The Greening Earth

Ranga B. Myneni
(rmyneni@bu.edu)

Final Workshop for the Arctic Biomass Project
October 20th - 23rd - 2015
Svalbard
Norway

Outline

1. AVHRR Data
2. Greening North
3. Greening Earth
4. Related Studies

Advanced Very High Resolution Radiometer (AVHRR)

Remote Sens. **2014**, *6*(8), 6929-6960; doi:10.3390/rs6086929 Open Access

Article

A Non-Stationary 1981–2012 AVHRR $NDVI_{3g}$ Time Series

Jorge E. Pinzon [1,*] and Compton J. Tucker [2]

[1] Science Systems and Applications Inc., Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Code 618, Greenbelt, MD 20771, USA

[2] Earth Science Division, NASA Goddard Space Flight Center, Code 610, Greenbelt, MD 20771, USA

- $NDVI_{3g}$ data set
- 8 x 8 km^2 pixels (spatial resolution)
- 15-day max NDVI temporal composites (2 per month)
- July 1981 to December 2013 (32.5 year long)
- Inter-sensor calibration
- Minimal atmospheric correction
- Residual corruption effects likely

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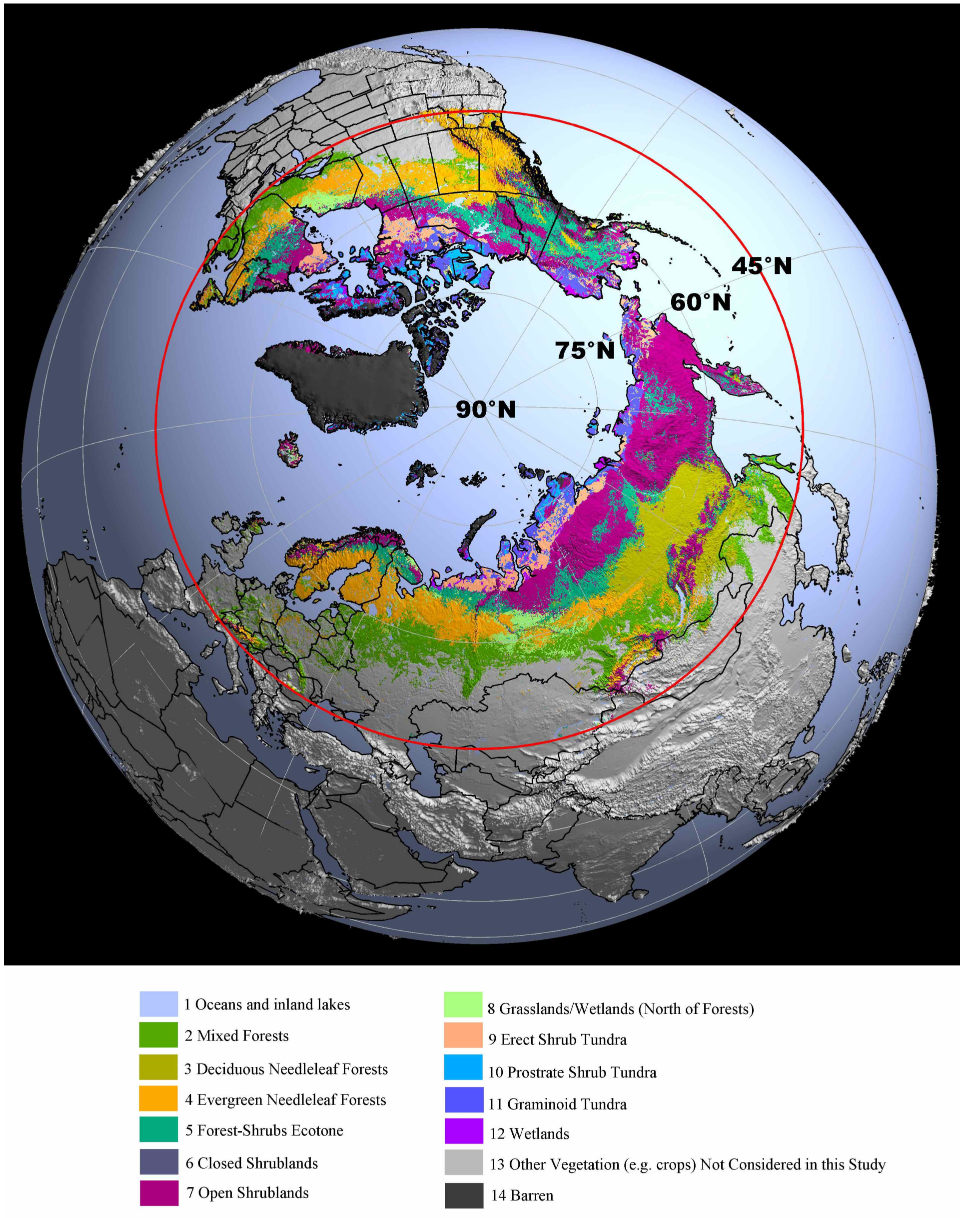
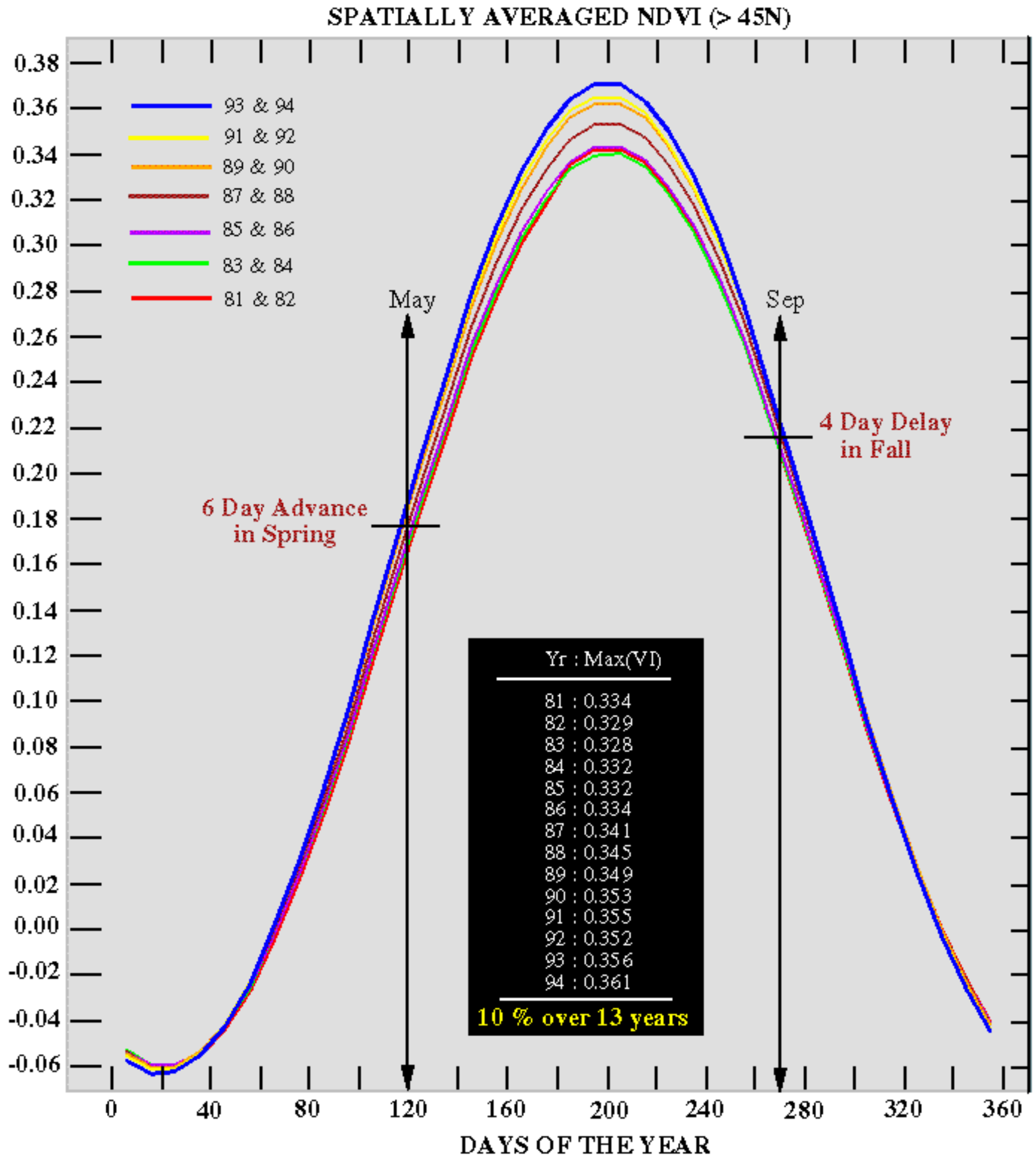
Greening North: The Northern Lands



