Assessment of carbon fluxes and stocks over India using a DGVM driven by climate projections from multiple CMIP5 climate models

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Introduction

- The Indian region has undergone significant environmental changes in the 20th century affecting the terrestrial carbon dynamics of the region. Thus, understanding and quantification of the terrestrial dynamics over India gains prime importance.

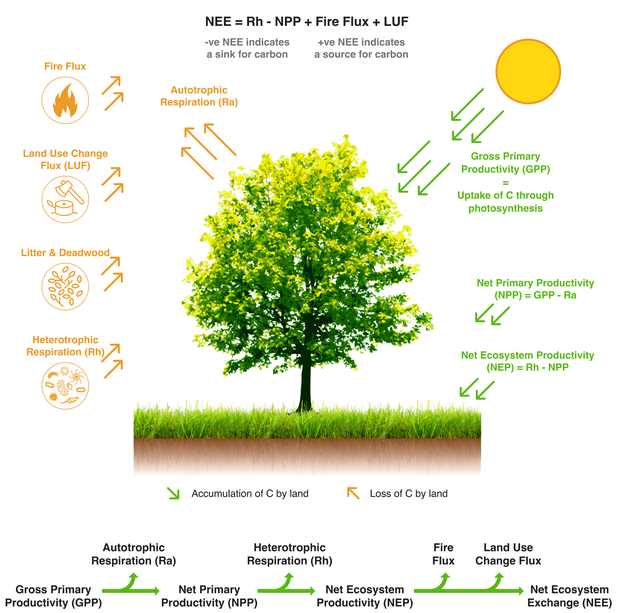
Objectives of the study

1. Assess the trends and variability of terrestrial carbon fluxes and stocks over the Indian region in the 20th century.
2. Project trends in the terrestrial carbon stocks and fluxes in the 21st century.
3. Assess the roles of climate change and CO2 fertilization in the trends and variability in the terrestrial carbon fluxes and stocks over India.

Status of terrestrial carbon cycle

- Cervarich et al. (2016) use model data along with other bottom up approaches to estimate the terrestrial carbon budget of South and Southeast Asia. They find that the Indian terrestrial ecosystems were a sink for atmospheric CO2 from 2000 to 2013 but a net source of carbon when fossil fuel emissions were also considered.
- Dadhwal et al. (2012), and Nayak et al. (2011) model the monthly NEP over India for a recent 26 year period (1981-2006) using a terrestrial ecosystem model and infer that India has been a net sink of atmospheric CO2 with total annual uptake of 9.5 Tg C yr-1 from 1981-2006.

Key Terms



Methodology

- Input from **24 CMIP5** (Coupled Model Intercomparison Project Phase 5) models are used to force the LPJ model for the Indian Region.
- Model spin-up: **1600 years** (1875-1900 climatology * 64)
- Experiments Designed :

Part A. All varying case	: Historical (1900-2005), RCP4.5 (2006-2100), RCP 8.5 (2006-2100)
Part B. CO2 Constant case	: Historical (1900-2005), RCP4.5 (2006-2100), RCP8.5(2006-2100)

- Model Description : The dynamic global vegetation model used is **LPJ (Lund-Postdam-Jena)** Model
- Resolution : **0.5 x 0.5°**
- Plant Functional Types : **9**

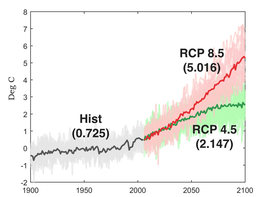
Key input variables

Soil type	**Monthly mean cloudiness (%)**
CO2 concentration	**Monthly mean precipitation (mm/month)**
Grid or domain	**Monthly mean temperature (°C)**

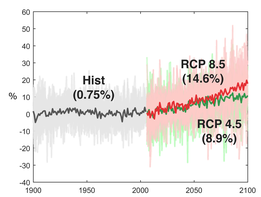
- 24 CMIP5 models

No	Model	Modelling Centre or Group	Resolution
1	BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration	2.81 x 2.81
2	CCSM4	National Center for Atmospheric Research (NCAR), USA	0.94 x 1.25
3	CESM1_CAM5	Community Earth System Model Contributors	0.93 x 1.25
4	CSIRO-Mk3_6-0	Commonwealth Scientific and Industrial Research Organization (CSIRO) in collaboration with Queensland Climate Change Centre of Excellence, Australia	1.87 x 1.88
5	FIO-ESM	The First Institute of Oceanography, SOA, China	2.81 x 2.81
6	GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory	2.00 x 2.50
7	GFDL-ESM2G		2.00 x 2.50
8	GFDL-ESM2M		2.00 x 2.50
9	IPSL-CM5A-LR	Institut Pierre-Simon Laplace, France	1.89 x 3.75
10	MIROC_5	Japan Agency for Marine- Earth Science and Technology, The	2.85 x 2.81
11	MIROC_ESM		2.85 x 2.81
12	MIROC_ESM_CHEM	University of Tokyo, and National Institute for Environmental Studies	2.85 x 2.81
13	MRI-CGCM3	Meteorological Research Institute, Japan	1.13 x 1.12
14	NorESM1-M	Norwegian Climate Centre	1.89 x 2.50
15	NorESM1-ME		1.89 x 2.50
16	ACCESS_1_0	Commonwealth Scientific and Industrial Research Organization and the Bureau of Meteorology, Australia (CSIRO-BOM)	1.25 x 1.87
17	GISS-E2-R	NASA Goddard Institute for Space Studies, USA	2.02 x 2.51
18	GISS_E2_H		2.02 x 2.51
19	GISS_E2_H_CC		2.02 x 2.51
20	GISS_E2_R_CC		2.02 x 2.51
21	HadGEM2-AO	Met Office Hadley Centre, UK	1.24 x 1.87
22	HadGEM2-ES		1.24 x 1.87
23	MPI_ESM_LR	Max Planck Institute for Meteorology, Germany	1.87 x 1.88
24	MPI_ESM_MR		1.87 x 1.88

