Assessing Carbon Sink Variations in India: Projections from Climate Models

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Abstract and conclusions

•The study suggests how India's terrestrial biosphere sequestered CO_2 in the recent past, and how it is going to change under a high emission scenario, SSP585.

• Gross Primary Productivity (GPP) is an indicator of primary productivity, hence, carbon sequestration by the biosphere. ~ 30% of the CO_2 released by human activities is sequestered by the terrestrial biosphere as primary productivity.

•Using Coupled Model Intercomparison Project (CMIP6) climate model simulations, we assess both past and future trends in GPP across India.

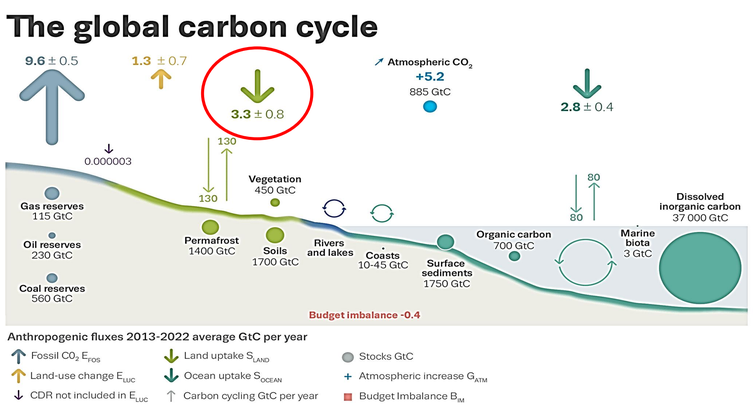
• The Indian biosphere's ability to sequester CO_2 has been increasing recently, with regional variation. Historically, India's GPP has grown by 2.37 $gCm^{-2}y^{-1}$, and future projections suggest it could increase to 6 $gCm^{-2}y^{-1}$ under SSP-585 high-emission scenarios with regional variations.

• Land-use land cover (LULC) changes, like deforestation and farming expansion etc., have implications for regional carbon sequestration. We noticed the decrease in observed green cover of the Northeast region in the recent past.

•Models suggest an overall increase, with some regions showing a high increase, e.g., the northeast, the Western Ghats, and Indo Gangetic India.

• Projections suggest that increased rainfall in models has a role in influencing the GPP trends.

Figures



~30% emitted global CO_2 is taken up by the terrestrial biosphere- **"the Sink"**, and recent past observations have shown an increase in this sink.

Question: How has this sink changed and is going to change over the Indian region in the future?

Figure 1: ***<u>The Global Carbon Budget</u>*** **(Friendlingstein et al. 2023, Global Carbon Project) & Global Carbon Sinks estimate : Fluxes are in gigatonnes of carbon per year (Gt C yr^{-1})**