The Arctic and Boreal regions
(26.02 million km^2)

(Xu et al., 2013)

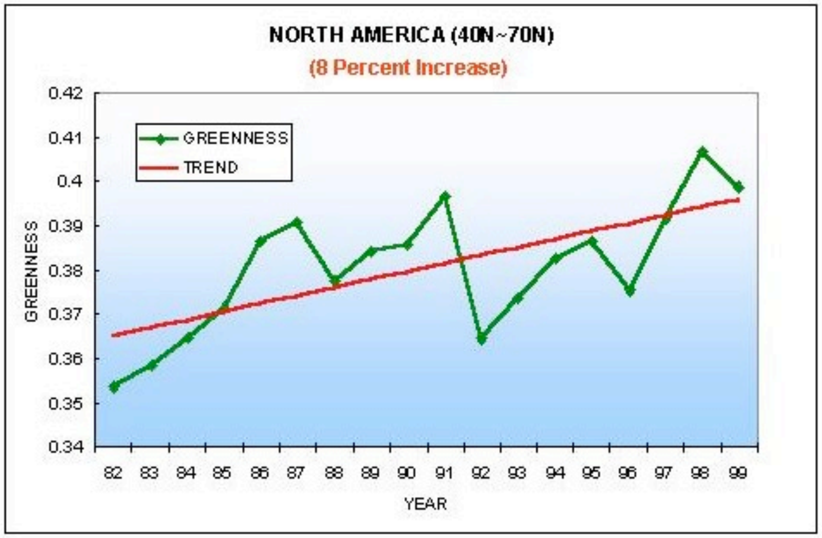
Greening North: Amplitude & Growing Season

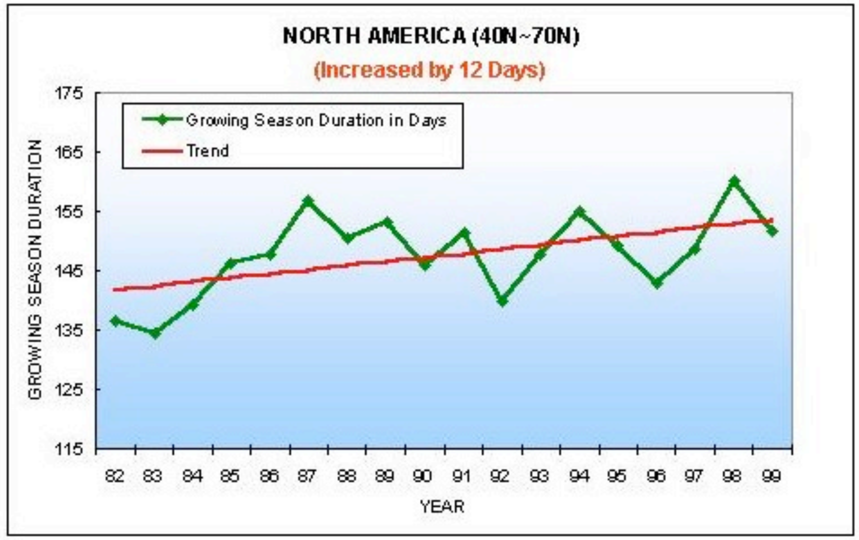


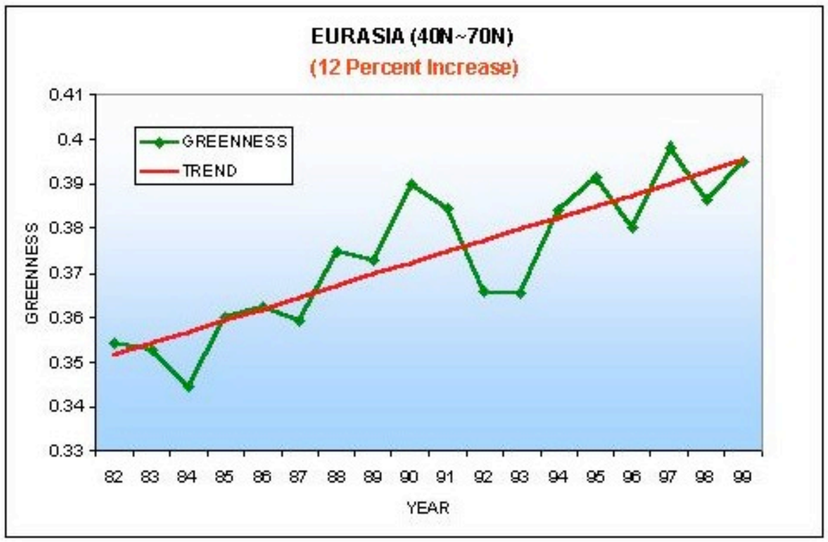
(1981 to 1994)

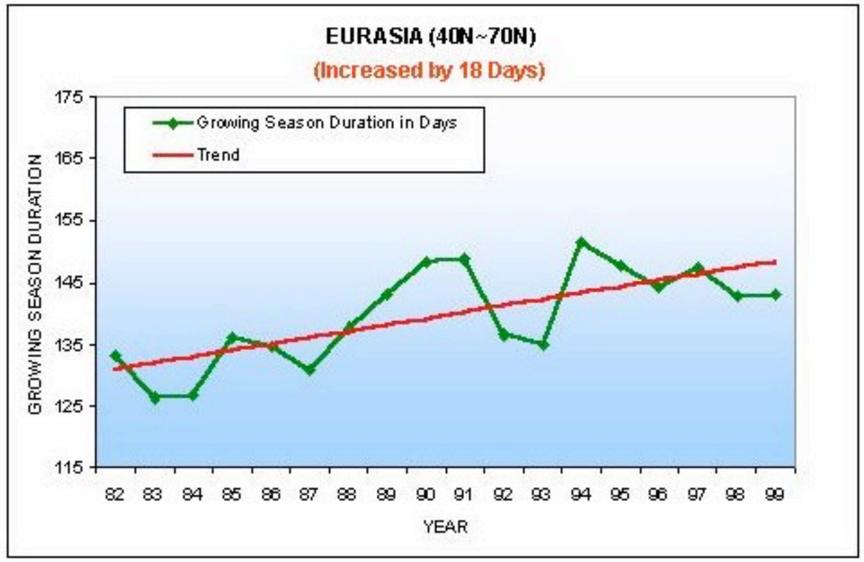
(Updated from Myneni et al., 1997)

Greening North: Amplitude & Growing Season (1981 to 1999)



