EMSAfrica
Ecosystem Management Support for Climate Change in Southern Africa

SENCKENBERG
world of biodiversity

Bundesministerium für Bildung und Forschung

Uncertainties of climate and CO_2 impacts on carbon stocks and biome distribution in Africa

Carola Martens, Thomas Hickler, Claire Davis-Reddy, Francois Engelbrecht, Steven I. Higgins, Graham P. von Maltitz, Guy F. Midgley, Mirjam Pfeiffer, and Simon Scheiter

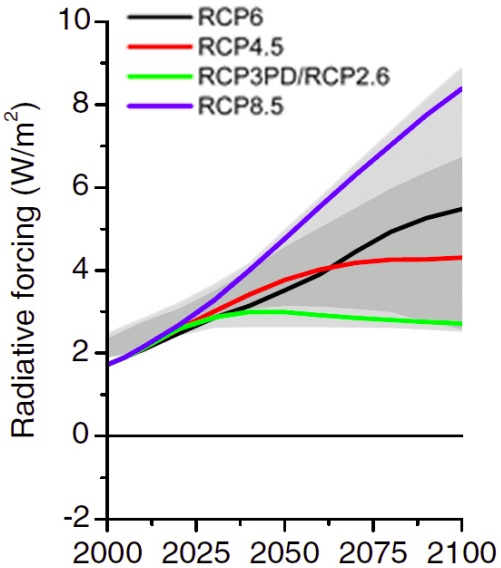
EGU General Assembly 2020 – Sharing Geoscience Online
Session BG3.15
08.05.2020

Leibniz Association

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Future vegetation projections are constrained by uncertainties

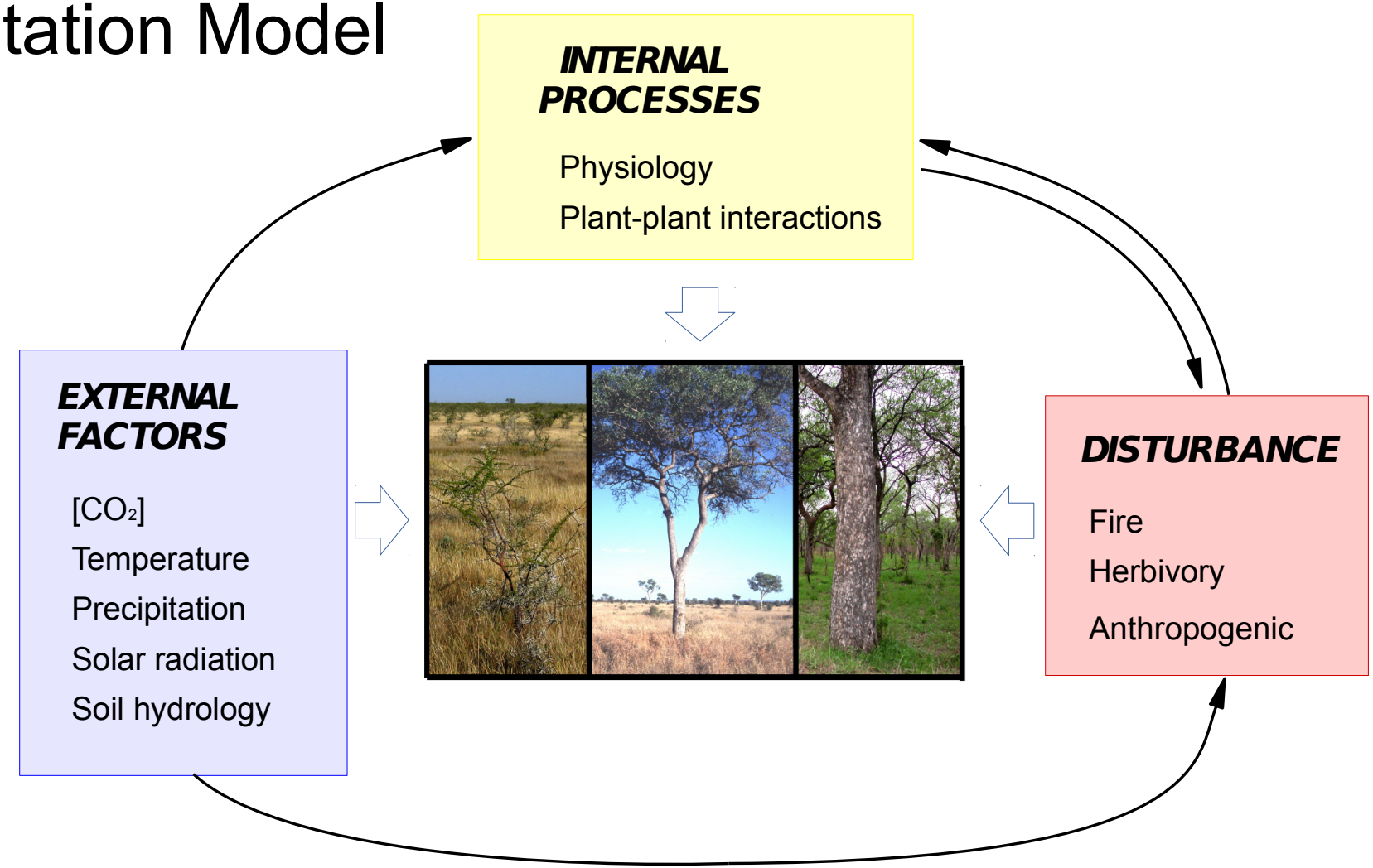
- Climate change is expected to have profound impacts on biodiversity and ecosystem services in Africa.
- But vegetation projections are constrained by uncertainties regarding
  - strength and impact of climate change,
  - socioeconomic futures, and
  - CO_2 fertilisation effects.



