Estimation of Mangrove Net Primary Production and Carbon Sequestration Service using Light Use Efficiency Models in the Sunderban Biosphere Region, India

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Introduction

The importance of coastal and terrestrial ecosystem is considered the relevant proxy indicator to assess the impact of increased concentration of atmospheric greenhouse components mainly carbon dioxide on global warming and other major climatic anomalies. Therefore actual quantification of the amount of carbon sequestered by terrestrial and maritime ecosystem is necessary to assess the nature of global and regional carbon cycle. Carbon sequestration by terrestrial ecosystem is the fluxes of gaseous carbon from atmosphere into an ecosystem via photosynthesis mechanism is also known as Gross Primary Productivity (GPP) and Net Primary Productivity (NPP). Therefore, it is necessary to quantify the spatiotemporal NPP to address the future changes in the global and regional carbon cycle.

Objectives

1. Incorporate several Light Use Efficiency (LUE) models to correctly quantify the spatiotemporal NPP in order to address the unavailability of robust flux network based carbon flux measurement
2. Quantify the seasonal dynamics of NPP in order to assess the impact of bioclimatic, biophysical and environmental stress factors on plant productivity

Study area, Methodology and Data

- The study area includes the Indian part of Sunderban under four broad subdivision as core zone covering 1700 km^2, a development zone covering 5300 km^2, a manipulation region covering 2400 km^2, and the restoration zone covering up to 230 km^2.

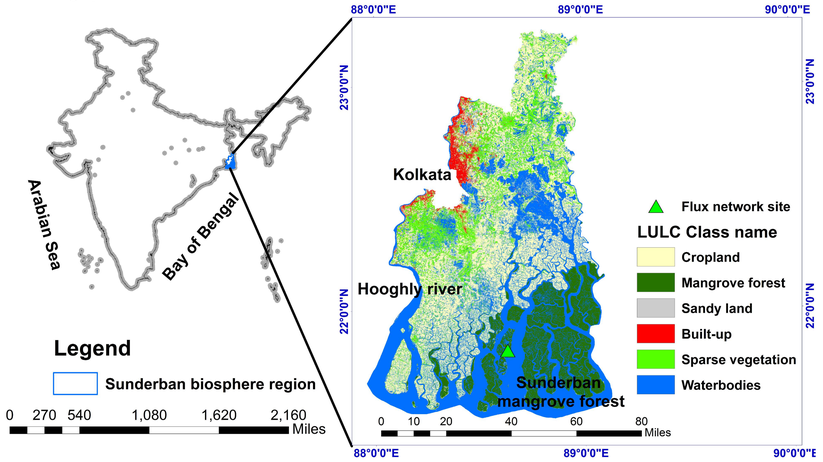
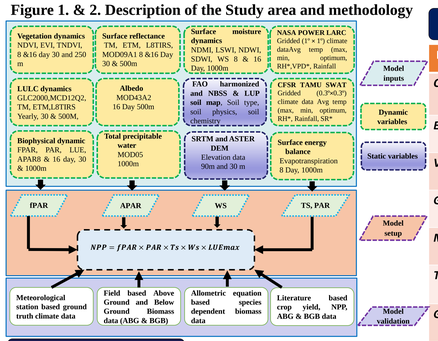


Figure 1. & 2. Description of the Study area and methodology



LUE model description

Model	Expression
CASA	$NPP = f(fPAR, PAR, \varepsilon_{\max}, Ts_1, Ts_2, Ws)$
EC-LUE	$NPP = f(fPAR, PAR, \varepsilon_{\max}, \min(Ts, Ws))$
VPM	$NPP = f(fPAR, PAR, \varepsilon_{\max}, Ts, Ws, Ps)$
GLOPEM	$NPP = f(fPAR, PAR, \varepsilon_{\max}, Ts, Ws, VPD)$
MOD17	$GPP = f(fPAR, PAR, \varepsilon_{\max}, T_{\min}, VPD)$
TG	$GPP = f(fPAR, PAR, \varepsilon_{\max}, EVI_{scaled}, LST_{scaled})$
GR	$GPP = f(fPAR, PAR, \varepsilon_{\max}, VI)$

Results

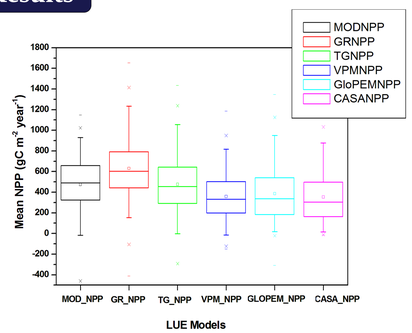


Figure 3. Boxplot of mean NPP calculated by MOD 17, CASA, GLOPEM, VPM, TG and GR model.