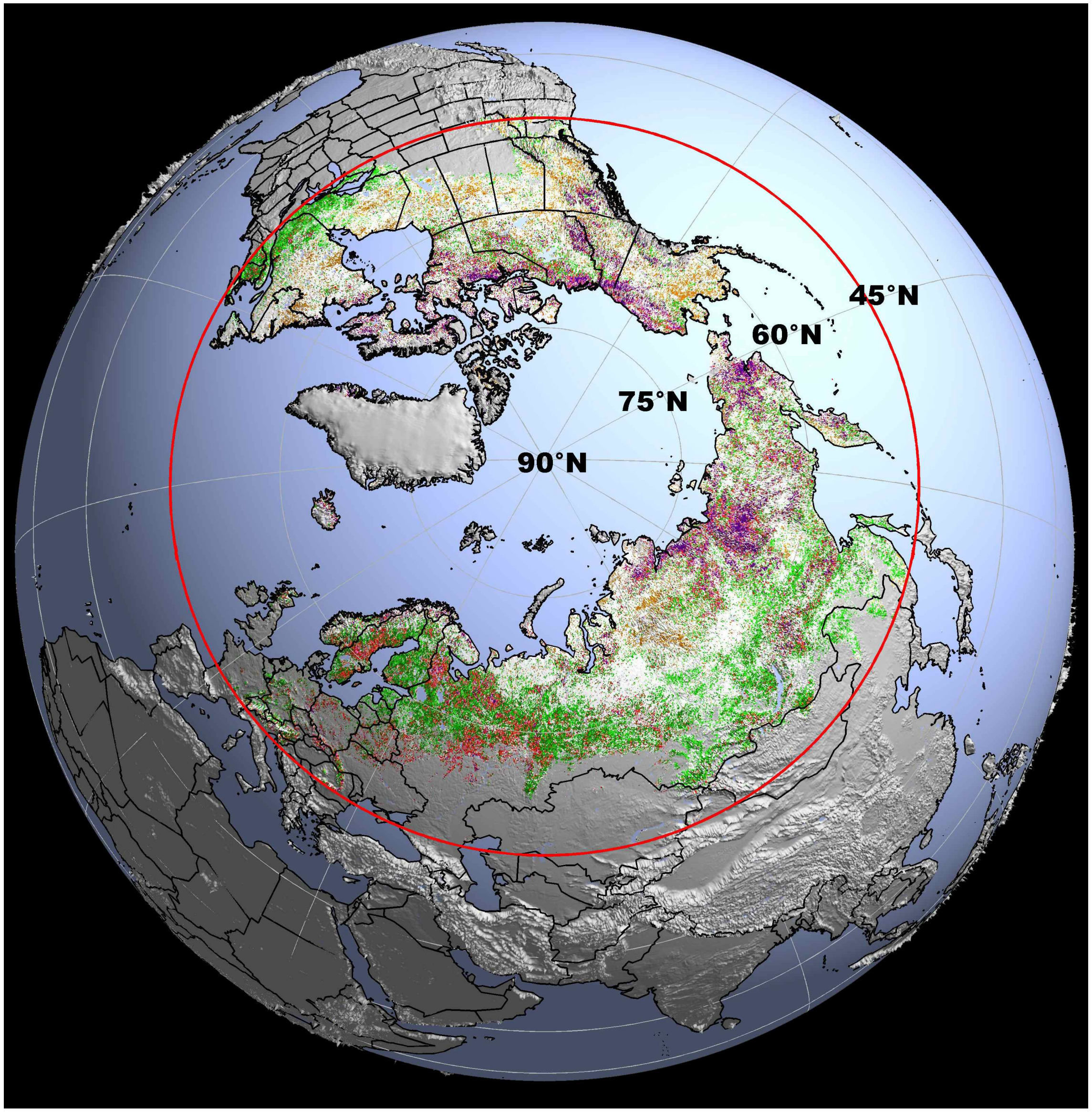






(Zhou et al., 2001)

Greening North: Spatial Pattern
(1981 to 2012)



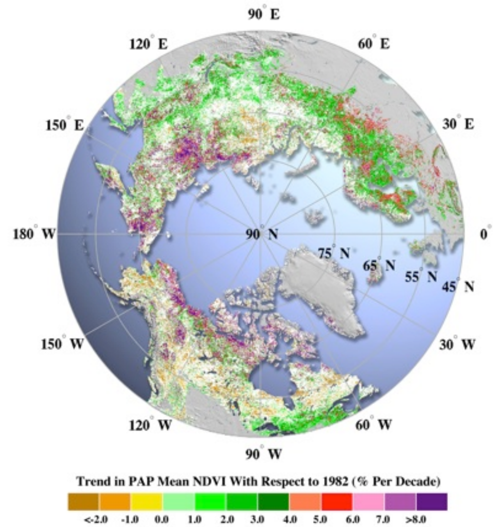
Trend in Arctic and Boreal Region Plant Growth with Respect to 1982 (% per Decade)

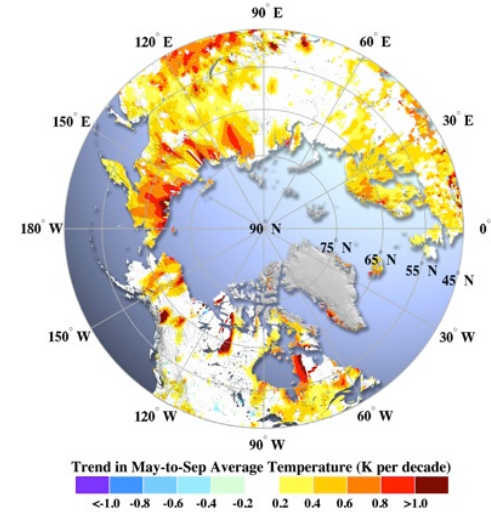
<-2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 >8.0

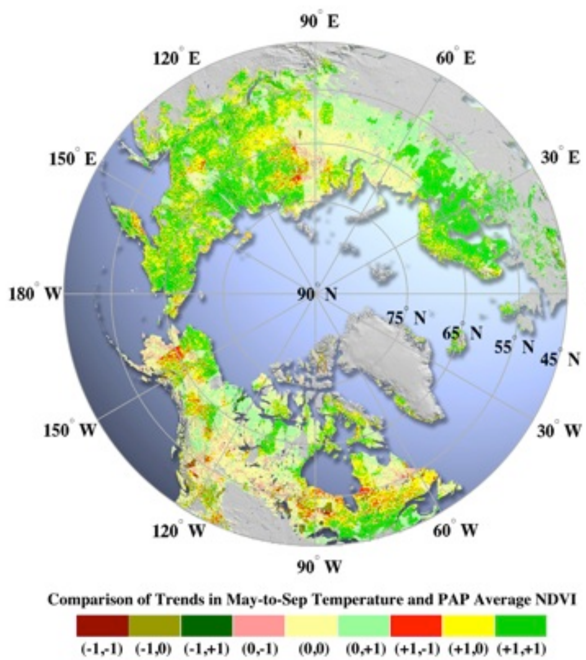
(Xu et al., 2013)

Greening North: The Temperature Connection

(Xu et al., 2013)







Trends did not oppose in 75% of the study area

Warming did not promote browning

Cooling did not promote greening

Greening North: Photographic Evidence

Finnmark in Norway (Courtesy of Dr. Hans Tommervik of NINA, Norway)

Increasing Abundance of Shrubs

Advancing Treeline in to Tundra

Near Altai Mountains in Russia (Courtesy of Prof. Sergey Kirpotin, Tomsk State University, Images provided by Prof. Terry Callaghan - EU-Interact)

Thawing Permafrost & Tree Establisment

Receding Glacier and Tree Establishment

Northernmost foothills of the Polar Ural Mountains on the Southern Yamal Peninsula in West Siberia, Russia (Courtesy of Prof. Bruce Forbes of The Arctic Centre, University of Lapland, Finland)

Increasing Abundance of Shrubs

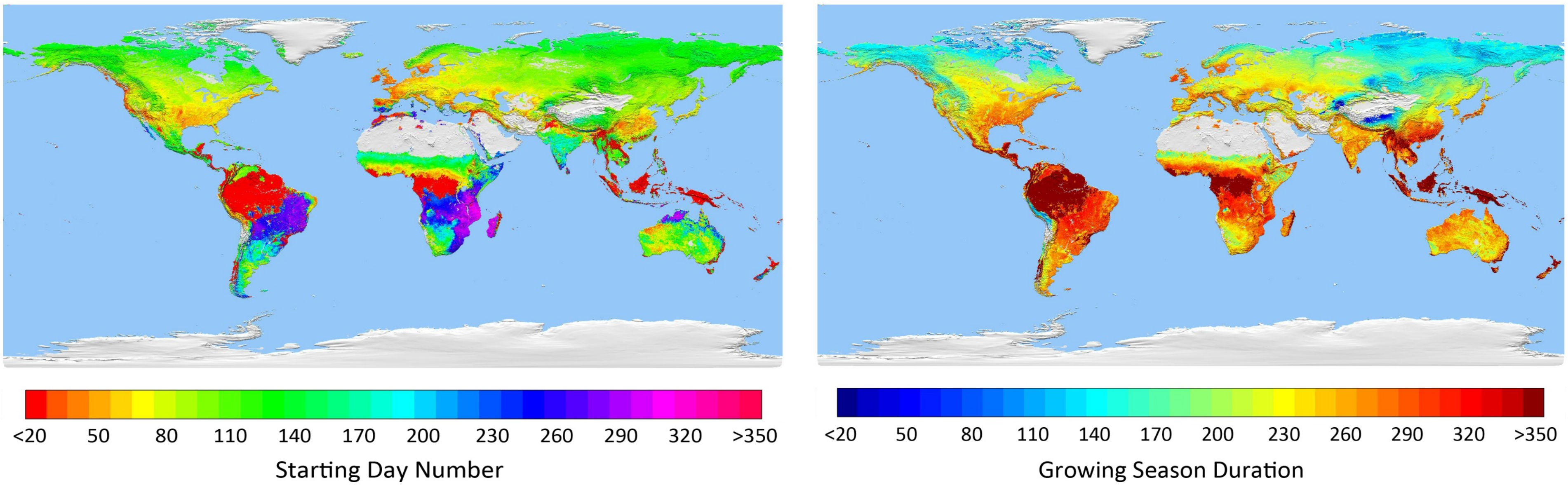
Vigorous Growth of Shrubs

Outline

1. **AVHRR Data**
2. **Greening North**
3. **Greening Earth**
4. **Related Studies**

