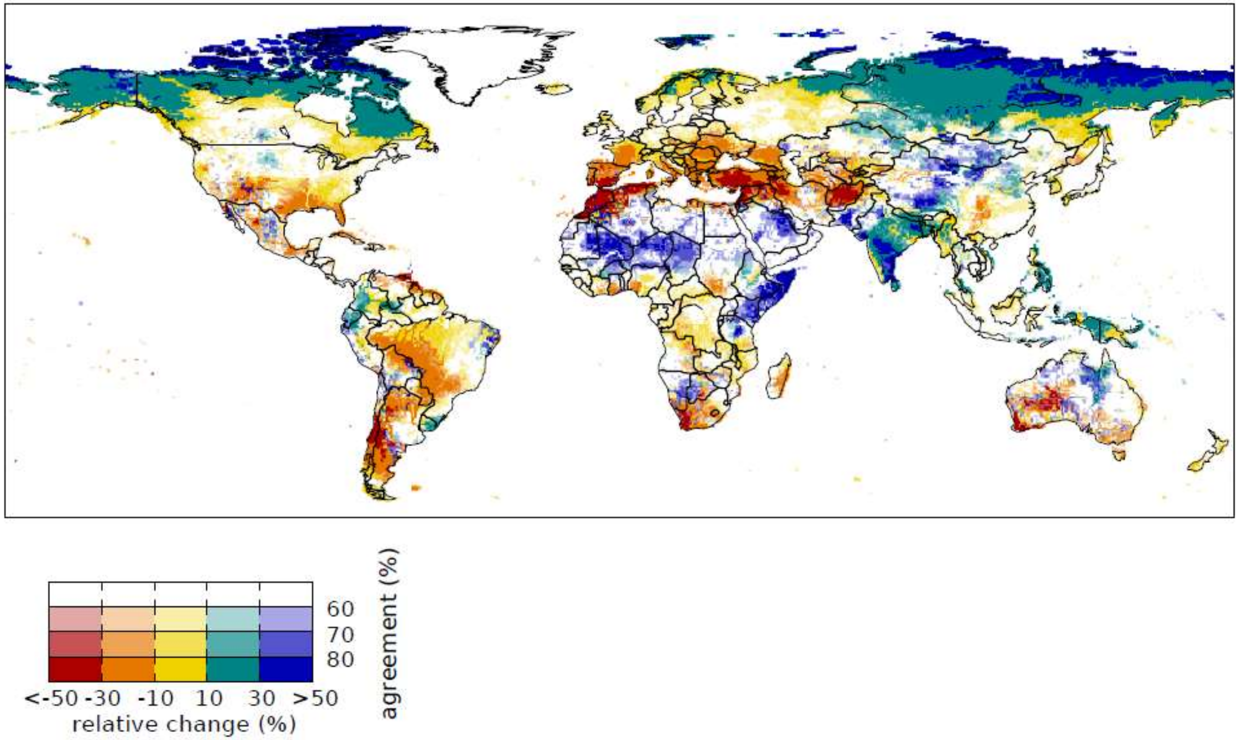
Tipping Points Related to 2°C-Guardrail



Schellnhuber et al., under review.

Multi-model assessment of water scarcity under climate change

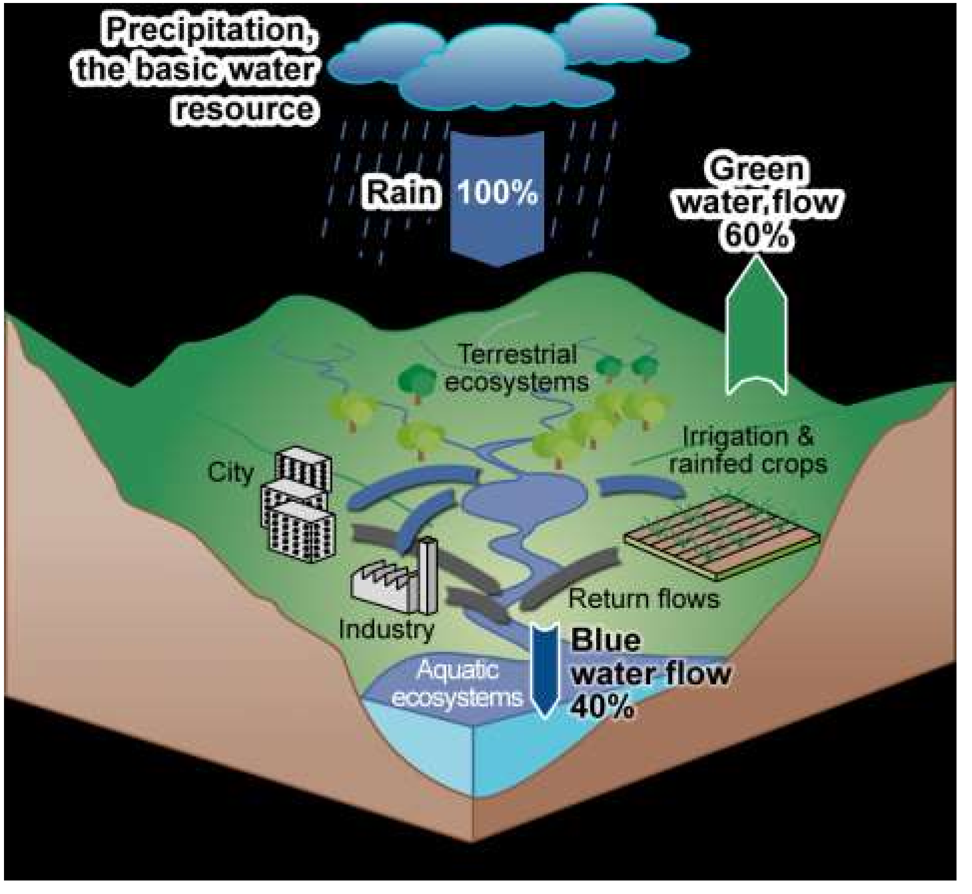
Jacob Schewe [*], Jens Heinke [*] [a], Dieter Gerten [*], Ingjerd Haddeland [†], Nigel W. Arnell [‡], Douglas B. Clark [§], Rutger Dankers [¶], Stephanie Eisner [‖], Balázs Fekete [**], Felipe J. Colón-González[b], Simon N. Gosling [††], Hyungjun Kim [‡‡], Xingcai Liu [§§], Yoshimitsu Masaki [¶¶], Felix T. Portmann [***], Yusuke Satoh [†††], Tobias Stacke [‡‡‡], Qiuhong Tang [§§], Yoshihide Wada [§§§], Dominik Wisser[c], Torsten Albrecht [*], Katja Frieler [*], Franziska Piontek [*], Lila Warszawski [*], and Pavel Kabat [¶¶¶]