(van Vuuren et al., 2011, Climatic Change)

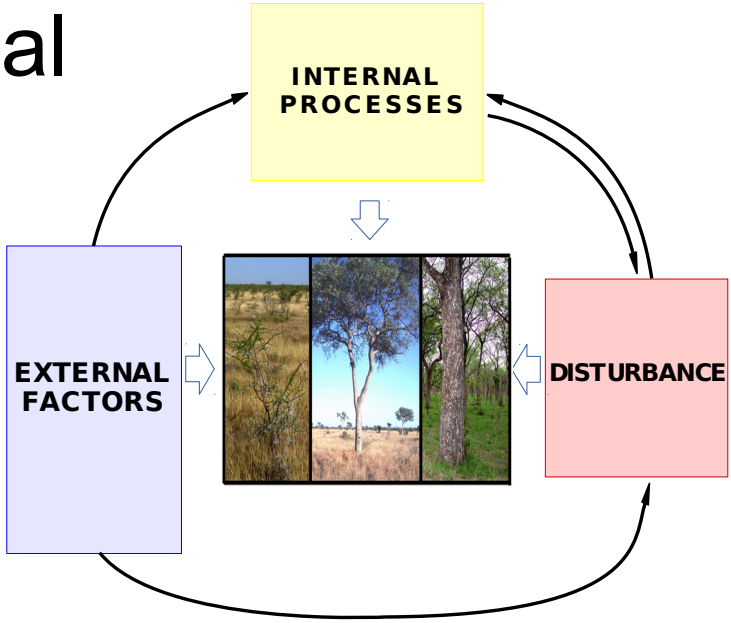
We used an ensemble of DGVM simulations with the aDGVM to look at the uncertainties.

aDGVM – adaptive Dynamic Global Vegetation Model



The aDGVM is a vegetation model for grass-tree ecosystems.

aDGVM – adaptive Dynamic Global Vegetation Model



The aDGVM …

- … was developed for tropical ecosystems;
- … simulates individual trees, and plants can adjust allocation and phenology to the environment;
- … simulates different vegetation types: savanna trees, forest trees, C_4 grasses, C_3 grasses;
- … includes fire dynamics, and impacts on trees are influenced by tree height.

Ensemble simulations to deal with uncertainty

We used an ensemble of aDGVM simulations to look at the uncertainties in vegetation projections.

We forced the aDGVM with climate projections from 6 different

- General Circulation Models (GCMs),
- for two different Representative Concentration Pathways (RCP4.5 & RCP8.5), and
- two CO_2 scenarios (increasing according to RCP scenario & fixed at 400ppm).

→ ensemble of 24 aDGVM simulations

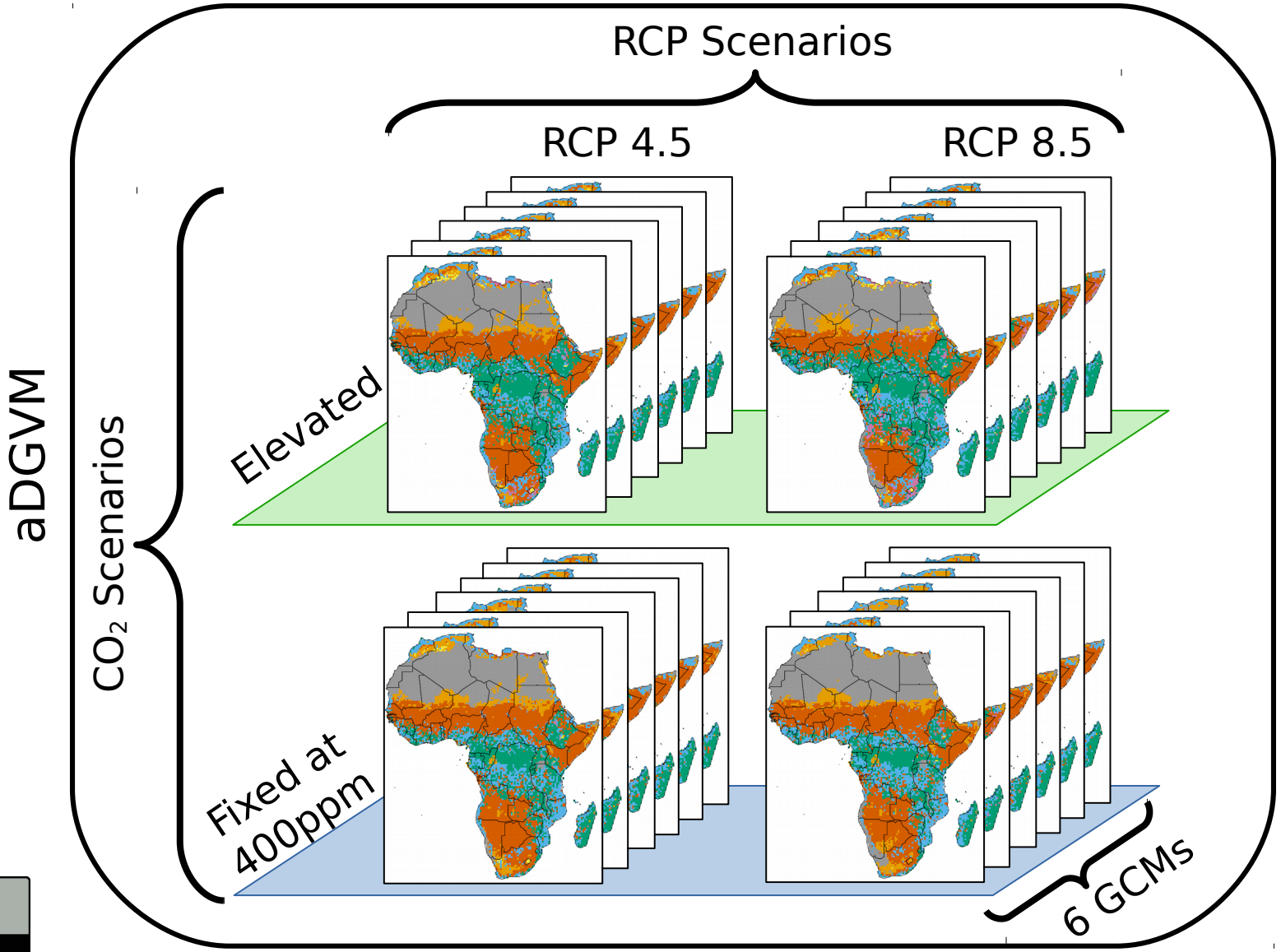
Differences within the ensemble allow quantification of different uncertainties in vegetation projections.