Greening Earth: Growing Season

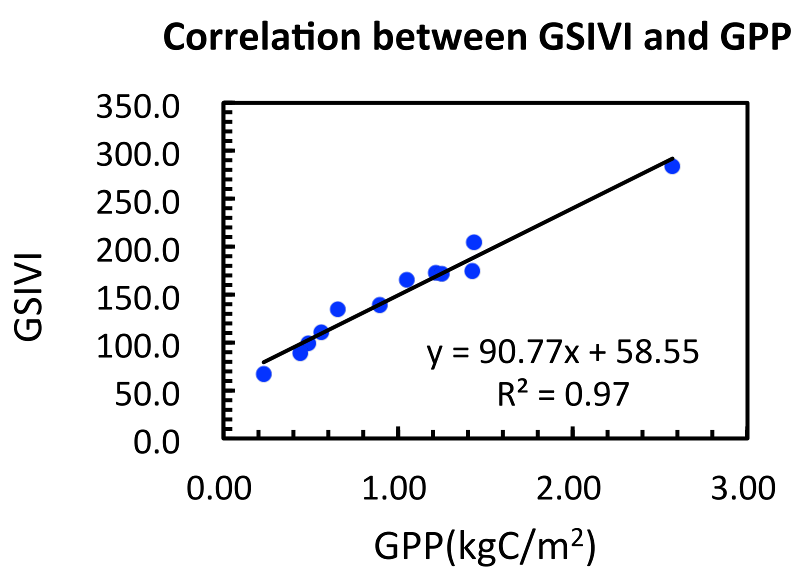
- Use NDVI thresholds to define the start/end of growing season
- Use ground freeze/thaw data to refine the NDVI thresholds definitions

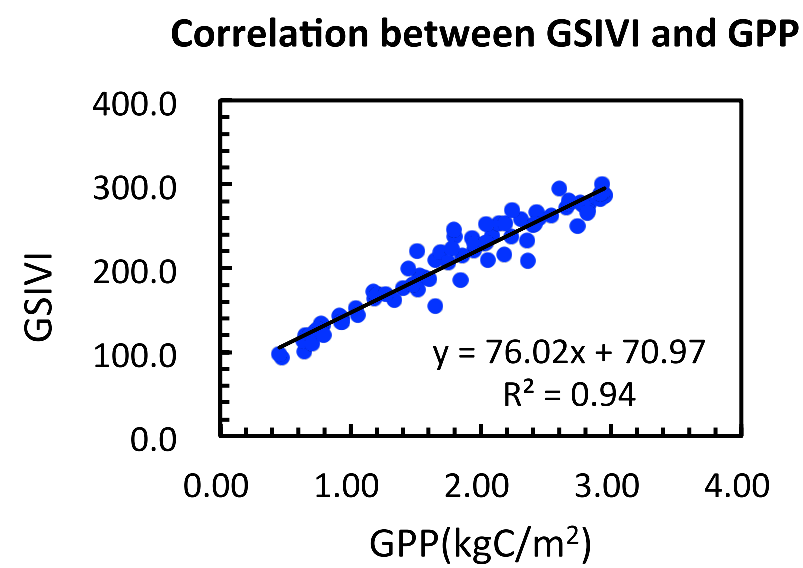


(Meyfroidt et al., 2015 in preparation)

96% of the pixels have one growing season per year (=12 consecutive months)
24.4% of the pixels have a growing season that span two calendar years

Greening Earth: Growing Season Integrated Vegetation Index (GSIVI)



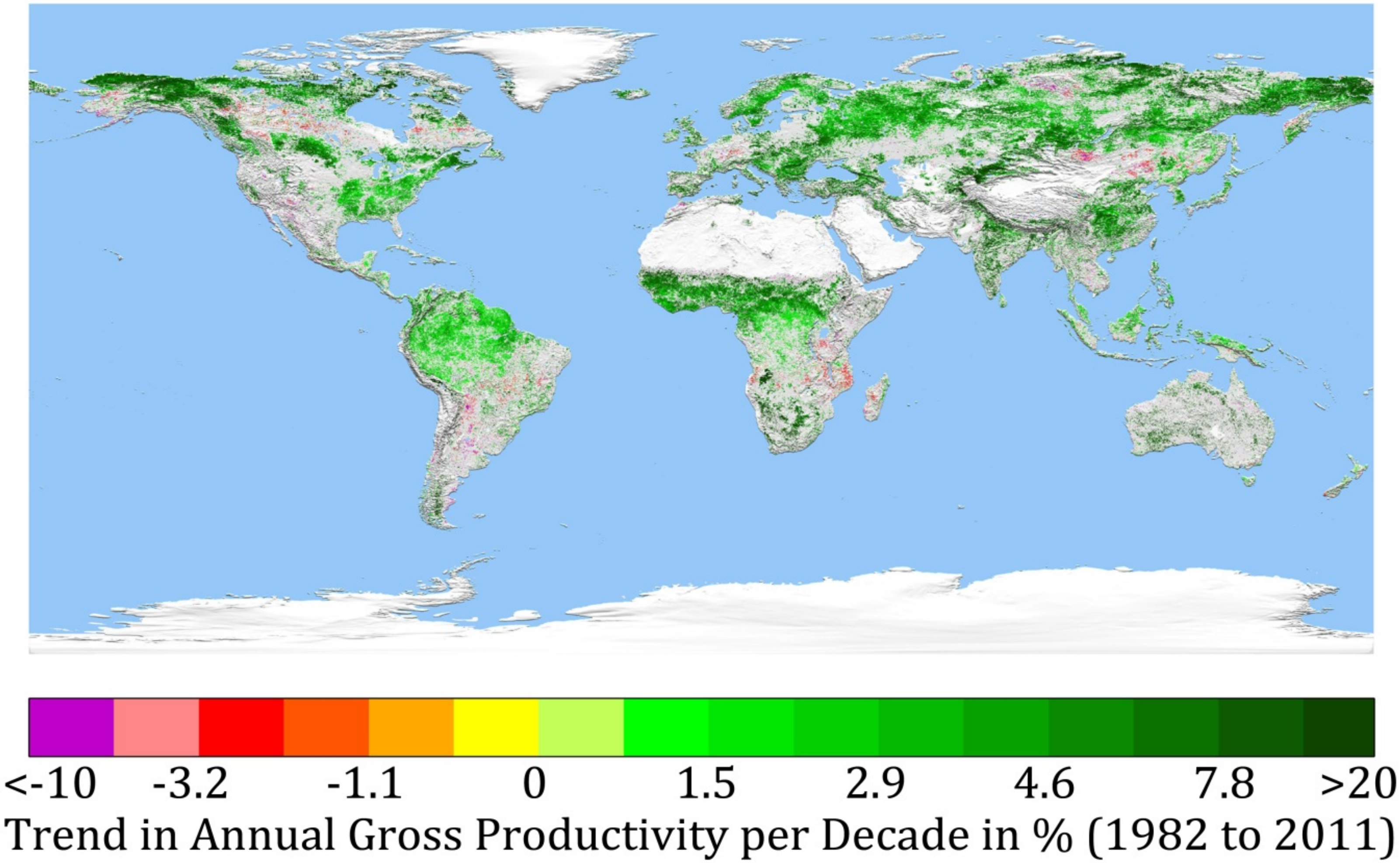


(Meyfroidt et al., 2015 in preparation)

Comparison between GSIVI and GPP (Beer et al., Science, 2010) for IGBP vegetation types (left panel) and 83 terrestrial eco-systems of the world (Olson et al., 2001) for the period 1998 to 2005

The GPP is a global gridded data set derived from flux tower measurements and ancillary data with machine learning tools