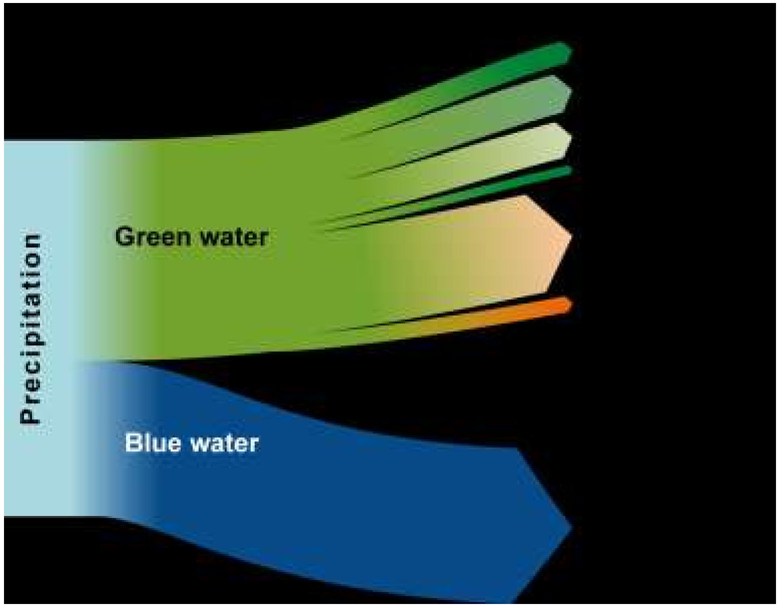
Humanity at a critical water junctre

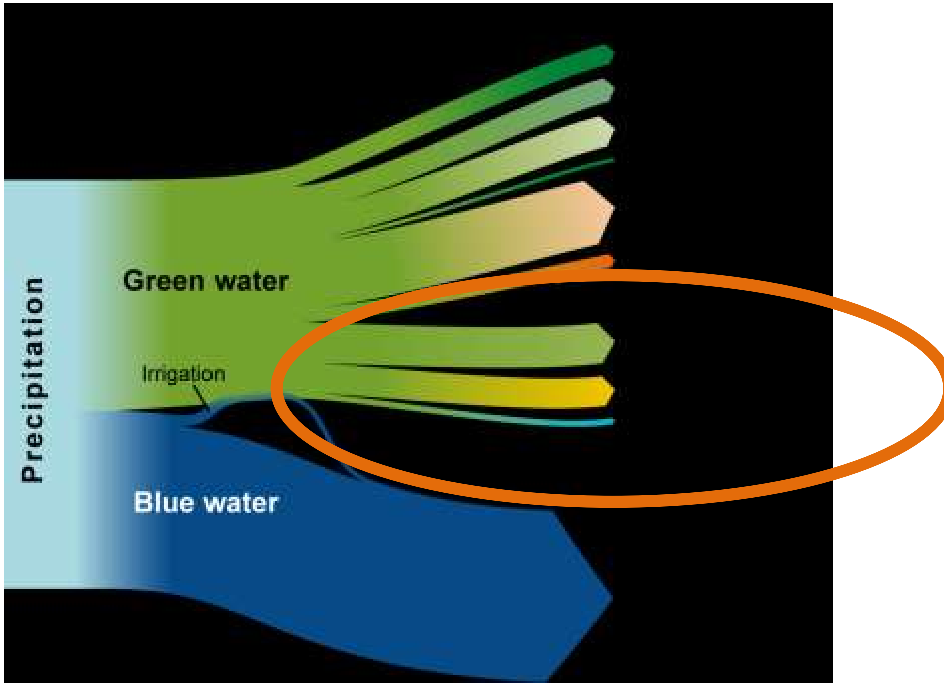
Green water provides (the only?) path forward