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

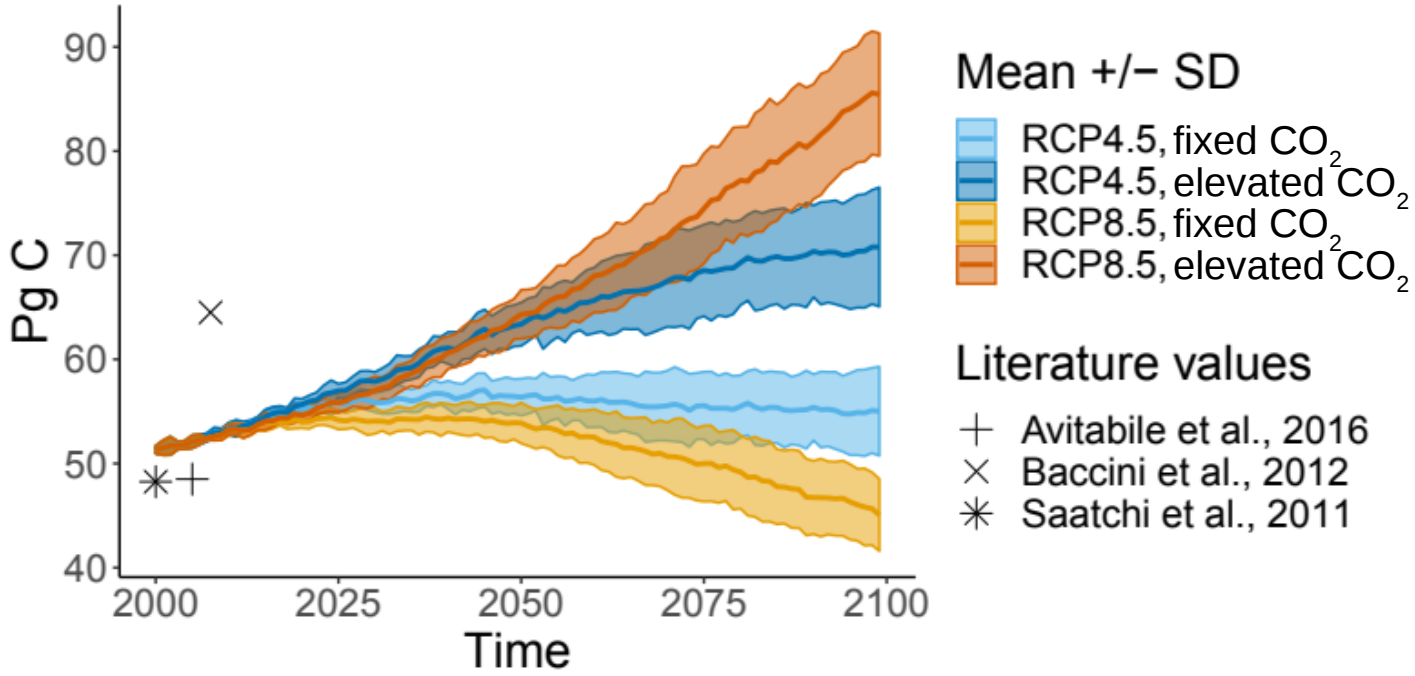
SENCKENBERG

EMSAfrica
Ecosystem Management Support for Climate Change in Southern Africa

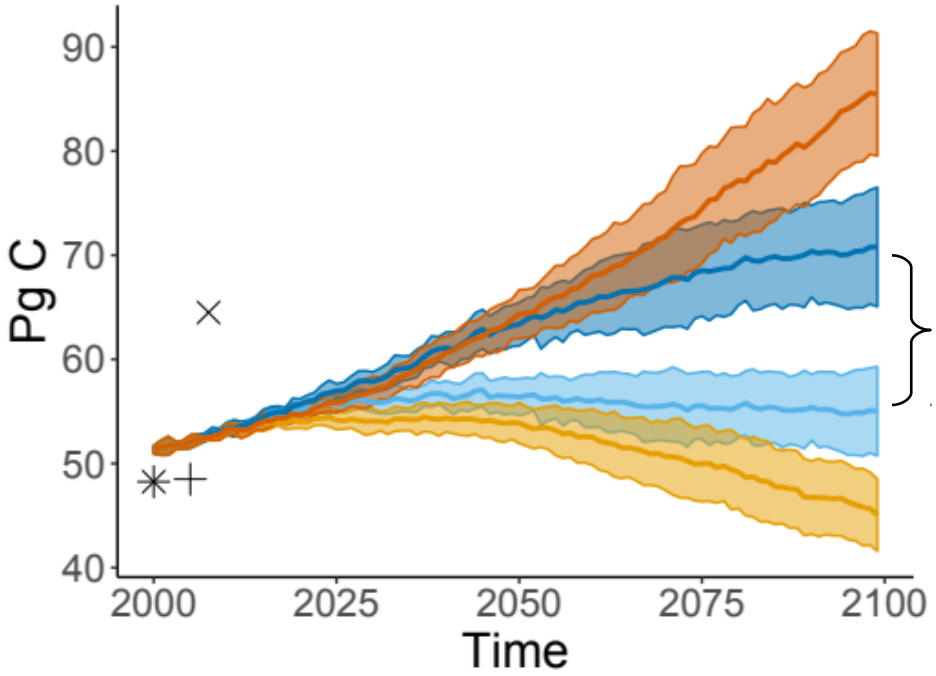
Ensemble of 24 aDGVM simulations with 6 GCMs, 2 RCPs, 2 CO_2 scenarios



aDGVM simulated carbon stocks in aboveground biomass



aDGVM simulates stronger CO_2 effect than elevated CO_2 experiments



Mean +/− SD

RCP4.5, fixed CO_2

RCP4.5, elevated CO_2

27%
140ppm ΔCO_2

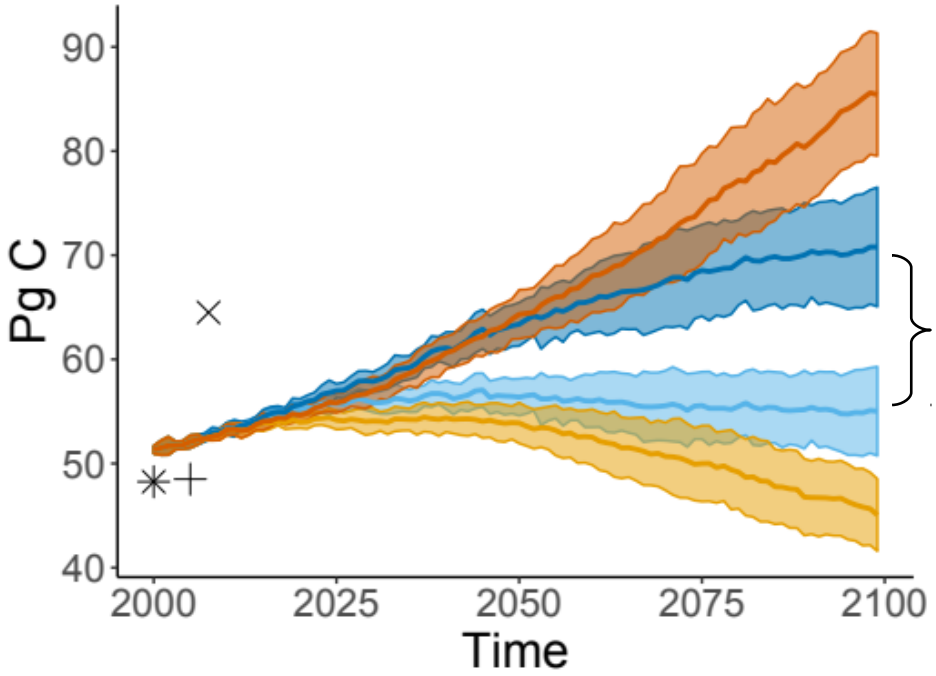
× Baccini et al., 2012
✳ Saatchi et al., 2011