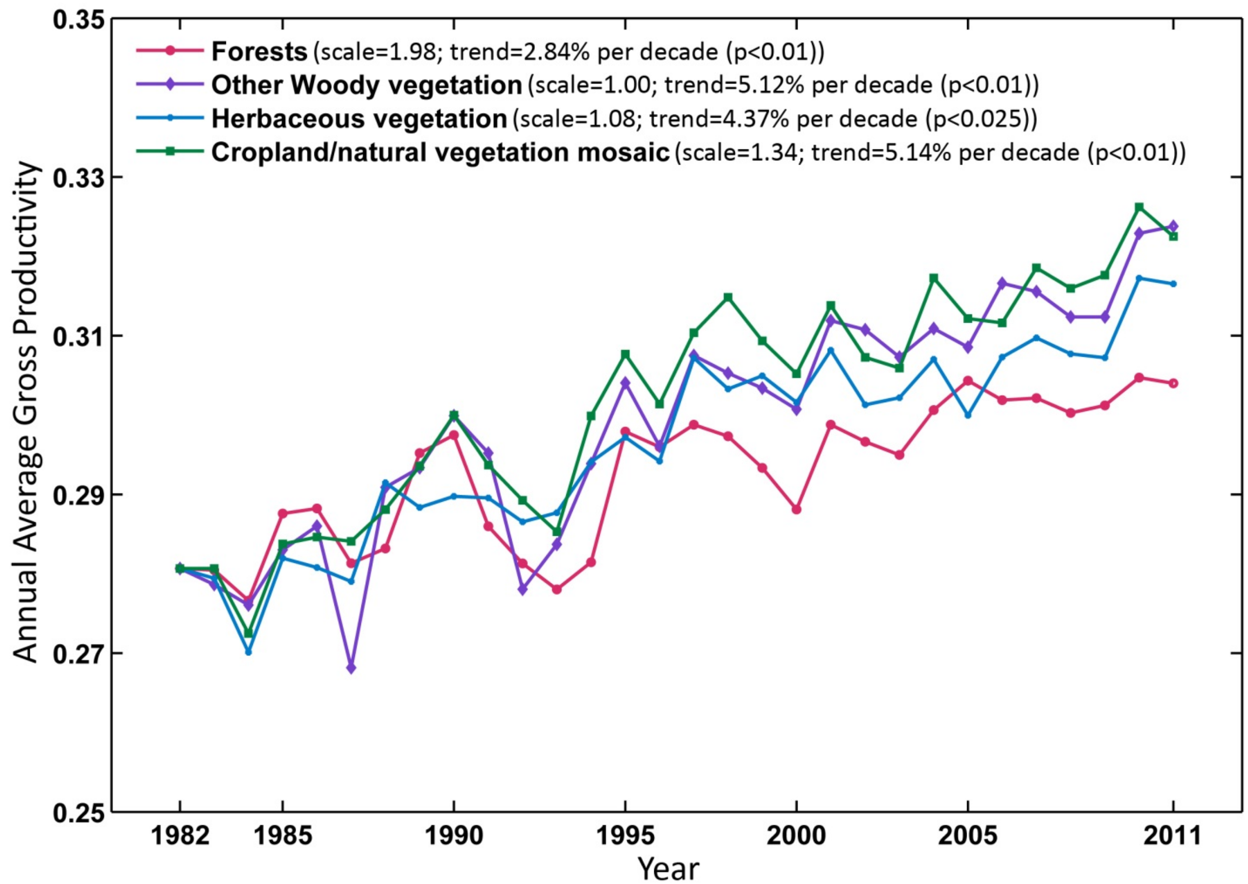
Greening Earth: Spatial Patterns



(Meyfroidt et al., 2015 in preparation)

Annual Gross Productivity = Growing Season Integrated Vegetation Index
Statistically significant ($p<0.1$) based on Vogelsang's t-PS_T test

Greening Earth: By Vegetation Types

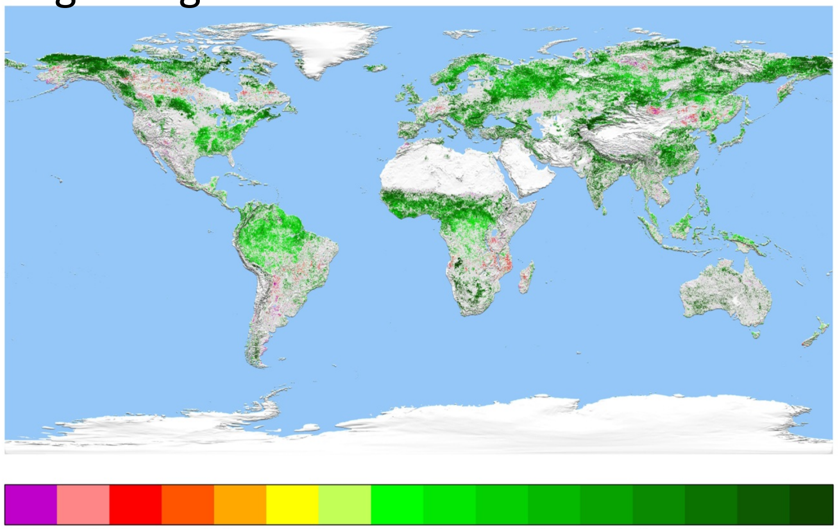


(Meyfroidt et al., 2015 in preparation)

A greening trend of 2.8 to 5.1% per decade is seen in all vegetation types

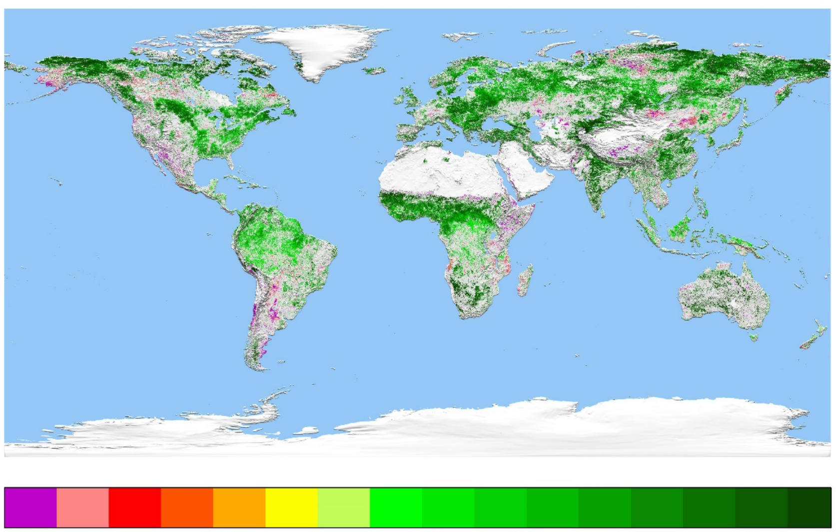
Greening Earth: Two Statistical Methods

Vogelsang



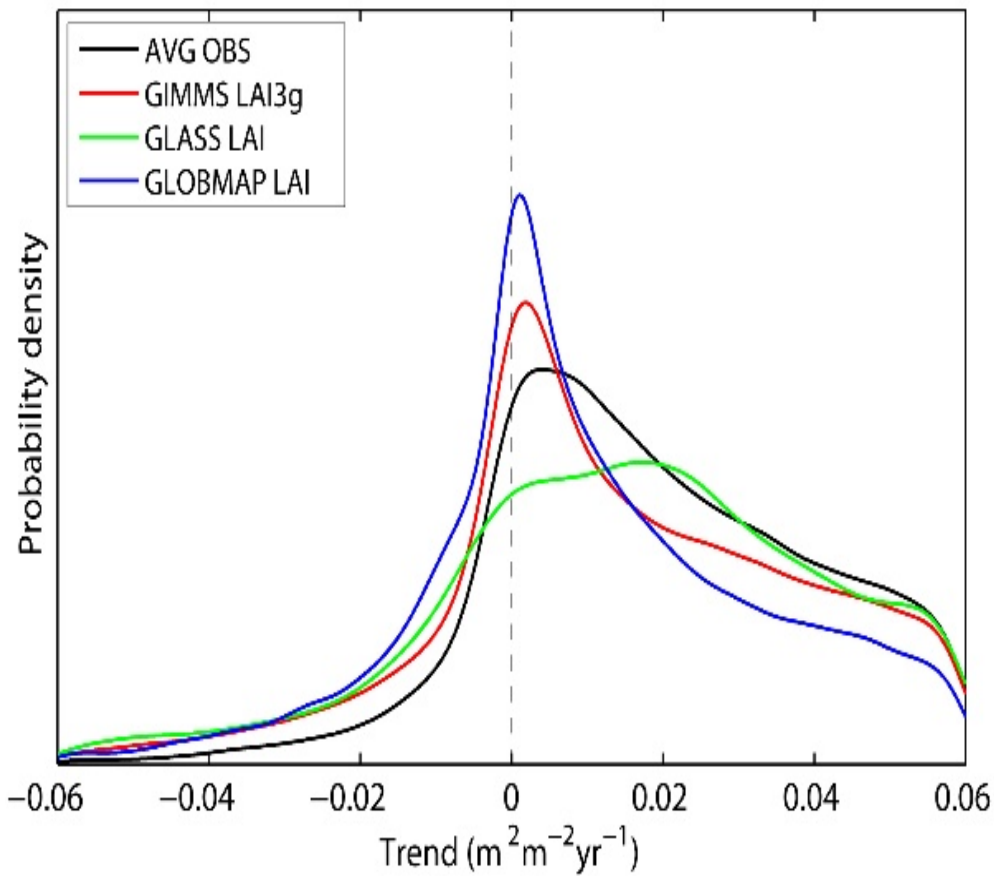
IGBP Land Cover Classes	Area			Productivity	
	G (%)	B (%)	N (%)	I (%)	D (%)
Evergreen broadleaf forests	5.62	0.15	7.10	2.27	-0.04
Deciduous broadleaf forests	0.54	0.09	0.95	0.23	-0.05
Cropland/Natural vegetation mosaics	2.27	0.13	4.30	1.26	-0.09
Savannas	1.67	0.40	6.03	0.94	-0.16
Mixed forests	3.56	0.40	8.33	1.96	-0.19
Woody savannas	2.85	0.05	2.96	1.22	-0.03
Croplands	3.41	0.21	7.15	1.75	-0.12
Closed shrublands	1.80	0.19	3.36	0.68	-0.06
Evergreen needleleaf forests	0.92	0.01	1.15	0.25	0.00
Deciduous needleleaf forests	0.18	0.09	1.07	0.11	-0.07
Grasslands	2.86	0.48	10.53	1.08	-0.18
Open shrublands	5.18	0.57	13.39	1.80	-0.22
Total	30.87	2.76	66.32	13.54	-1.21