The issues:
Pressures for green water management

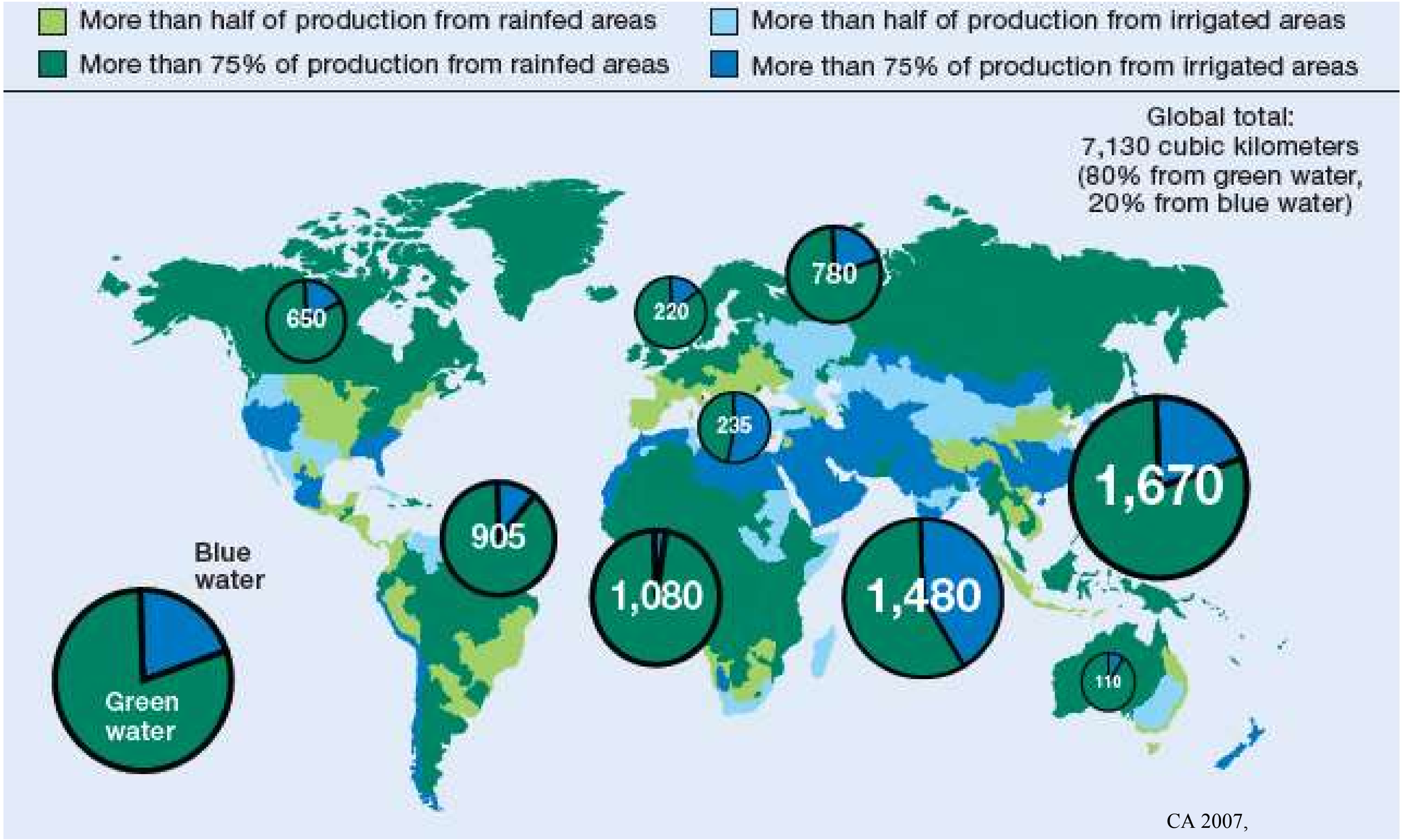


Fundamental changes in global water appropriation

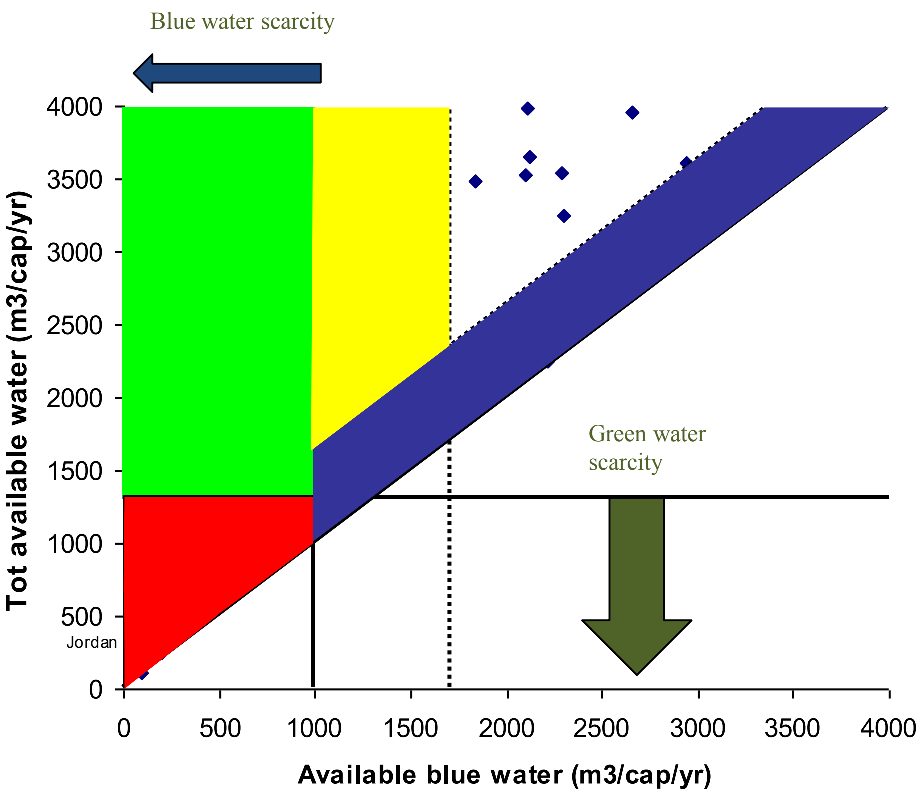


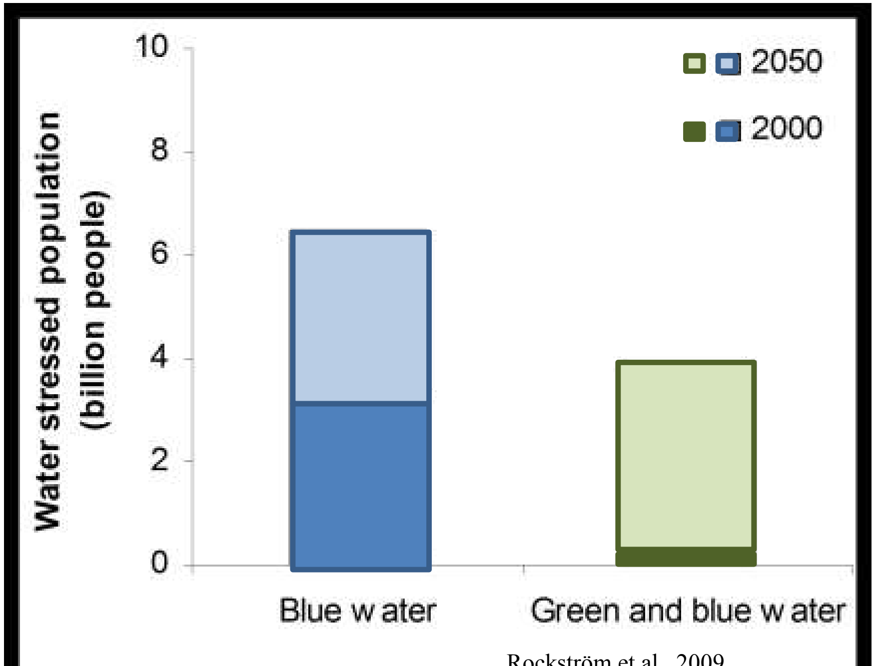


Green water management sustaining food, fodder and fibre production



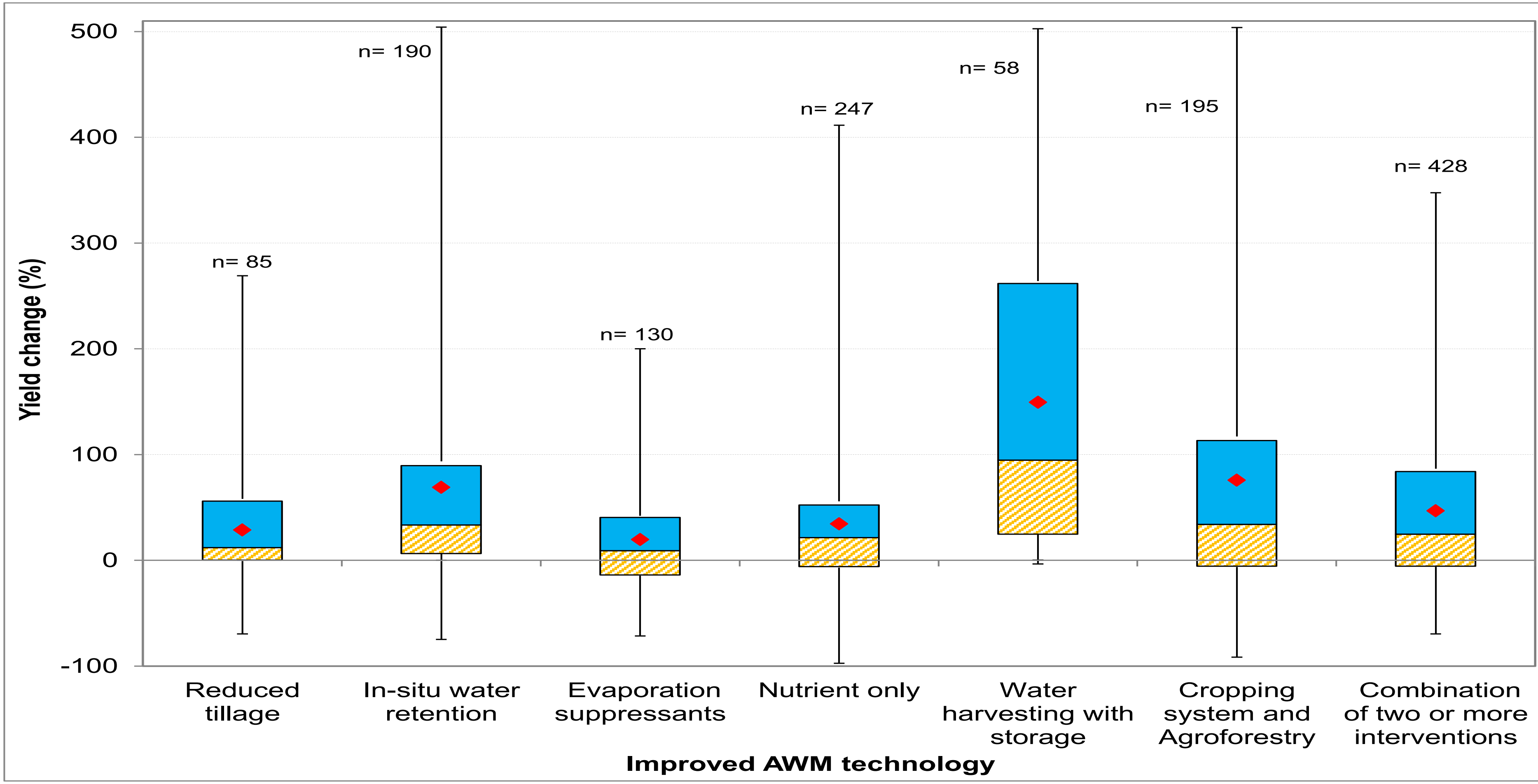
Green water management real opportunity





Rockström et al., 2009.

We know how to explore green water to close yield gaps