Direct CO_2 effect derived from eCO_2 experiments is smaller:

12±3%
250ppm ΔCO_2

(Terrer et al., 2019, Nature CC)

Population dynamic effects are accounted for in aDGVM, but large uncertainties remain



Mean +/− SD

RCP4.5, fixed CO_2

RCP4.5, elevated CO_2

27%
140ppm ΔCO_2

× Baccini et al., 2012

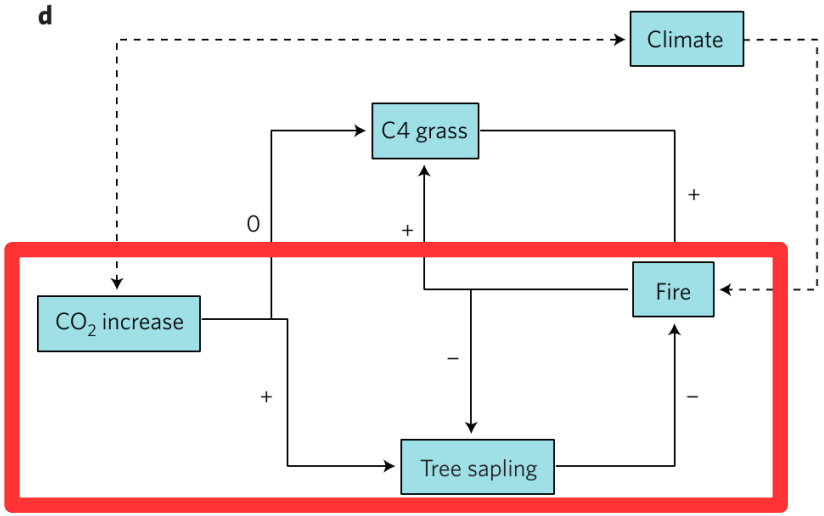
✳ Saatchi et al., 2011

Direct CO_2 effect derived from eCO_2 experiments is smaller:

12±3%
250ppm ΔCO_2

(Terrer et al., 2019, Nature CC)

But eCO2 experiments currently do not include **population dynamic effects** like tree saplings escaping fire zones more easily under eCO2.



Midgley & Bond, 2015, Nature CC

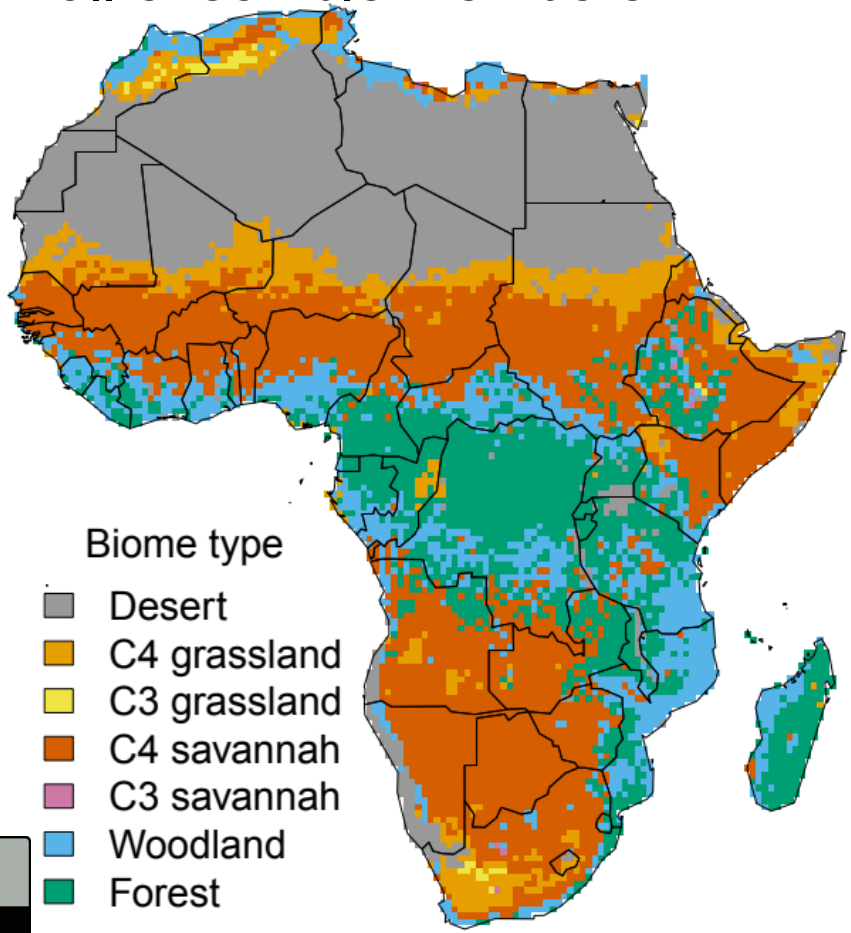
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