Mann-Kendall



IGBP Land Cover Classes	Area			Productivity	
	G (%)	B (%)	N (%)	I (%)	D (%)
Evergreen broadleaf forests	5.63	0.30	6.93	1.99	-0.08
Deciduous broadleaf forests	0.58	0.12	0.88	0.20	-0.05
Cropland/Natural vegetation mosaics	2.76	0.15	3.80	1.28	-0.08
Savannas	4.28	0.50	7.51	1.79	-0.19
Mixed forests	2.16	0.39	5.55	0.95	-0.14
Woody savannas	3.20	0.06	2.60	1.14	-0.02
Croplands	4.37	0.37	6.02	1.85	-0.16
Closed shrublands	2.21	0.22	2.92	0.69	-0.06
Evergreen needleleaf forests	1.12	0.03	0.93	0.25	-0.01
Deciduous needleleaf forests	0.22	0.14	0.97	0.10	-0.08
Grasslands	3.83	0.79	9.25	1.20	-0.21
Open shrublands	6.44	1.16	11.53	1.86	-0.31
Total	36.81	4.22	58.90	13.29	-1.38

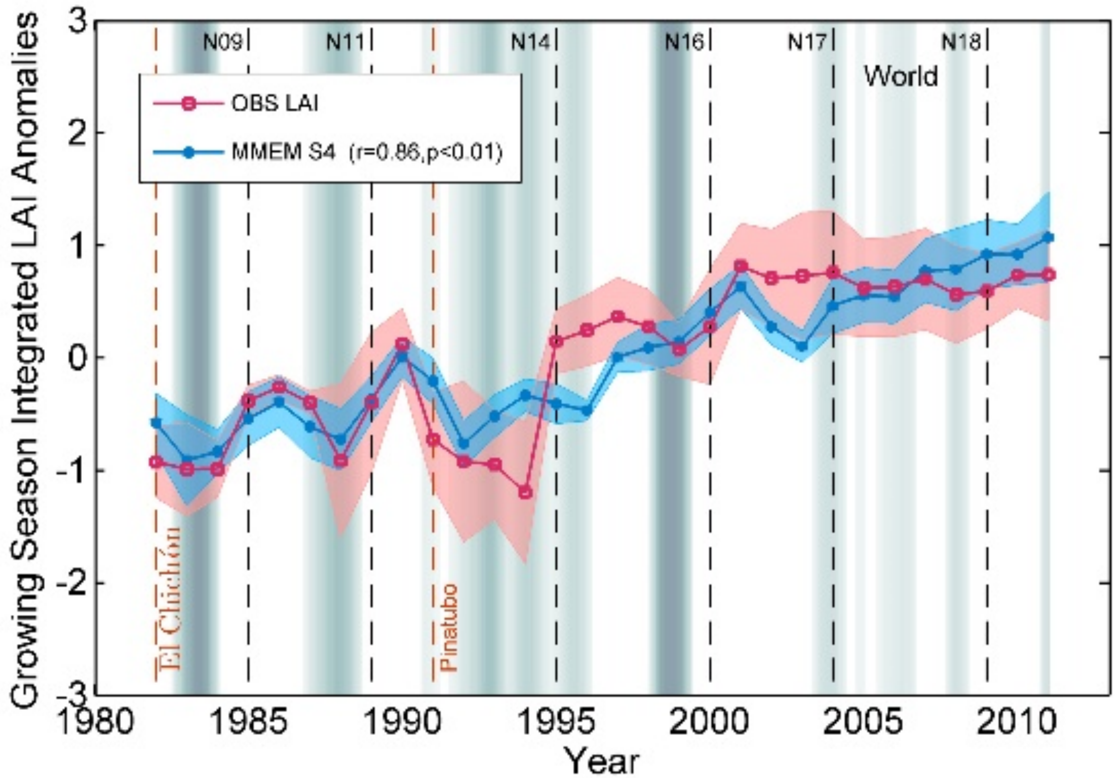
Greening Earth: Three Data Sets



(Zhu et al., 2015 in review)

Three semi-independent satellite data sets show abundance of positive LAI trends

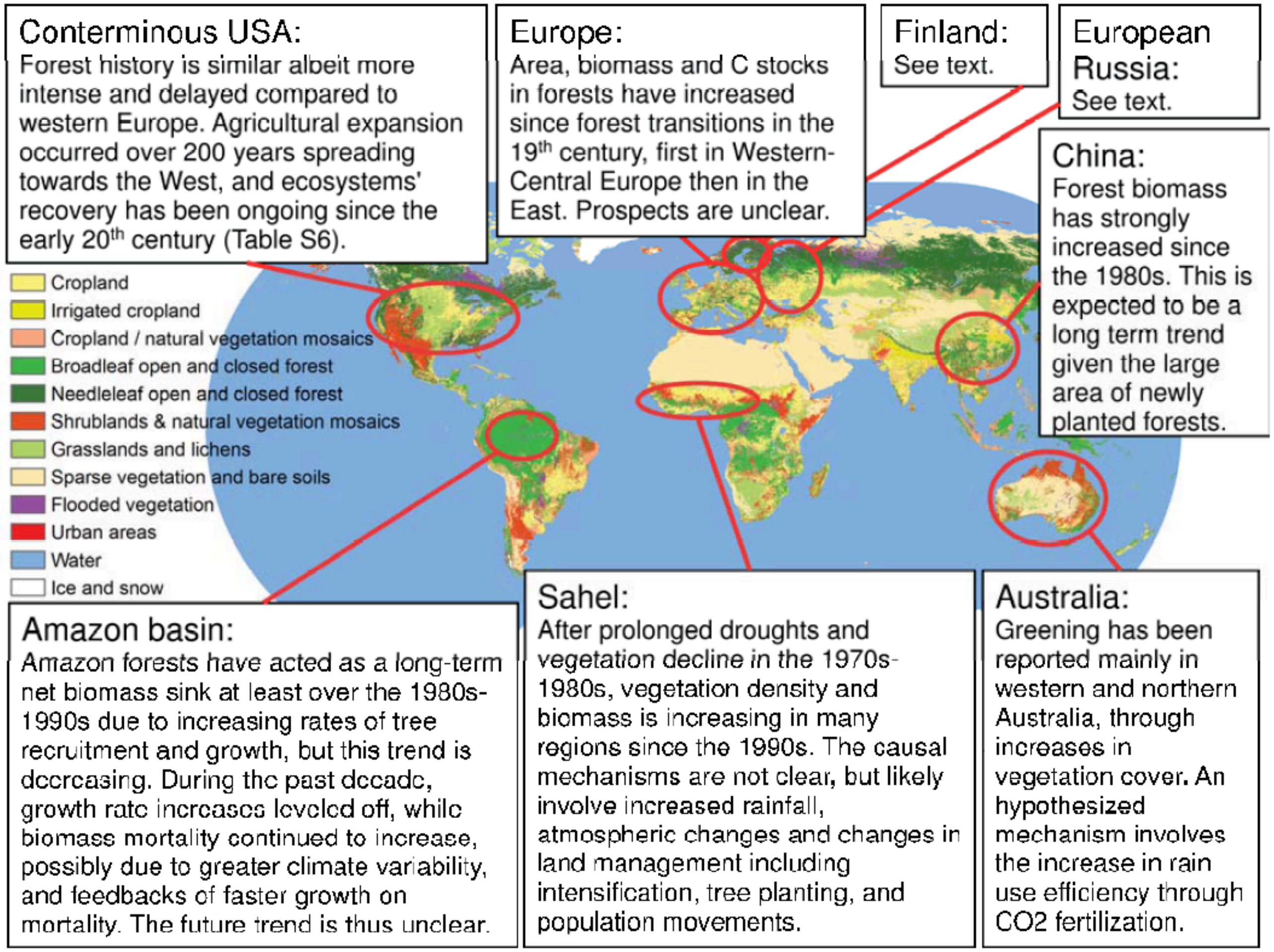
Greening Earth: Simulation by Veg Models



(Zhu et al., 2015 in review)

