Impact of climate change on biomes distribution and productivity of the tropical ecosystem under RCP scenarios in South Asia

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Introduction

- South Asian vegetation provides essential ecosystem services to the region and its 1.7 billion inhabitants that are closely linked to its land-use forms and carbon storage potential.
- South Asia is likely to experience drastic climatic changes in the future, but the consequences of such changes on biome distributions are highly uncertain.
- Understanding and assessing how ecosystems respond to simultaneous increases in atmospheric CO_2 and future climate change is of vital importance to avoid undesired ecosystem change.
- A failure to react to increasing CO_2 and climate change will likely have severe consequences for biodiversity and humankind.

Questions

We used the updated version of aDGVM2 and addressed the following questions:

1) How do projected changes in climate and CO_2 following two Representative Concentration Pathways (RCP8.5 and RCP4.5) change the distribution, boundaries and climatic niches of biomes in South Asia?
2) How does the relationship between projected biomass, temperature and precipitation change in response to CO_2 fertilization?
3) What is the sensitivity of predicted changes in relation to presence and absence of CO_2 fertilization?

Materials and Methods

Study Region: South Asia

Data Used: RCP 4.5 and RCP 8.5 climate scenarios (ISIMIP2)
Harmonized World Soil Database v 1.2 (F.A.O)

Model Description

- aDGVM2 (Scheiter *et al*., 2013; Langan *et al*., 2017) is an individual based ecosystem model which explicitly simulates key processes governing the dynamics of ecosystems.
- To adapt the aDGVM2 to the requirements of the study region, we incorporated new sub-routines into the model. We improved the representation of (a) the water balance by including snow, (b) the carboxylation rate, (c) leaf temperature, and (d) we included C_3 grasses (previous model versions only simulate C_4 grasses).

Results and Discussions

Model benchmarking

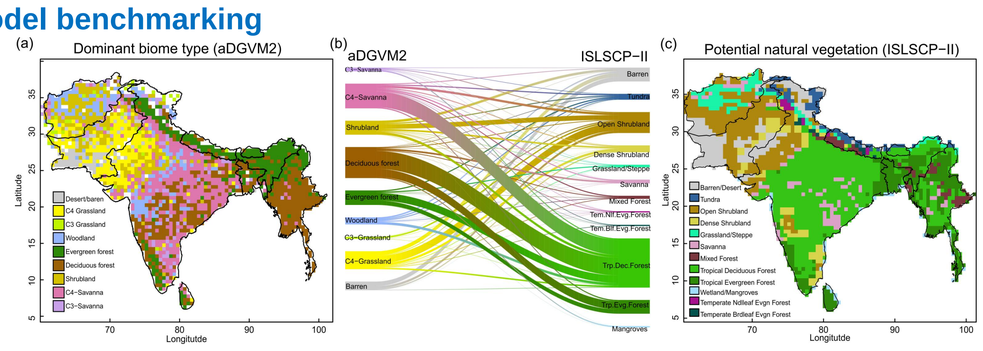

Fig. 1: Comparison between simulated and observed biome patterns. (a) Simulated dominant biome type, (b) Sankey diagram showing overlap between simulated biomes and potential natural vegetation cover (ISLSCP-II, Ramankutty et al., 2010) and (c) potential natural vegetation. The Sankey graph shows how aDGVM2 biomes and PNV classes overlap.