SENCKENBERG

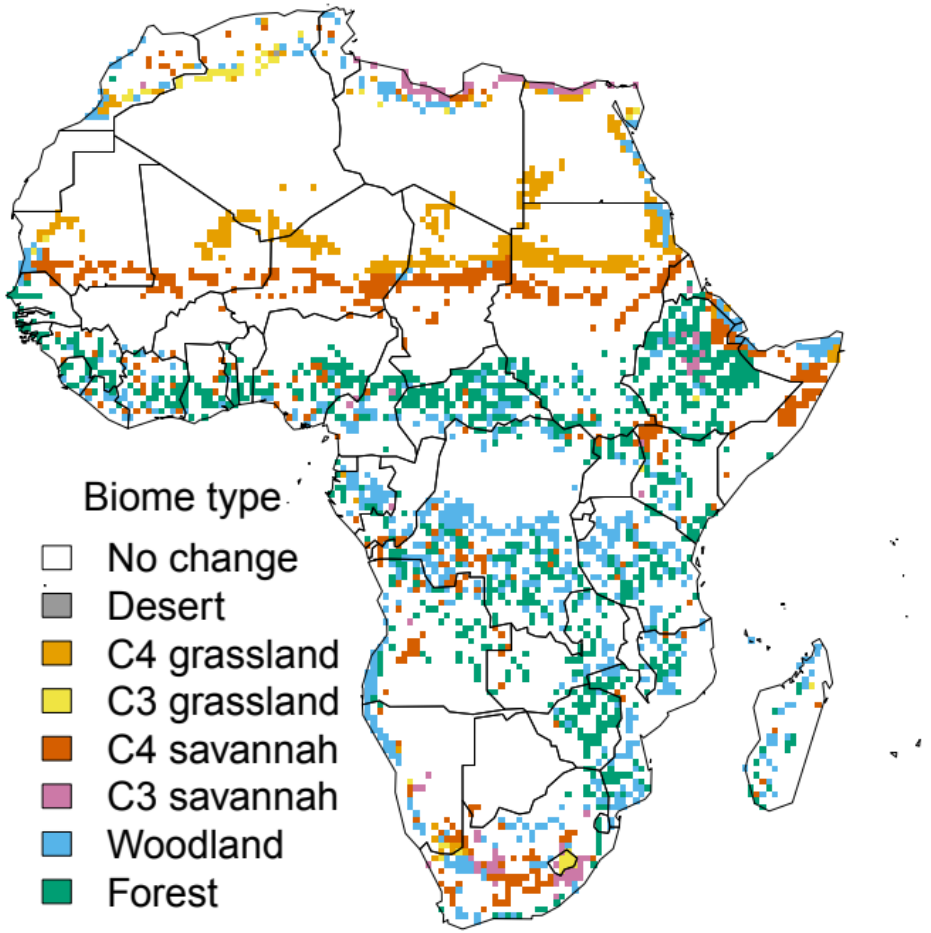
EMSAfrica
Ecosystem Management Support for Climate Change in Southern Africa

Considerable biome shifts by the end of the century for RCP4.5 under elevated CO_2

2000-2019
consensus biomes from all ensemble members

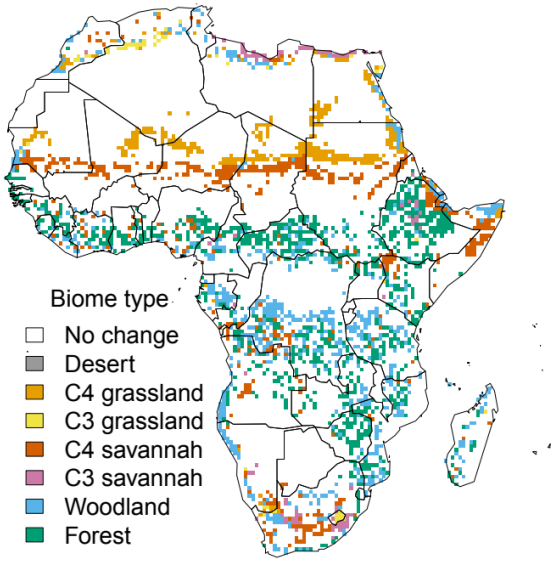


2080-2099
RCP 4.5, elevated CO_2

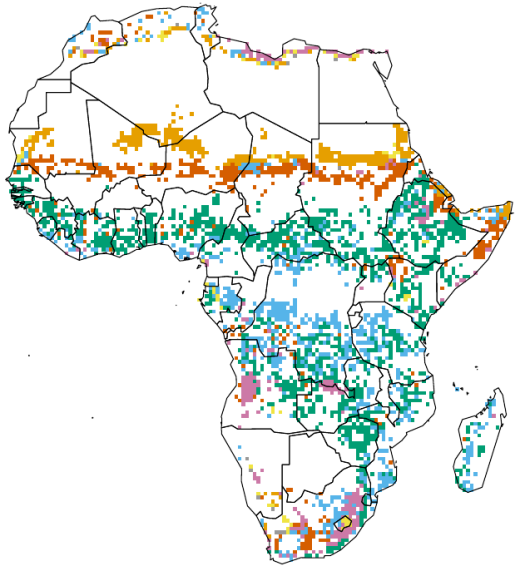


Biome shifts from 2000-2019 to 2080-2099 under elevated CO_2 for consensus biome

RCP 4.5, elevated CO_2 consensus biomes



RCP 8.5, elevated CO_2 consensus biomes



➔ Woody encroachment into grassy biomes across both RCPs under elevated CO_2

➔ 25% (RCP 4.5) and 29% (RCP 8.5) of terrestrial Africa are projected to experience biome shifts

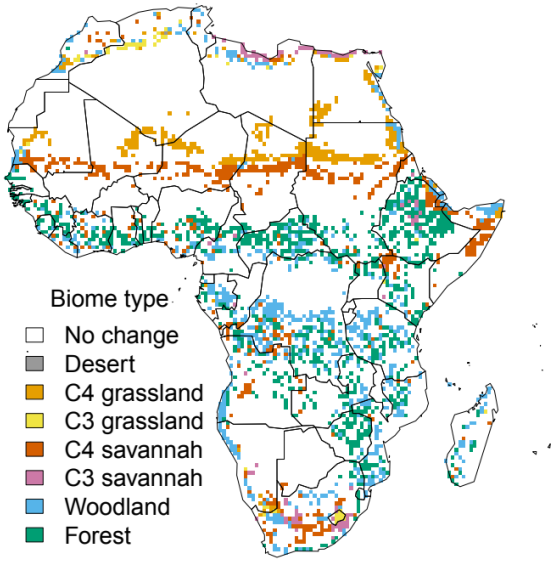
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

SENCKENBERG

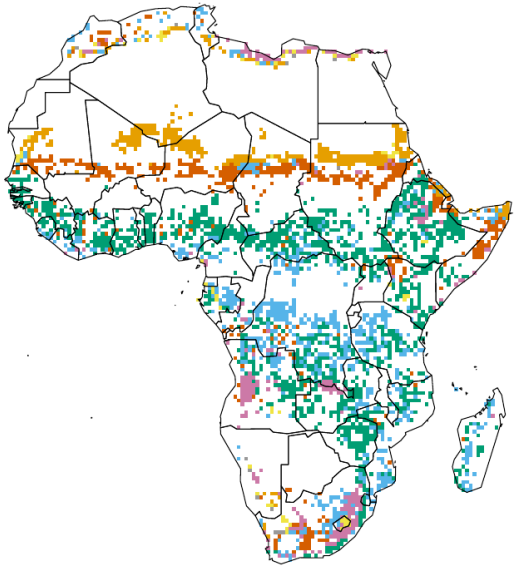
EMSAfrica
Ecosystem Management Support for Climate Change in Southern Africa