Dynamic vegetation models forced with observed CO2, N-deposition, climate and land cover changes (blue) reproduce the observations (red)

Greening Earth: Some Reasons



(Meyfroidt et al., 2015)

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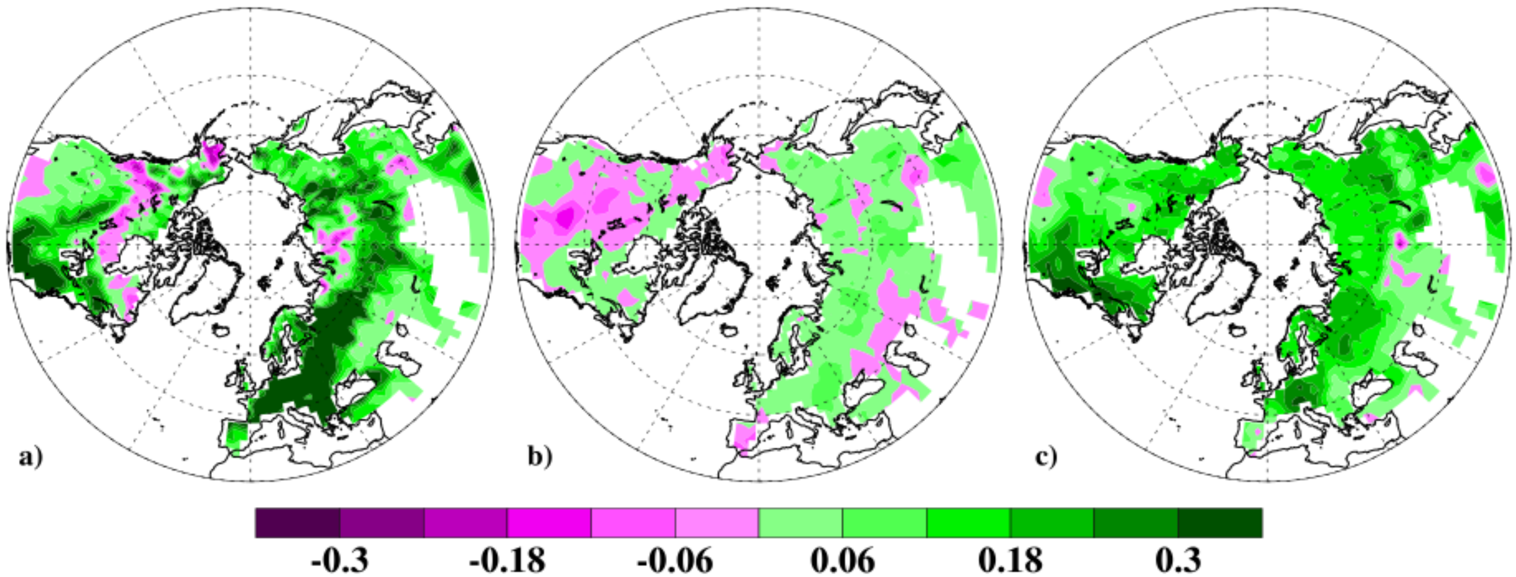
Greening Earth: Simulation by Climate Models



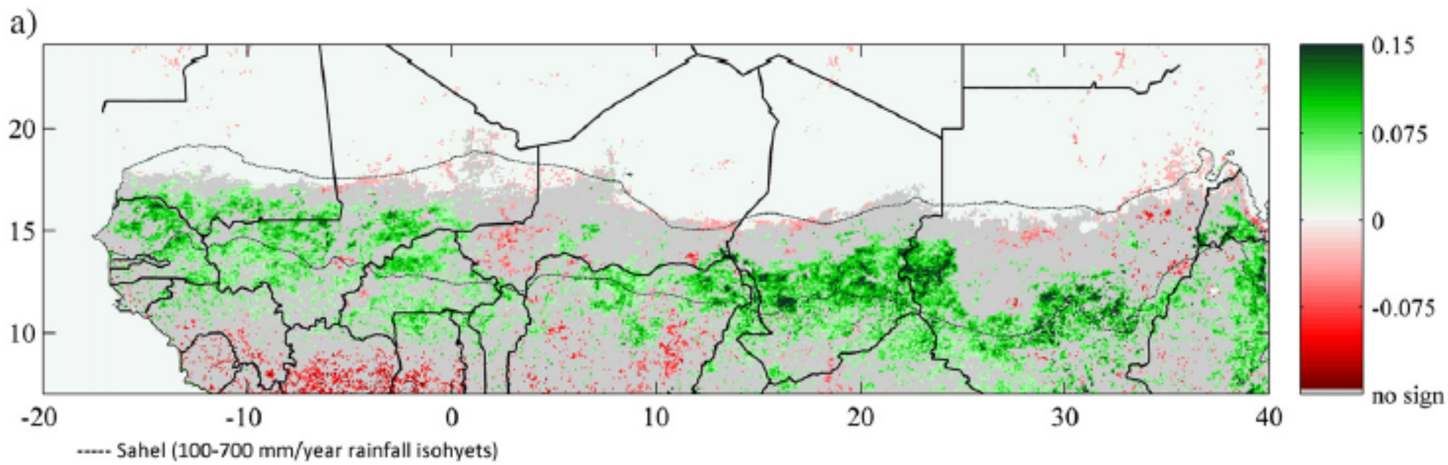
(Mao et al., 2015 in preparation)

Leaf Area Index (LAI) trends in **coupled climate models** forced with natural variations only (middle panel) and with both natural and anthropogenic forcings (right panel).

Observations in left panel.

Anthropogenic forcings are required to simulate observed trends in LAI

Greener Sahel



NDVI$_{3g}$ Trends 1981 to 2011

Remote Sensing of Environment 140 (2014) 350–364

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Re-greening Sahel: 30 years of remote sensing data and field observations (Mali, Niger)

C. Dardel [a,*], L. Kergoat [a], P. Hiernaux [a], E. Mougin [a], M. Grippa [a], C.J. Tucker [b]

[a] Geosciences Environnement Toulouse (GET), Observatoire Midi-Pyrénées, UMR 5563 (CNRS/UPS/IRD/CNES), 14 Avenue Edouard Belin, 31400 Toulouse, France
[b] NASA Goddart Space Flight Center, Mail Code 610.9, Greenbelt, MD 20771, USA

Desertification of the Sahel region has been debated for decades, while the concept of a "re-greening" Sahel appeared with satellite remote sensing data that allowed vegetation monitoring across wide regions and over increasingly long series of years (nowadays 30 years with the GIMMS-3g dataset). However, the scarcity of long-term field observations of vegetation in the Sahel prevents ground validation and deeper analysis of such trends. After assessing the consistency of the new GIMMS-3g NDVI product by comparison to three other AVHRR-NDVI datasets and MODIS NDVI, regional GIMMS-3g NDVI trends over 1981–2011 are analyzed. Trends are found positive and statistically significant almost everywhere in Sahel over the 1981–2011 period. Long-term field observations of the aboveground herbaceous layer mass have been collected within the Gourma region in Mali (1984–2011) and within the Fakara region in western Niger (1994–2011). These observations sample ecosystem and soil diversity, thus enabling estimation of averaged values representative of the Gourma and Fakara. NDVI measurements are found in good agreement with field observations, both over the Gourma and Fakara regions where re-greening and negative trends are observed respectively. A linear regression analysis performed between spatially averaged seasonal NDVI and a weighted average of field measurements explains 59% of the variability for the Gourma region over 1984–2011, and 38% for the Fakara region over 1994–2011. In the Gourma, which is a pastoral region, the re-greening trend is mainly observed over sandy soils, and attests for the ecosystem's resilience to the 1980s' drought, able to react to the more favorable rainfall of the 1990s and 2000s. However, contrasted changes in the landscape's functioning have occurred locally. An increase in erosion and run-off processes in association with decreasing or stable vegetation cover was observed over shallow soils, which occupy 30% of the area. In the agro-pastoral Fakara, the decreasing trends observed both from satellite NDVI and field assessments of herbaceous mass are hardly explained by rainfall. These results give confidence in the dominant positive trends in Sahelian greenness, but indicate that degradation trends can also be observed, both in situ and from satellite time series.