Impact of climate change and elevated CO_2 on biome distribution

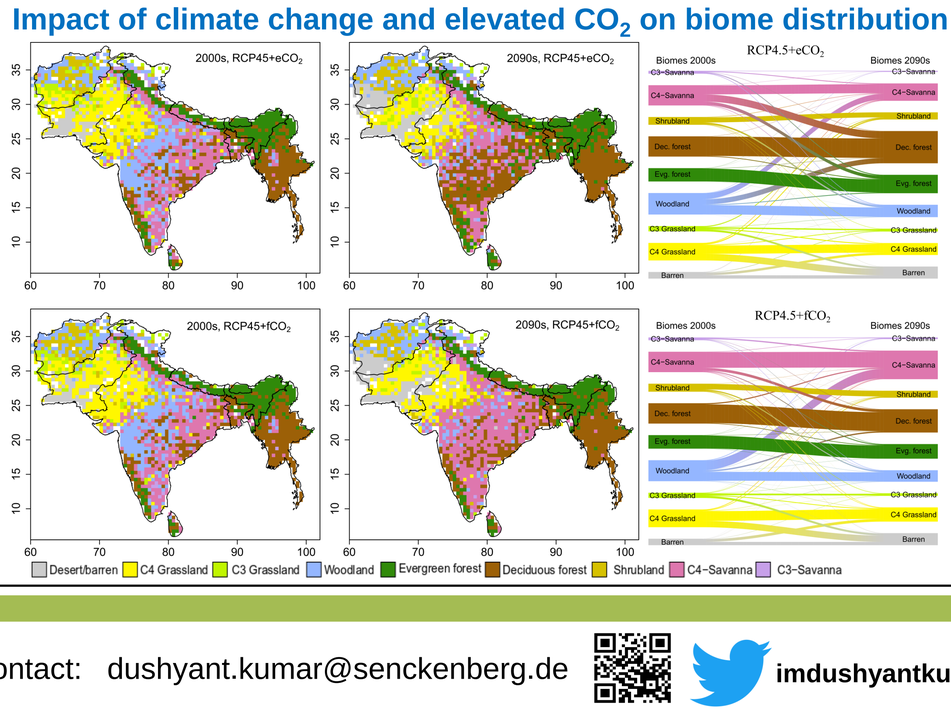

Fig. 2: Simulated biome distribution for the 2000s and 2090s under eCO_2 and fCO_2 for RCP4.5.Sankey diagrams showing the fractional cover of biomes and transitions between biomes from the 2000s to the 2090s.

Relationships between AGBM with MAP and MAT

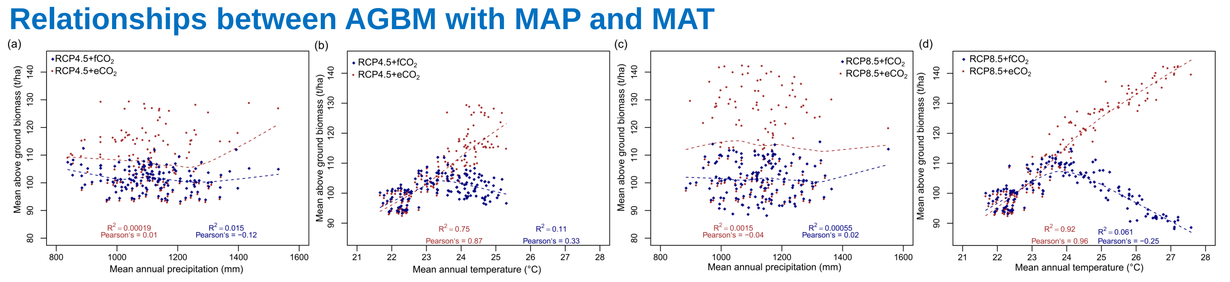

Fig. 3: Relationship between (a, c) mean above ground biomass and mean annual precipitation, and (c, d) mean above ground biomass and mean annual temperature under RCP4.5 and RCP8.5. The dashed lines in all figures represent the best-fit regression line. Data points represent spatially averaged biomass for each year from 1950 to 2099.

Impact of CO_2 fertilization on biomass, canopy cover and evapotranspiration

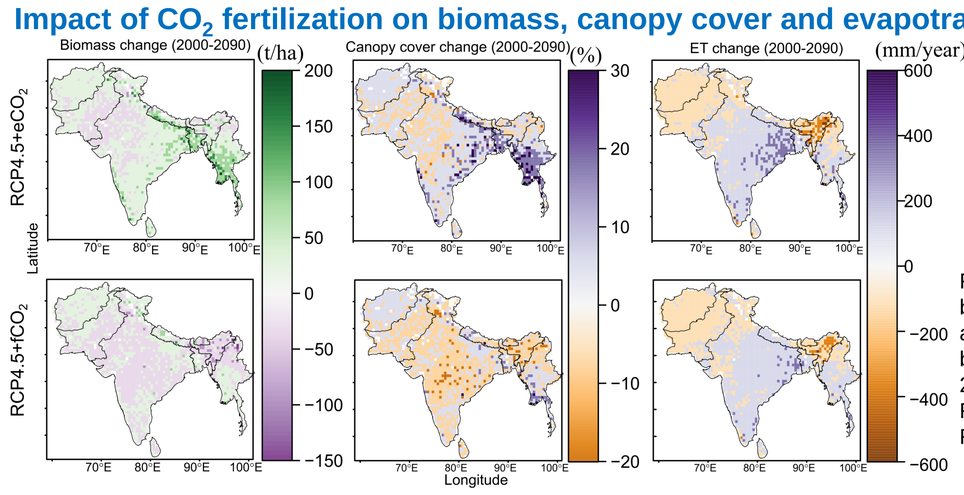

Fig. 4: Projected change in biomass (t/ha), canopy area (%) and ET (mm/year) between the 2000s and 2090s, under RCP4.5+eCO_2 and RCP4.5+fCO_2