Temperature

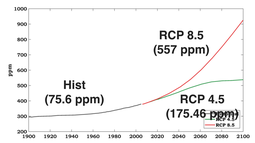


Precipitation



- Trends in the **input climate** data for the historical period, the RCP 4.5 and the RCP 8.5 scenario

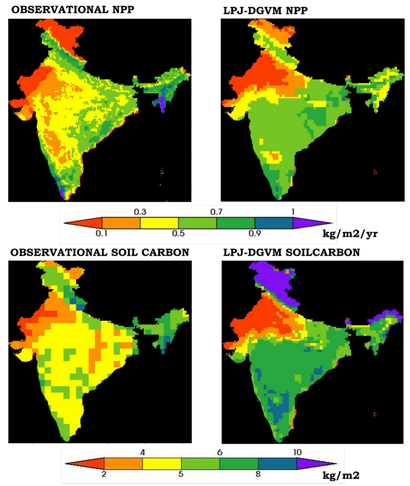
Carbon Dioxide



Bias Correction & Validation

- The difference between the CMIP5 model simulated climate and the observed climate (CRU) over India is removed for the historical and future periods using with 1961-1990 as the base period monthly climatology.
- Validation of **LPJ-DGVM**

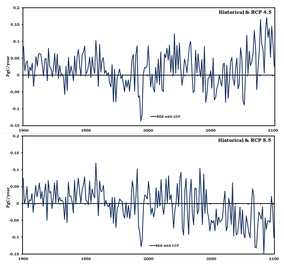
NPP shows a correlation of **0.51**
Soil Carbon shows a correlation of **0.33**



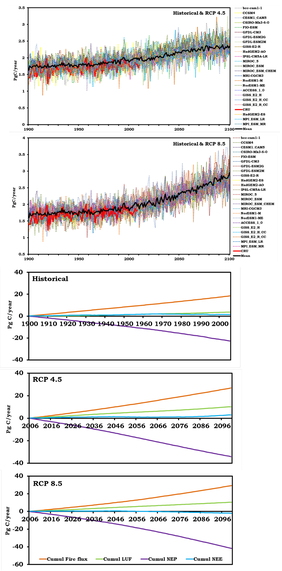
Results Part A

- Trends in terrestrial carbon stocks and fluxes in the historical period (1900-2005), the RCP 4.5 scenario (2006-2100) and the RCP 8.5 scenario (2006-2100)

NEE



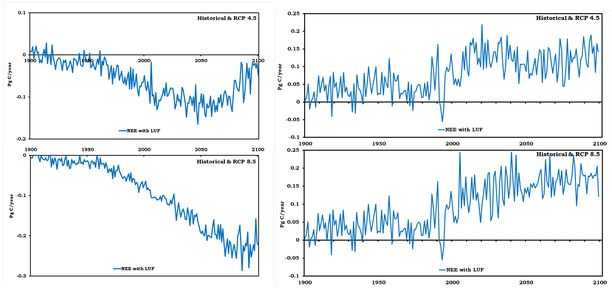
NPP



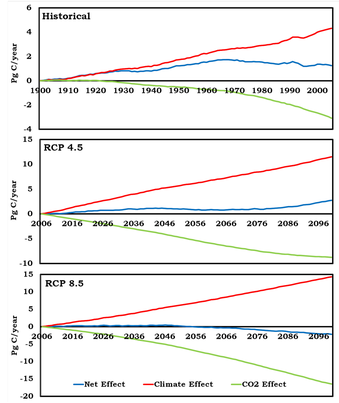
- The **Cumulative Fluxes** :

The **cumulative NEE** for the Indian region is a slight **source** for the **historical period**, **source** for the **RCP 4.5 scenario** and is a slight **sink** in the **RCP 8.5 scenario**.

Results Part B



- Terrestrial ecosystems over India are a sink for carbon due to the CO2 effect
- Terrestrial ecosystems over India are a source for carbon due to the climate effect



Conclusions

- The 24 LPJ-DGVM simulations indicate that the terrestrial ecosystems over the Indian region **were neither a strong source nor a significant sink** for carbon in the historical period **(1901-2005)** and concur with the TRENDY multi-model results.
- The **cumulative NEE** for the Indian region is **slight source for the historical period, source for the RCP 4.5 scenario and is a small sink in the RCP 8.5 scenario.**
- The changes in the climate over the Indian region alone **(warming)** would cause a **release of carbon** to the atmosphere in the historical period as well as the two future scenarios.
- The increasing **CO2** in the atmosphere alone with constant climate at 1900 levels would cause the terrestrial ecosystems to be a **sink** for carbon(as a result of CO2-fertilisation effect).
- Our study can be utilized by policy makers for the inclusion of various **land management techniques to mitigate climate change** over the Indian region.