Magombeyi et al (forthcoming) : Agricultural water management systematic review and yield benefits for Limpopo

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.

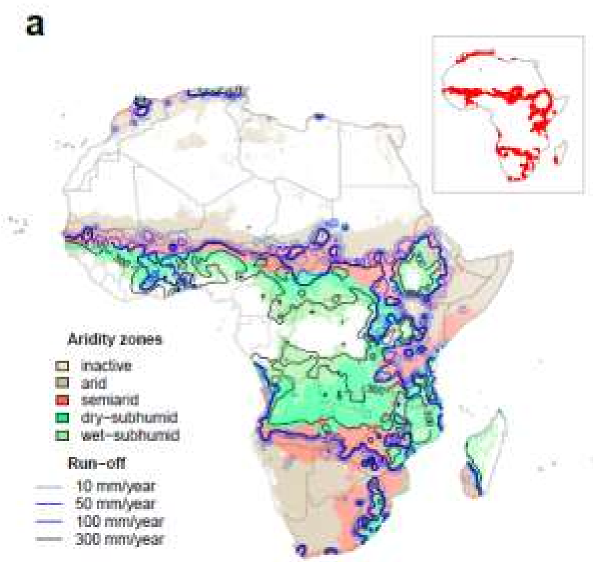
Sustainable development for the poorest dryland farmers depends on the ability to build resilience and raise agricultural production within the capacity of local and severely underutilised rainwater. Management practices and techniques, such as rainwater storage, efficient supplementary irrigation, and 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.