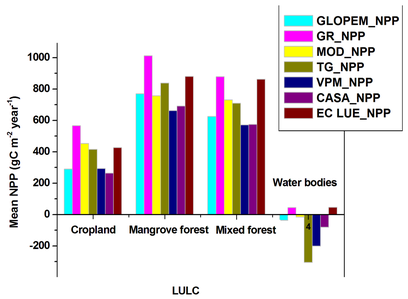


Figure 4. Comparison of NPP estimated by several LUE models among different LULC types.

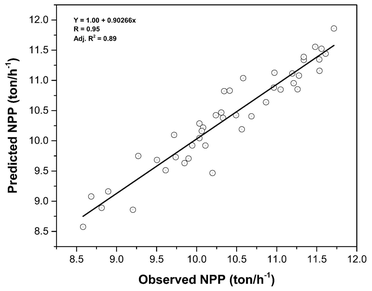


Figure 5. Relation between the CASA model derived NPP and observed NPP.
Correlation is significant at the 0.01 level.

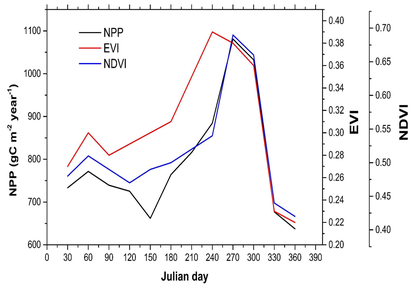


Figure 6. Seasonal dynamics of NPP, Enhanced Vegetation Index (EVI), Normalized Difference Vegetation Index (NDVI) in the study area.

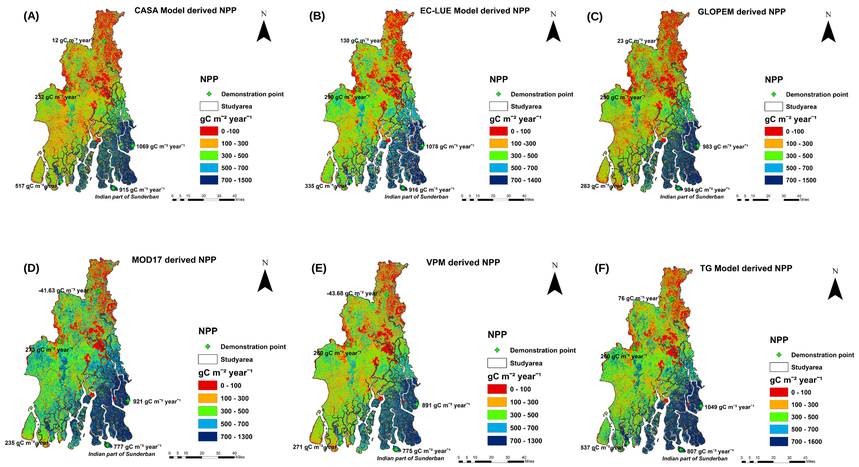


Figure 7. Spatial variation of the satellite remote sensing estimation of (A) Carnegie-Ames-Standford Approach (CASA) model NPP, (B) Eddy Covariance-Light Use Efficiency (EC-LUE) model NPP, (C) Global Production Efficiency Model (GloPEM) NPP, (D) Moderate Resolution Imaging Spectro Radiometer (MODIS) 17 (MOD 17) model NPP, (E) Vegetation Photosynthesis Model (VPM) NPP and (F) Temperature and Greenness (TG) model NPP in the study area.