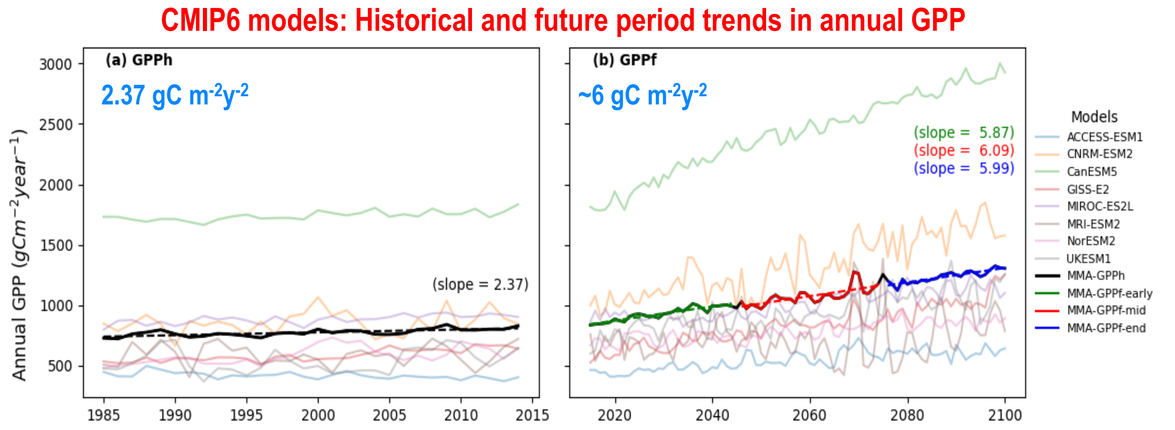


Figure 2: ***<u>Annual GPP from CMIP6 models</u>*****, (a) Historical period: GPPh (1985-2014), (b) Future period- (experiment- esm-ssp585): GPPf (2015-2100). Multimodel average (MMA) for early (2015-2044), middle (2045-2074), and end-century (2075-2100) period.**

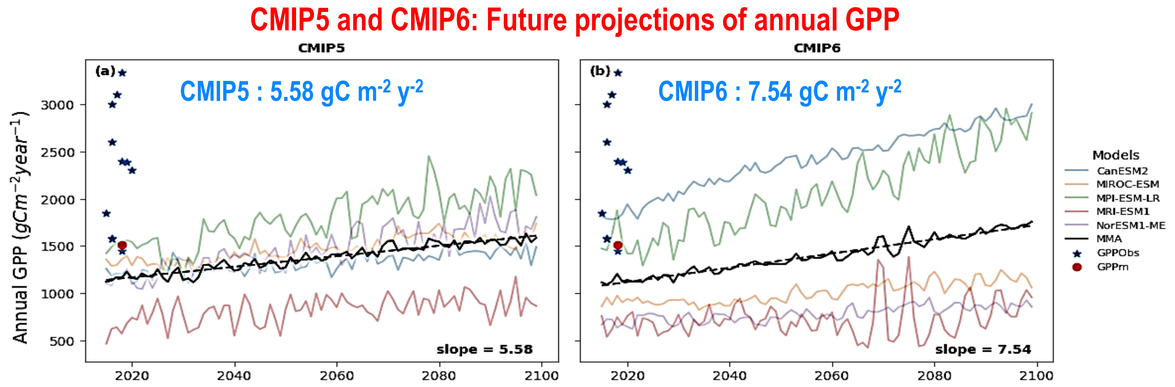


Figure 3: ***<u>Comparison of GPPf</u>*** **between (a) CMIP5 (experiment: esm-rcp85) and (b) CMIP6 (experiment: esm-ssp585), five common models in r1i1p1 initialization (color coded), their MMA (black thick line), and regression line (black dash line, p~0.000)**

Model Used in the study

Table 1

S. No.	Model Name	Institute	Atmosphere resolution	N2 cycle	Land Carbon and BGC	Reference
1	ACCESS-ESM1-5	CSIRO	1.25 x 1.875	Yes	CABLE2.4 with CASA CNP	Ziehn et al. (2020)
2	CNRM-ESM2-1	CNRM	1.4 x 1.4	No	ISBA-CTRIP	S´ef´erian et al. (2019)
3	CanESM5	CCCma	2.81 x 2.81	No	CLASS-CTEM	Swart et al. (2019)
4	GISS-E2-1-G-CC	NASA GISS	2 x 2.5			Kelley et al. (2020)
5	MIROC-ES2L	JAMSTEC	2.81 x 2.81	Yes	MATSIRO VISIT-e	Hajima et al. (2019)
6	MRI-ESM2-0	MRI	1.00 × 0.50	No	HAL	Yukimoto et al (2019)
7	NorESM2-LM	NCC	1.9 x 2.5	Yes	CLM5	Seland et al. (2020)
8	UKESM1-0-LL	UK	1.875 x 1.25	Yes	JULES-ES-1.0	Sellar et al., (2019)

Table 1: Eight CMIP6 Models: C4MIP experiment, BGC models (esm-historical, future: esm-ssp585 (Eyring et al., 2016) all initializations