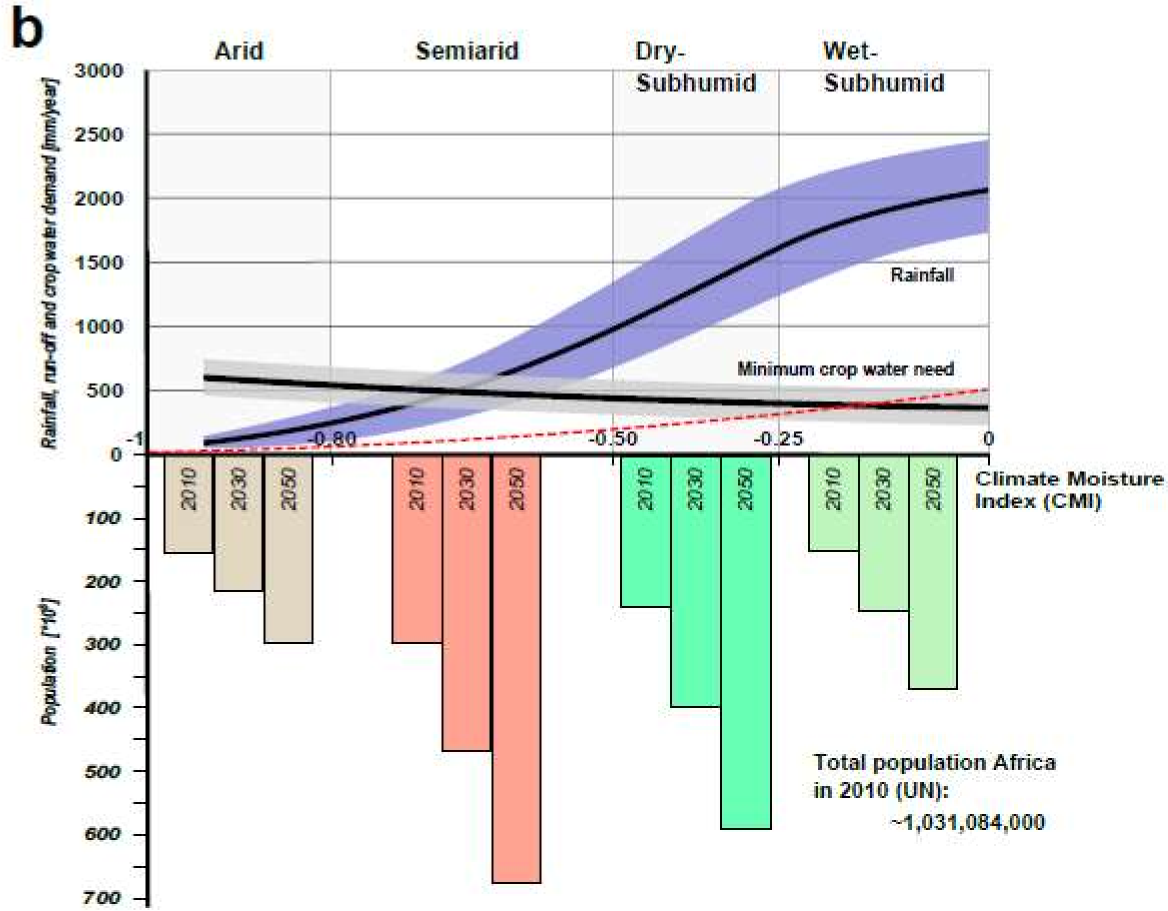
We therefore call upon the United Nations General Assembly to add in any Hunger Goal a target on sustainable and resilient rainwater management for improved food production, through the adoption of sustainable watershed management practices at all scales aiming for an increase of over 50% in the yield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

Stockholm 31 August 2014,

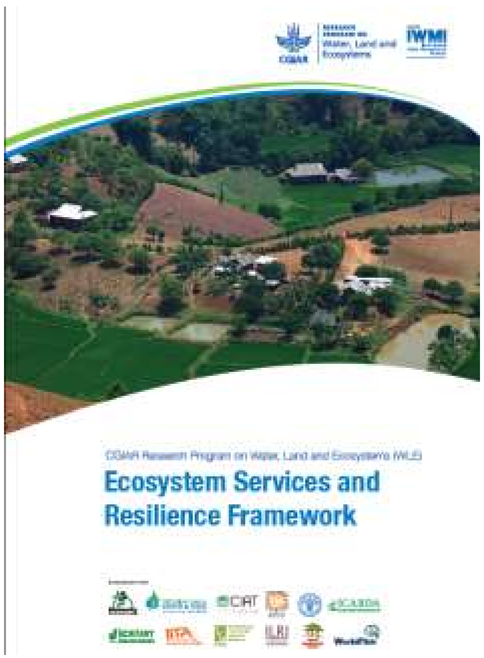
Malin Falkenmark, SIWI	Johan Rockström, SRC	Torgny Holmgren, SIWI
Mohamed Ait Kadi, GWP	Tony Allan, King's College	Naty Barak, NETAFIM
Jeremy Bird, IWMI	Fred Boltz, Rockefeller Foundation	Peter Gleick, Pacific Institute
David Grey, University of Oxford	Jerson Kelman, Federal University of Rio de Janeiro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