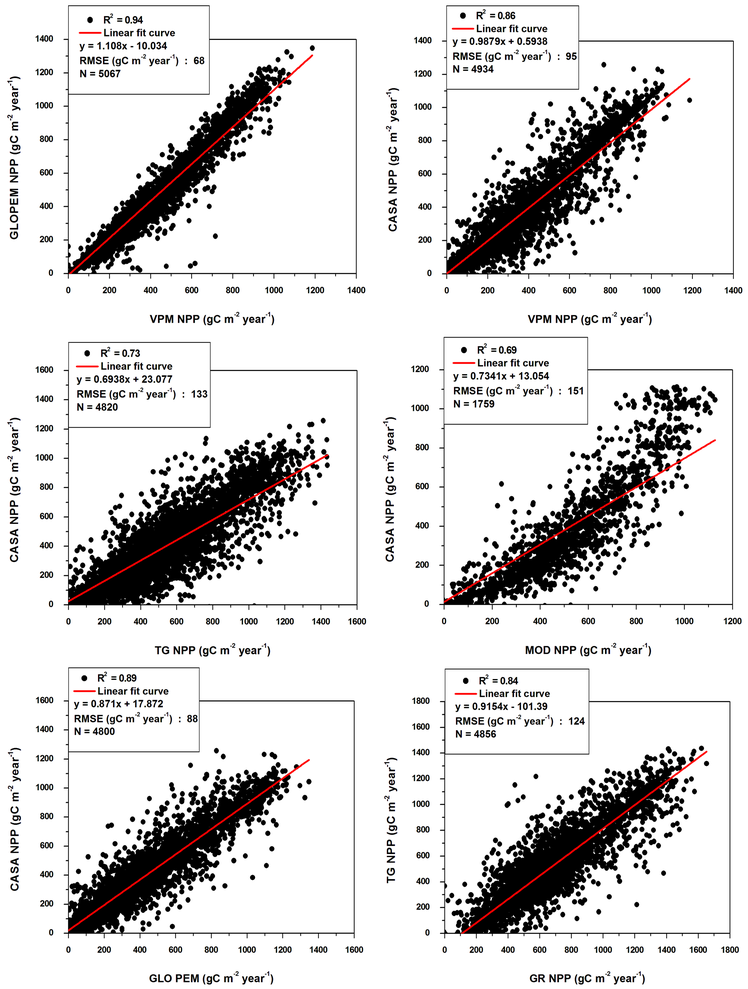


Figure 8. Coefficient of Determination (R^2) between different LUE models in the study area. All correlations are significant at the 0.01 level.

Table 2. Pearson correlation coefficient test (R) between different Bioclimatic (PAR, SR, Ta, Pr, RH, Ta_Max, Ta_Min), Biophysical (APAR, FPAR, NDVI, NDMI, NDWI, EVI, OSAVI, TNDVI, DVI, LSWI, LUE) and Environmental stress factors (TDIFF, Tdiff, Ws, Ts_1, Ts_2, LST, VPD).