Biome changes from 2000-2019 to 2080-2099 for the four RCP-CO_2-scenario combinations

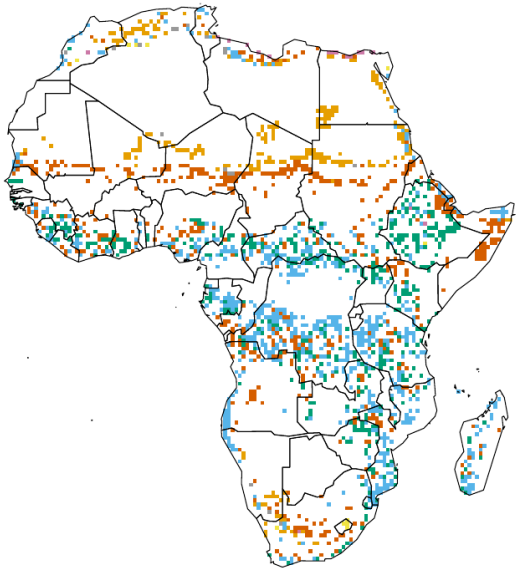
RCP 4.5, elevated CO_2



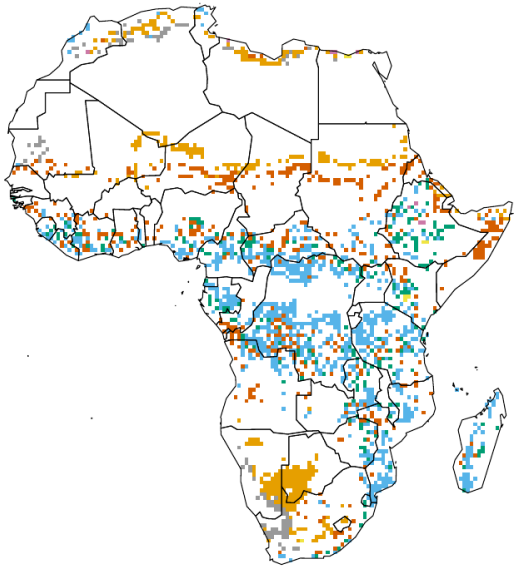
RCP 8.5, elevated CO_2



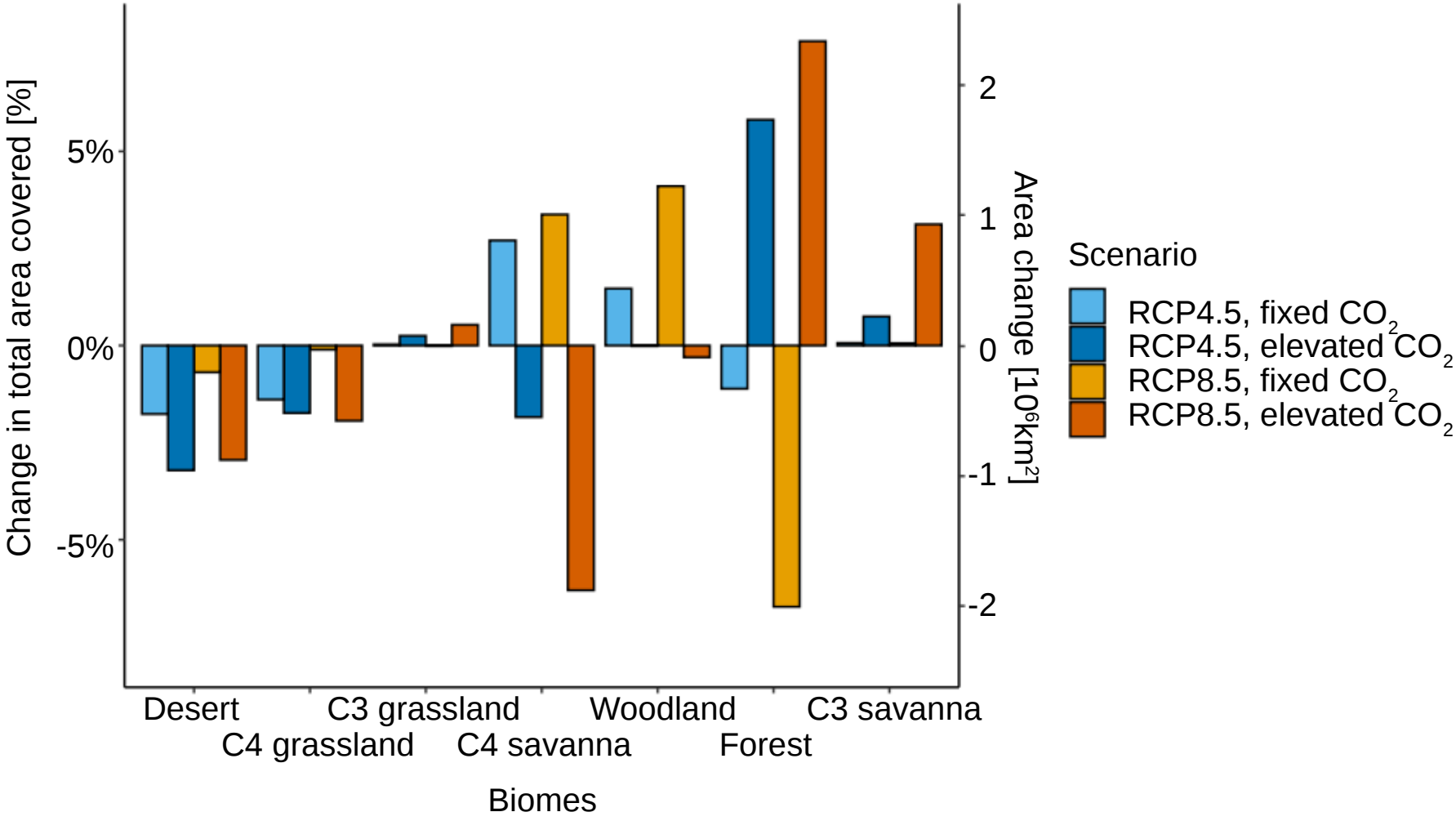
RCP 4.5, fixed CO_2



RCP 8.5, fixed CO_2

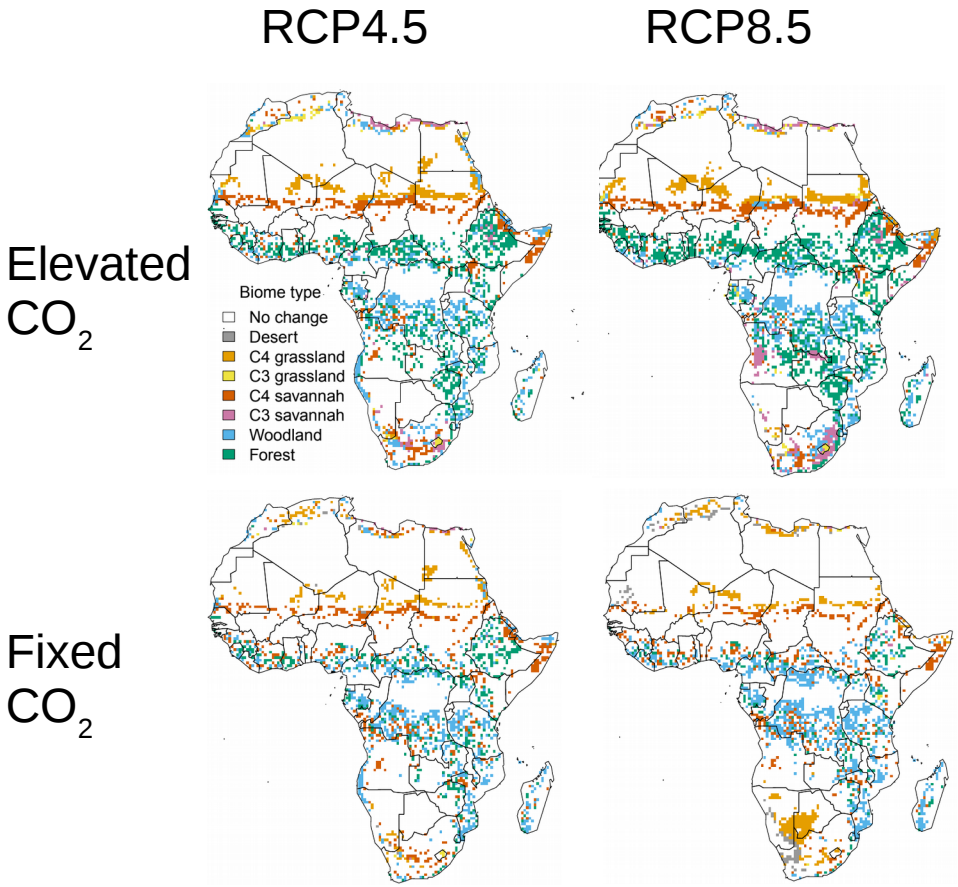


Area change of consensus biomes is uncertain for woody biomes



Biome changes from 2000-2019 to 2080-2099

- Fewer biome changes with fixed CO_2
- Fixed-CO_2 scenarios are dominated by transitions from forest to woodland or savanna
- Even for RCP4.5, a less extreme emission scenario, considerable biome changes are projected.



Large uncertainties in future biome changes in Africa call for flexible climate adaptation strategies

- Future biome changes due to climate and CO_2 change are likely in large parts of Africa.
- CO_2 effects in combination with RCP scenarios caused greater uncertainty in projected ecosystem changes than downscaled GCM projections.
- Climate mitigation and adaptation response measures that rely upon vegetation-derived ecosystem services will need to account for alternative climate futures.

Thanks for your attention!

SENCKENBERG world of biodiversity

Leibniz-Gemeinschaft

Emmy Noether-Programm
DFG Deutsche Forschungsgemeinschaft

AfricaE
ARS

SPONSORED BY THE
Federal Ministry of Education and Research

CSIR our future through science

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

UNIVERSITEIT STELLENBOSCH UNIVERSITY

UNIVERSITÄT BAYREUTH

NRF National Research Foundation
SAEON South African Environmental Observation Network