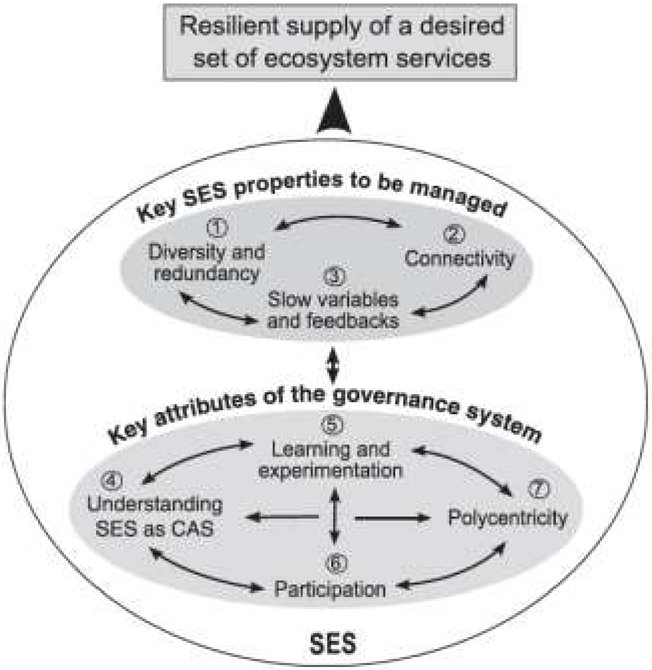
The Grand African Predicament

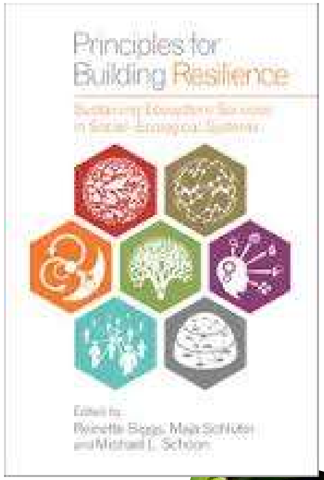


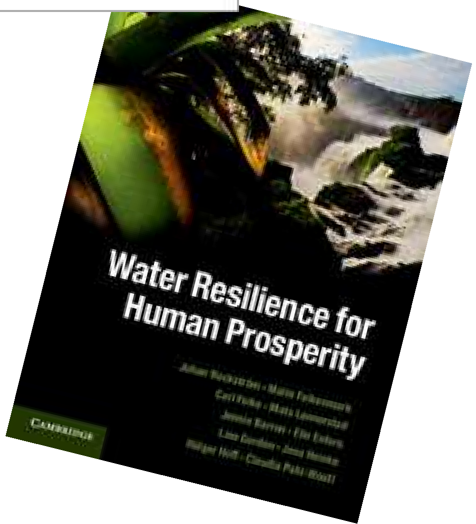


Green water management in the context of sustainable intensification and building water resilience