	NPP	APAR	FPAR	NDVI	NDMI	NDWI	EVI	OSAVI	TNDVI	DVI	LSWI	PAR	LUE	SR	Ta	Pr	RH	Ta_max	Ta_min	TDIFF	Tdiff	WS	TS_1	TS_2	LST	VPD
NPP	1.00**																									
APAR	0.98**	1.00**																								
FPAR	0.97**	1.00**	1.00**																							
NDVI	0.97**	1.00**	1.00**	1.00**																						
NDMI	0.92**	0.88**	0.75**	0.85**	1.00**																					
NDWI	0.86**	0.78**	0.78**	0.78**	0.61**	1.00**																				
EVI	0.94**	0.96**	0.97**	0.97**	0.70**	0.73**	1.00**																			
OSAVI	0.96**	0.99**	0.99**	0.99**	0.77**	0.65**	1.00**	1.00**																		
TNDVI	0.96**	0.99**	1.00**	1.00**	0.74**	0.58**	0.97**	0.99**	1.00**																	
DVI	0.90**	0.92**	0.93**	0.93**	0.64**	0.83**	0.98**	0.96**	0.93**	1.00**																
LSWI	0.81**	0.75**	0.71**	0.71**	0.84**	0.32*	0.65**	0.68**	0.70**	0.60**	1.00**															
PAR	0.74**	0.69**	0.67**	0.67**	0.74**	0.40**	0.60**	0.63**	0.63**	0.55**	0.85**	1.00**														
LUE	0.71**	0.58**	0.56**	0.56**	0.66**	0.49**	0.55**	0.56**	0.54**	0.57**	0.63**	0.57**	1.00**													
SR	0.74**	0.69**	0.62**	0.62**	0.74**	0.40**	0.60**	0.61**	0.61**	0.60**	0.85**	1.00**	0.57**	1.00**												
Ta	0.79**	0.78**	0.78**	0.78**	0.74**	0.70**	0.61**	0.74**	0.68**	0.69**	0.57**	-0.04	-0.12*	-0.04	1.00**											
Pr	-0.01	0.00	0.03	0.03	0.00	-0.04	-0.01	0.03	0.04	0.01	0.05	-0.16*	-0.02	-0.16*	0.19*	1.00**										
RH	0.73**	0.68**	0.62**	0.62**	0.73**	0.51**	0.62**	0.62**	0.61**	0.62**	0.83**	0.95**	0.55**	0.95**	-0.11*	-0.07	1.00**									
Ta_max	-0.84**	-0.67**	-0.67**	-0.67**	-0.73**	-0.52**	-0.63**	-0.58**	-0.58**	-0.63**	-0.73**	-0.32*	-0.22*	-0.32*	0.67**	0.30*	-0.34*	1.00**								
Ta_min	0.60**	0.64**	0.54**	0.54**	0.65**	0.48**	0.55**	0.54**	0.53**	0.55**	0.73**	0.52**	0.50**	0.93**	-0.15*	-0.30*	0.94**	-0.44**	1.00**							
TDIFF	0.68**	0.64**	0.57**	0.57**	0.68**	0.31*	0.54**	0.55**	0.56**	0.50**	0.75**	0.89**	0.47**	0.89**	0.06	-0.49**	0.85**	-0.30*	0.92**	1.00**						
Tdiff	-0.54**	-0.52**	-0.46**	-0.46**	-0.53**	-0.39*	-0.51**	-0.46**	-0.44**	-0.54**	-0.64**	-0.83**	-0.50**	-0.83**	0.41**	0.41**	-0.90**	0.59**	-0.90**	-0.86**	1.00**					
WS	0.97**	1.00**	1.00**	1.00**	0.75**	0.59**	0.89**	0.90**	1.00**	0.91**	0.74**	0.62**	0.42**	0.62**	0.18*	0.03	0.62**	-0.07	0.54**	0.59**	-0.45**	1.00**				
TS_1	-0.84**	-0.86**	-0.79**	-0.75**	-0.71**	-0.66**	-0.78**	-0.76**	-0.79**	-0.89**	-0.74**	-0.30*	-0.22*	-0.30*	0.99**	0.19*	-0.26*	0.71**	-0.23*	-0.07	0.53**	0.09	1.00**			
TS_2	-0.79**	-0.77**	-0.79**	-0.72**	-0.70**	-0.66**	-0.71**	-0.64**	-0.69**	-0.58**	-0.64**	-0.20	-0.22*	-0.20*	0.99**	0.21*	-0.28*	0.71**	-0.10*	-0.08	0.54**	0.09	1.00**	1.00**		
LST	-0.36*	-0.37*	-0.39*	-0.39*	-0.40**	-0.22*	-0.37*	-0.38*	-0.39*	-0.35*	-0.29*	-0.19*	-0.23*	-0.19*	-0.03	-0.42**	-0.23*	-0.02	-0.06	-0.01	0.05	-0.39**	0.00	-0.01	1.00**	
VPD	-0.37*	-0.38*	-0.39*	-0.39*	-0.41**	-0.22*	-0.37*	-0.38*	-0.40*	-0.38*	-0.30*	-0.19*	-0.23*	-0.19*	-0.03	-0.42**	-0.24*	-0.02	-0.07	-0.02	0.05	-0.39**	0.00	0.00	1.00**	1.00**

Conclusions and Discussions

1. All LUE models were correctly estimate the NPP of different ecosystem with less significant errors.
2. CASA, VPM and GLOPEM were explained the maximum variances (>80%) among the all models.
3. NPP is highly correlated with the biophysical variables, followed by bioclimatic and stress variables.
4. The mean NPP was estimated between 500 gC m^{-2} year^{-1} to 700 gC m^{-2} year^{-1} by the LUE models.

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