Ensemble simulations reveal uncertainties in vegetation projections in Africa due to CO_2 and RCP scenarios

Carola Martens
Institute of Physical Geography, Goethe University Frankfurt

Introduction

Climate change will cause biome shifts in Africa with impacts on biodiversity and ecosystem services.

Uncertainties in climate change impacts and the effects of **elevated atmospheric CO_2** on ecosystems challenge projections of future ecosystem states.

We identified uncertainties in vegetation states in Africa until 2099 with **ensemble simulations** using the **adaptive Dynamic Global Vegetation Model** (**aDGVM**, Scheiter & Higgins 2009).

Simulation design

aDGVM ...
... simulates potential natural vegetation,
... simulates ecological processes from leaf to plant population level,
... simulates tree individuals,
... is forced with climate and soil data.

Ensemble of 24 aDGVM runs with high-resolution climate data for Africa (Archer et al. 2018) and CO_2 scenarios (Fig. 1):

- 2 Representative Concentration Pathways (RCPs 4.5 & 8.5)
- 2 CO_2 scenarios (elevated CO_2 corresponding to RCPs 4.5 & 8.5, and CO_2 fixed at 400ppm),
- 6 downscaled General Circulation Models (GCMs)

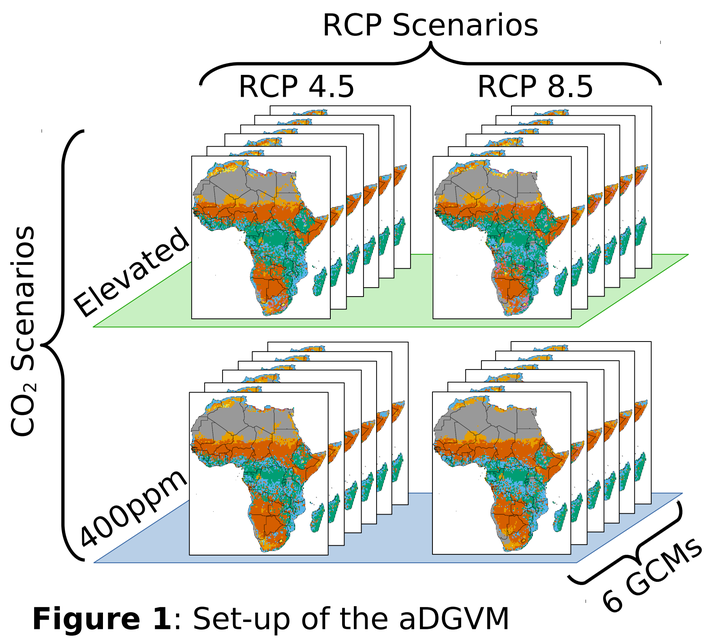


Figure 1: Set-up of the aDGVM ensemble simulations

Take home message

- Ensemble simulations disentangle sources of uncertainty in climate impact modeling.
- Uncertainties in climate future and CO_2 fertilisation effect result in **alternative future vegetation states**.
- Climate mitigation and adaptation need to consider alternative vegetation futures.
- Despite uncertainties, **today's policy decisions shape climate change** (i.e. RCP scenario), and thus future environments.