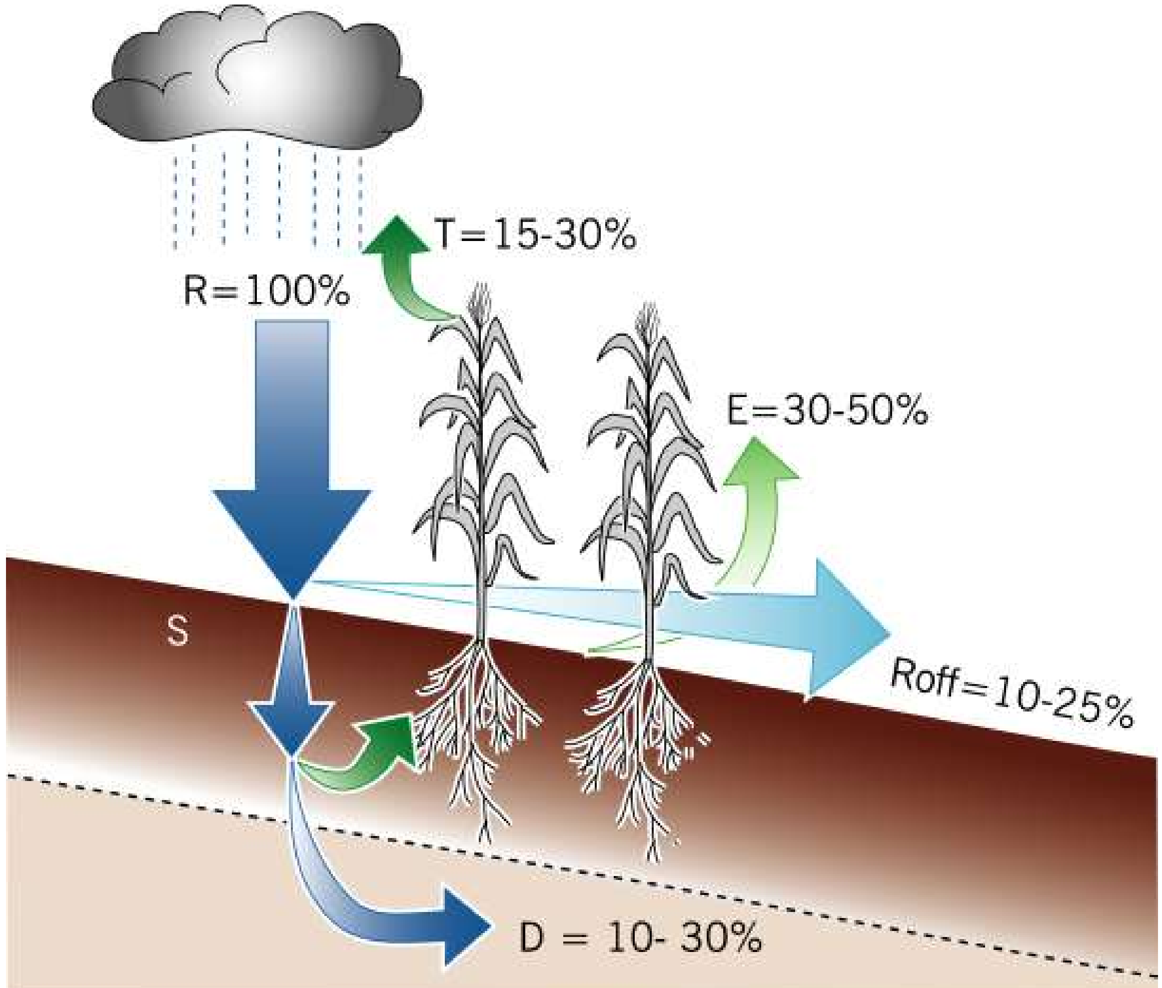








Green Water Solutions



T=15-30%
R=100%
E=30-50%
S
Roff=10-25%
D = 10- 30%

Rainfall dependent on moisture feedback from functioning forest landscapes

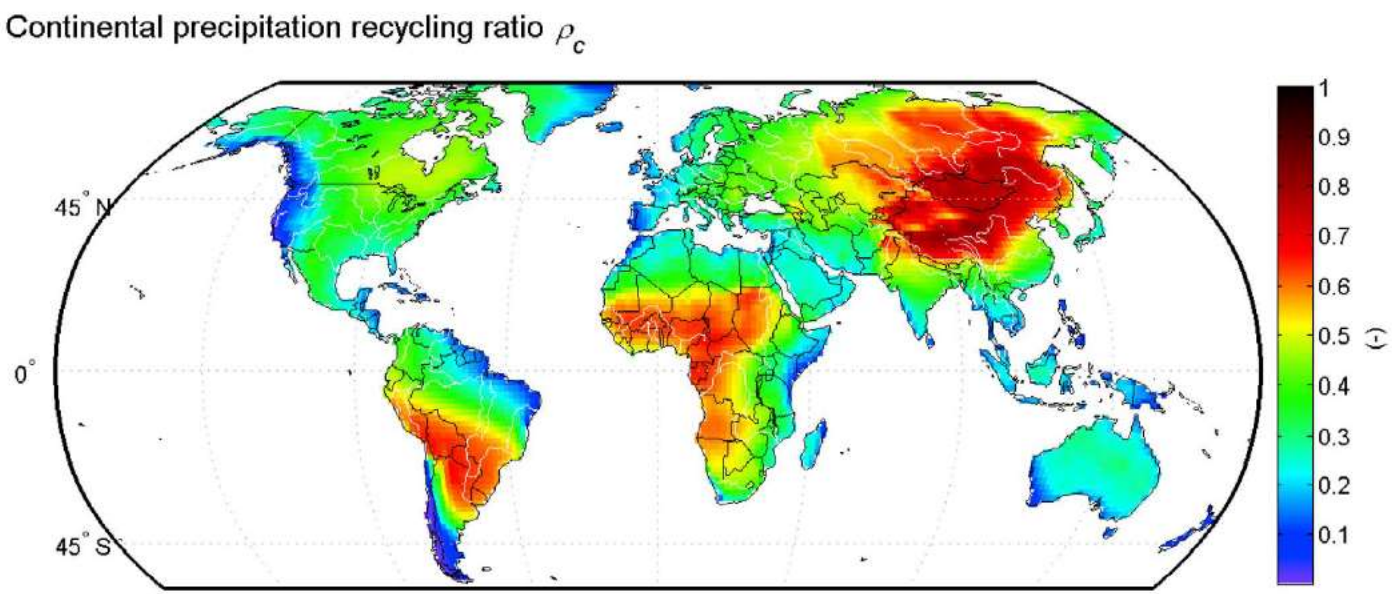
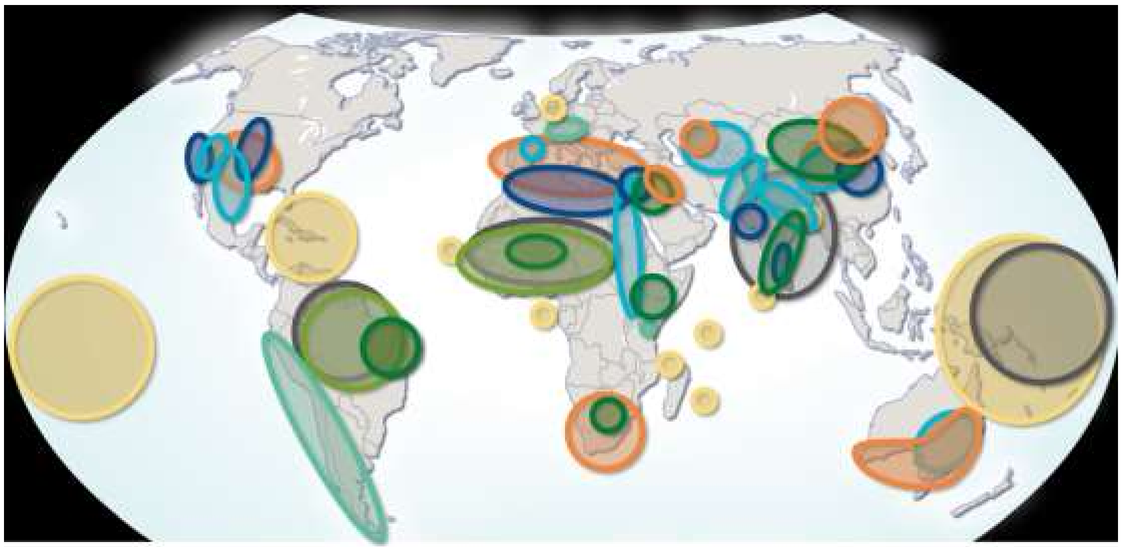