Table 2 CMIP5 esmrcp85, 2006-2100 r1i1p1 | CMIP6: esmssp585, 2015-2100, r1i1p1f1

S. No.	Institute	Model Name CMIP5	Corresponding CMIP6 model	Atmosphere resolution	Land Carbon and BGC	N_2 cycle CMIP5	Reference CMIP5
1	CCCma	CanESM2	CanESM5	2.81 × 2.81	CLASS2.7+CTEM1	No	Arora and Boer. 2010
2	MIROC	MIROC-ESM	MIROC5	2.81 × 2.81	MATSIRO+SEIB–DGVM	No	Watanabe et al. 2011
3	MPI	MPI-ESM-LR	MPI-ESM1-2-LR	1.88 × 1.88	JSBACH	No	Reick et al. 2013
4	MRI	MRI-ESM1	MRI-ESM2-0	3.2 ×1.6	LPJDGVM at ecosystem level	No	Adachi et al. 2013
5	NorESM	NorESM1-ME	NorESM2-MM	1.88 × 2.50	CLM4	Yes	Tjiputra et al. 2013

Table 2: Five common CMIP5 & CMIP6 Models: BGC models (future: esmrcp585 & esm-ssp585) first initializations

Results

Historical and future SSP585 projections suggest increase in annual GPP, consistent with the observed forest and crop cover increase in the past.