Results

- Many regions at **risk of biomass changes and biome shifts**
- Strongest effect on carbon storage variability through interaction effects between CO_2 and RCP scenario
- Projected woody encroachment and shifts to tree-dominated biomes under elevated CO_2 (Fig. 3b) correspond to biomass increases (Fig. 2)

Total carbon in aboveground biomass in Africa from 2000-2099

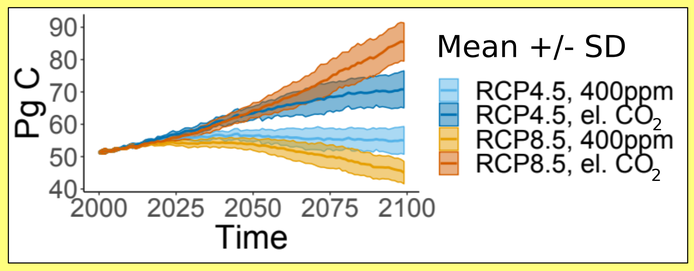


Figure 1: Mean total carbon in above-ground biomass [Pg C] in Africa from 2000 to 2099 for the four RCP and CO_2 scenario combinations. Standard deviation (SD) is derived from the six GCM runs per scenario.

Biome shifts from 2000-2019 to 2080-2099

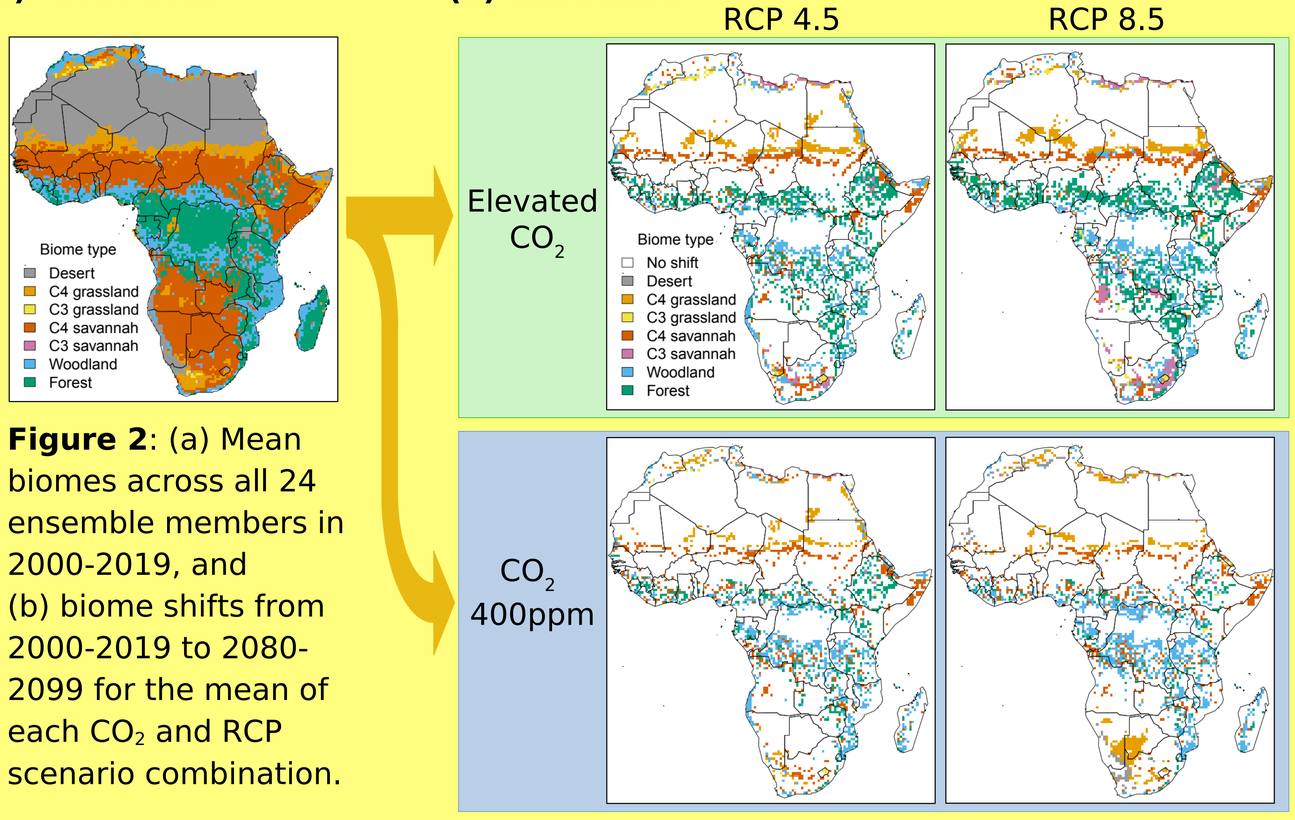


Figure 2: (a) Mean biomes across all 24 ensemble members in 2000-2019, and (b) biome shifts from 2000-2019 to 2080-2099 for the mean of each CO_2 and RCP scenario combination.

- Low-impact scenarios (both RCP 4.5 scenarios) with considerable vegetation changes
- Lower projected change for both RCP 4.5 scenarios than for RCP 8.5 scenarios
- Alternative climate futures lead to **alternative future vegetation states**.

Literature

Archer, E., Engelbrecht, F. et al. 2018: Seasonal prediction and regional climate projections for southern Africa, *Biodiversity & Ecology*, 6, 14-21

Scheiter, S. & Higgins, S.I., 2009: Impacts of climate change on the vegetation of Africa: an adaptive dynamic vegetation modelling approach. *Global Change Biology* 15, 2224-2246.

Acknowledgements

I would like to thank the Federal Ministry of Education and Research (BMBF) for funding, EMS Africa, Goethe University, Senckenberg Society for Nature Research, and T. Hickler & S. Scheiter

GOETHE UNIVERSITÄT FRANKFURT AM MAIN
SENCKENBERG world of biodiversity

Further information

- Email: carola.martens@senckenberg.de
- http://adgvm.wordpress.com for more details on the **aDGVM** project
- https://emsafrica.org for more information on the EMS Africa project