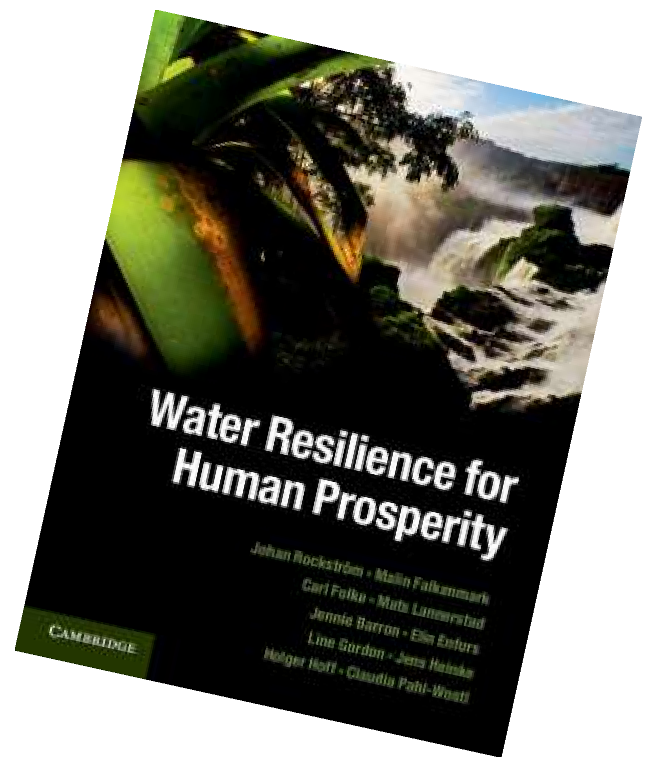
Figure 3. Average continental precipitation recycling ratio ρ_c (1999–2008).

Water related Tipping Elements in the Earth system



Water related possible tipping points

- Deforestation moisture feedback
- Land mismanagement (e.g. soil loss, land degradation)
- Salinisation
- Glacier melt
- Groundwater collapse
- [redacted]



Building on adaptive Innovation

A triply green approach to sustainable intensification

Rainwater harvesting

IWRM discourse advancing to explicitly include green water management

Dominating pre-1990s

Blue water - sector approach

Economic and engineering approach to freshwater, water supply

Established 1990s

Integrated blue water - IWRM

Economic approach to freshwater, including environmental water flows

Starting 2000s

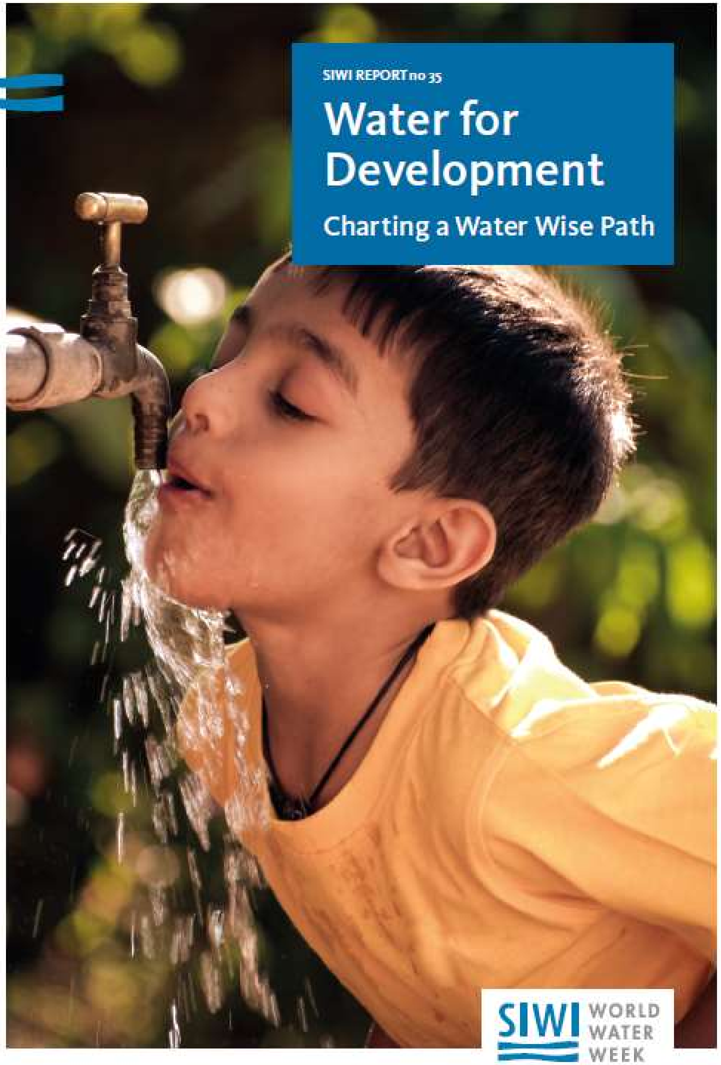
Integrated green and blue water - ILWRM

IWRM adding land interactions, i.e. green water resources for food and ecosystem services

Green and blue water with social-ecological interactions and global change - Resilience based ILWRM

ILWRM with resilience addressing: the need to sustain rainfall, cross-scale interactions and feedbacks

Implications for the SDGs?



Chapter 13

Double water blindness delaying sub-Saharan green revolution

By Malin Falkenmark and Johan Rockström

Chapter 7

Healthy freshwater ecosystems: an imperative for human development and resilience

Frederick Boltz, Alex Martinez, Casey Brown and Johan Rockström

From MDGs to SDGs

SUSTAINABLE DEVELOPMENT GOALS

GOAL 1	End poverty in all its forms everywhere
GOAL 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
GOAL 3	Ensure healthy lives and promote well-being for all at all ages
GOAL 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
GOAL 5	Achieve gender equality and empower all women and girls
GOAL 6	Ensure availability and sustainable management of water and sanitation for all
GOAL 7	Ensure access to affordable, reliable, sustainable and modern energy for all
GOAL 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
GOAL 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
GOAL 10	Reduce inequality within and among countries
GOAL 11	Make cities and human settlements inclusive, safe, resilient and sustainable
GOAL 12	Ensure sustainable consumption and production patterns
GOAL 13	Take urgent action to combat climate change and its impacts
GOAL 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
GOAL 15	Protect, restore and promote sustainable use of terrestial ecosystems, sustainably manage forests, combat destertification, and halt and reverse land degradation and halt biodiversity loss
GOAL 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountabe and inclusive institutions at all levels
GOAL 17	Strenghten the means of implementation and revitalize the global partnership for sustainable development

Sustainable Development Goals for People and Planet

The Earth Statement

8 Essential Elements for a Successful Paris Deal