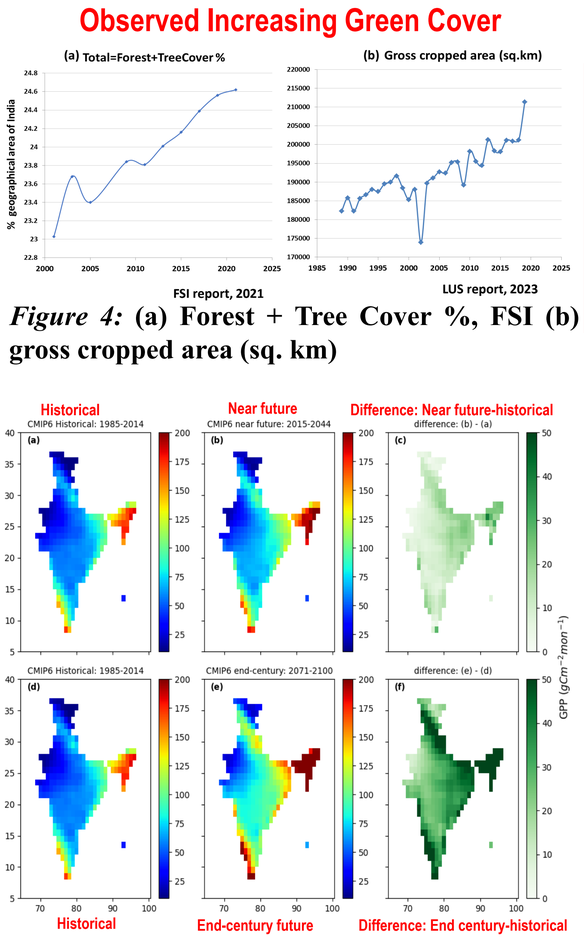


Figure 4: **(a) Forest + Tree Cover %, FSI (b) gross cropped area (sq. km)**

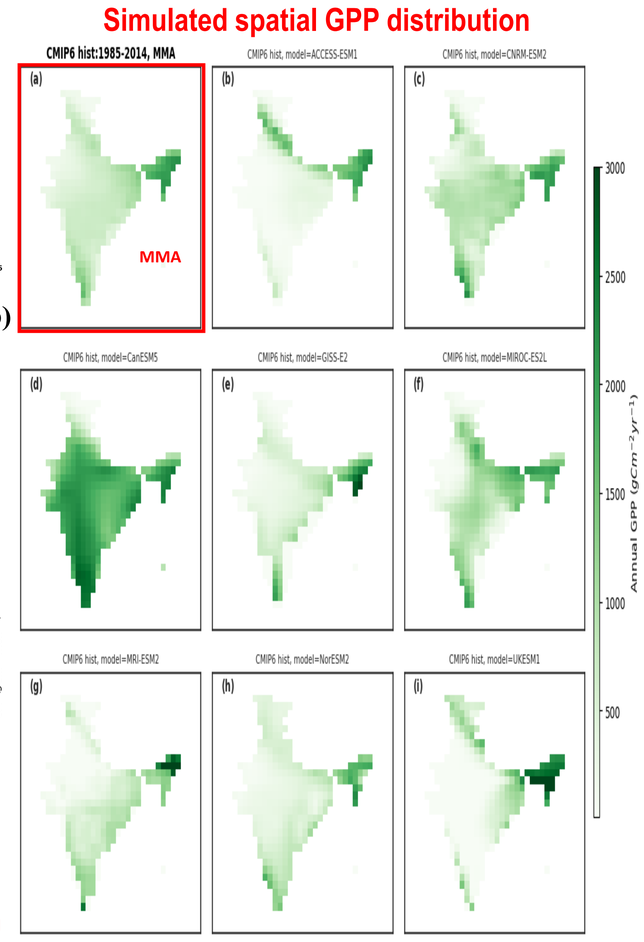


Figure 6: ***<u>Regional changes monthly GPP</u>*** **(a) historical, (b) near future, (c) early-century-historical (d) historical, (e) end-century, and (f) end century - historical**

Figure 5: ***<u>Spatial distribution of historical annual GPP from 1985-2014</u>*****: (a) Average of all eight models (MMA), and (b-i) Average annual GPP of individual eight models**

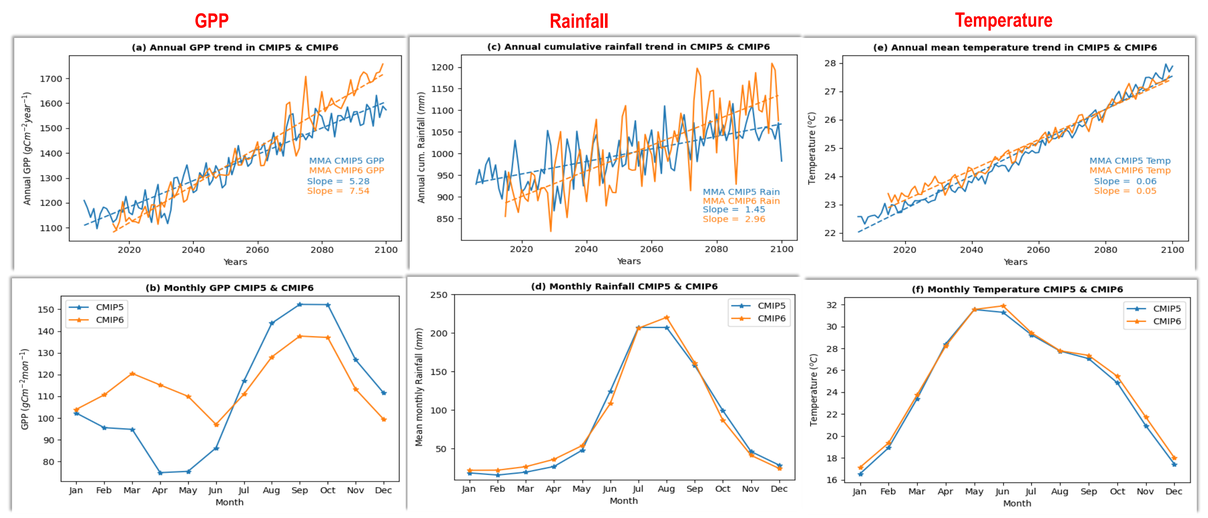


Figure 7: ***<u>Comparison between common CMIP5 & CMIP6</u>*** **(a) Annual GPP trend, (b) Mean monthly GPP, (c) Annual total rainfall, (d) Mean monthly rainfall, (e) Annual mean temperature, and (f) Mean monthly temperature**

Acknowledgements and References

Acknowledgments:

- Director, IITM, Pune; ESRL (https://psl.noaa.gov/data/gridded/)
- FSI report 2021 (<u>https://fsi.nic.in/forest-report-2021</u>); LUS report (Department of Economic Survey, MAFW, GOI, (<u>https://eands.dacnet.nic.in/LUS_latest_year.htm</u>)

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