Effect of CO_2 fertilization

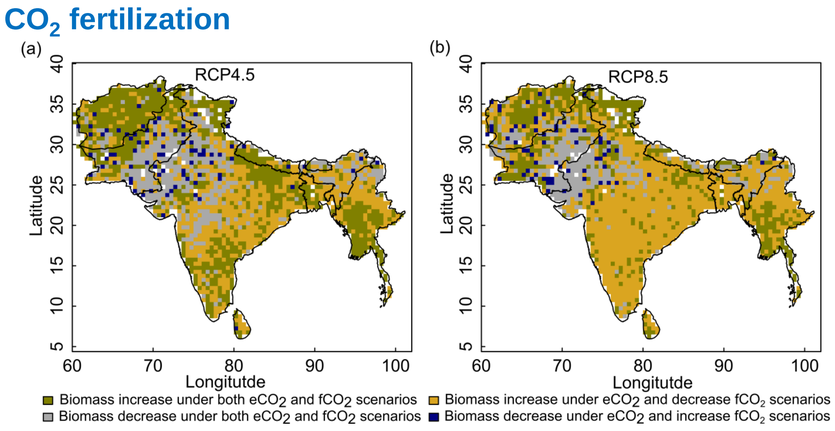

Fig. 5: Maps showing areas where CO_2-fertilization compensates biomass dieback caused by climate change between 2000s and 2090s under (a) RCP4.5 and (b) RCP8.5.

Climatic niches of biomes under elevated CO_2

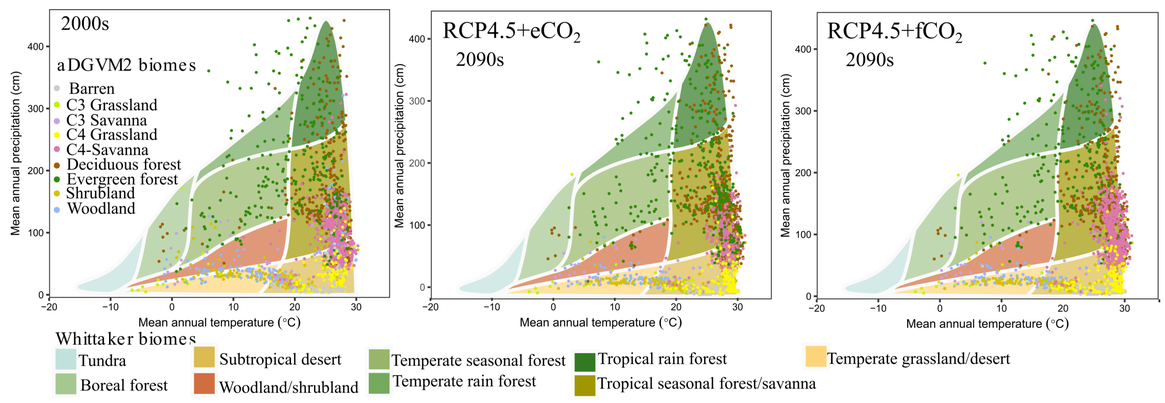

Fig. 6 Simulated climate niches of biomes for the 2000s and 2090s under RCP4.5+eCO_2 and RCP4.5+fCO_2. The simulated biomes are overlaid on the climate envelopes of Whittaker's biomes and are plotted following Ricklefs (2008) and Whittaker (1975).

Conclusions

- The model predicted changes in above ground biomass and canopy cover that trigger biome transition towards tree-dominated systems.
- We found that savanna regions are at high risk of woody encroachment and transitioning into forest.
- Projections showed that the bioclimatic envelopes of biomes need adjustments to account for shifts caused by climate change and eCO_2.
- Proactive management strategies are required to develop regional strategies for biodiversity conservation to cope with climate change.

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