Greener China

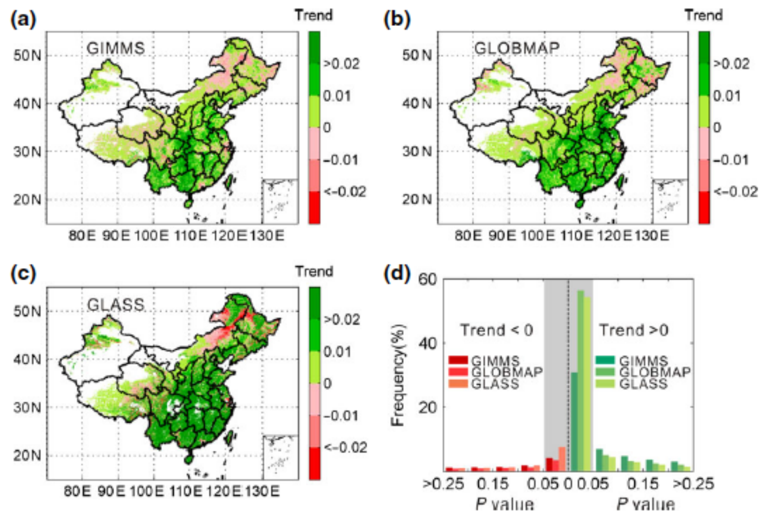


Fig. 1 Spatial distribution of the trend in growing-season (April–October) LAI (LAI_{GS}) during the period 1982–2009. The trends were calculated based on different LAI products: (a), GIMMS dataset; (b) GLOBMAP dataset; (c) GLASS dataset. (d) Frequency distribution of the significance level (P value) of the trends in LAI_{GS} derived by three datasets. The *P* value of the trend in LAI_{GS} for each pixel is estimated based on t test.

Global Change Biology

Global Change Biology (2015), doi: 10.1111/gcb.12795

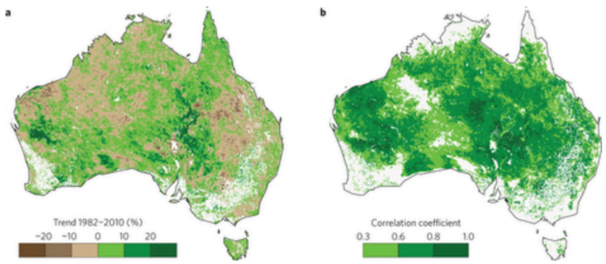
Detection and attribution of vegetation greening trend in China over the last 30 years

SHILONG PIAO[1,2], GUODONG YIN[1], JIANGUANG TAN[1], LEI CHENG[3], MENGTIAN HUANG[1], YUE LI[1], RONGGAO LIU[4], JIAFU MAO[5], RANGA B MYNENI[6], SHUSHI PENG[1], BEN POULTER[7], XIAOYING SHI[4], ZHIQIANG XIAO[8], NING ZENG[9], ZHENZHONG ZENG[1] and YINGPING WANG[3]

The reliable detection and attribution of changes in vegetation growth is a prerequisite for the development of strategies for the sustainable management of ecosystems. This is an extraordinary challenge. To our knowledge, this study is the first to comprehensively detect and attribute a greening trend in China over the last three decades. We use three different satellite-derived Leaf Area Index (LAI) datasets for detection as well as five different process-based ecosystem models for attribution. Rising atmospheric CO_2 concentration and nitrogen deposition are identified as the most likely causes of the greening trend in China, explaining 85% and 41% of the average growing-season LAI trend (LAI_{GS}) estimated by satellite datasets (average trend of 0.0070 yr^{-1}, ranging from 0.0035 yr^{-1} to 0.0127 yr^{-1}), respectively. The contribution of nitrogen deposition is more clearly seen in southern China than in the north of the country. Models disagree about the contribution of climate change alone to the trend in LAI_{GS} at the country scale (one model shows a significant increasing trend, whereas two others show significant decreasing trends). However, the models generally agree on the negative impacts of climate change in north China and Inner Mongolia and the positive impact in the Qinghai–Xizang plateau. Provincial forest area change tends to be significantly correlated with the trend of LAI_{GS} ($P < 0.05$), and marginally significantly ($P = 0.07$) correlated with the residual of LAI_{GS} trend, calculated as the trend observed by satellite minus that estimated by models through considering the effects of climate change, rising CO_2 concentration and nitrogen deposition, across different provinces. This result highlights the important role of China's afforestation program in explaining the spatial patterns of trend in vegetation growth.

Greener Australia

Figure 1: Spatial patterns of vegetation greening.



a, Pixel-by-pixel linear trends in annual NDVI. **b**, Areas of water-limited vegetation, determined as pixels with significan ($P \leq 0.10$) positive annual NDVI–precipitation correlations. Nonsignificant or negative correlations were masked…

NATURE CLIMATE CHANGE | LETTER

Reduced streamflow in water-stressed climates consistent with CO_2 effects on vegetation

Anna M. Ukkola, I. Colin Prentice, Trevor F. Keenan, Albert I. J. M. van Dijk, Neil R. Viney, Ranga B. Myneni & Jian Bi

Affiliations | Contributions | Corresponding author

Nature Climate Change (2015) | doi:10.1038/nclimate2831
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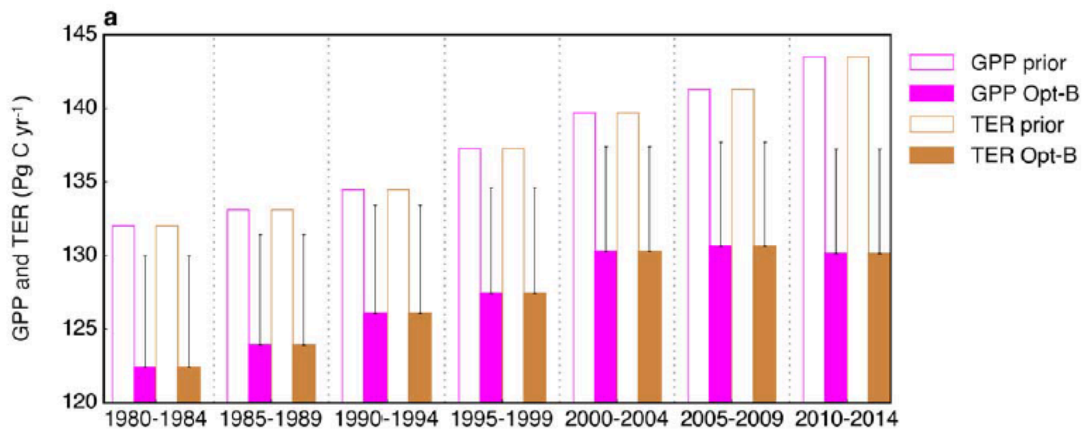
Citation | Reprints | Rights & permissions | Article metrics

Global environmental change has implications for the spatial and temporal distribution of water resources, but quantifying its effects remains a challenge. The impact of vegetation responses to increasing atmospheric CO_2 concentrations on the hydrologic cycle is particularly poorly constrained[1, 2, 3]. Here we combine remotely sensed normalized difference vegetation index (NDVI) data and long-term water-balance evapotranspiration (ET) measurements from 190 unimpaired river basins across Australia during 1982–2010 to show that the precipitation threshold for water limitation of vegetation cover has significantly declined during the past three decades, whereas sub-humid and semi-arid basins are not only ‘greening’ but also consuming more water, leading to significant (24–28%) reductions in streamflow. In contrast, wet and arid basins show nonsignificant changes in NDVI and reductions in ET. These observations are consistent with expected effects of elevated CO_2 on vegetation. They suggest that projected future decreases in precipitation[4] are likely to be compounded by increased vegetation water use, further reducing streamflow in water-stressed regions.

Trends in Terrestrial Carbon Fluxes

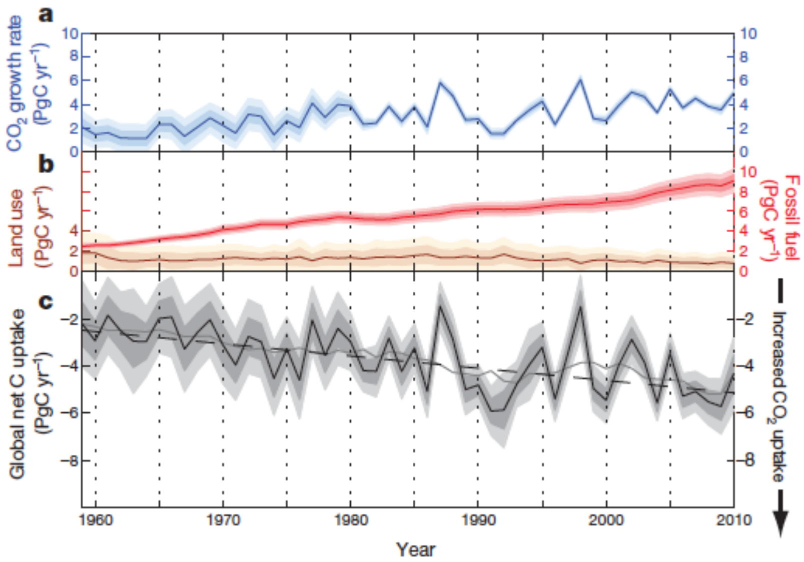


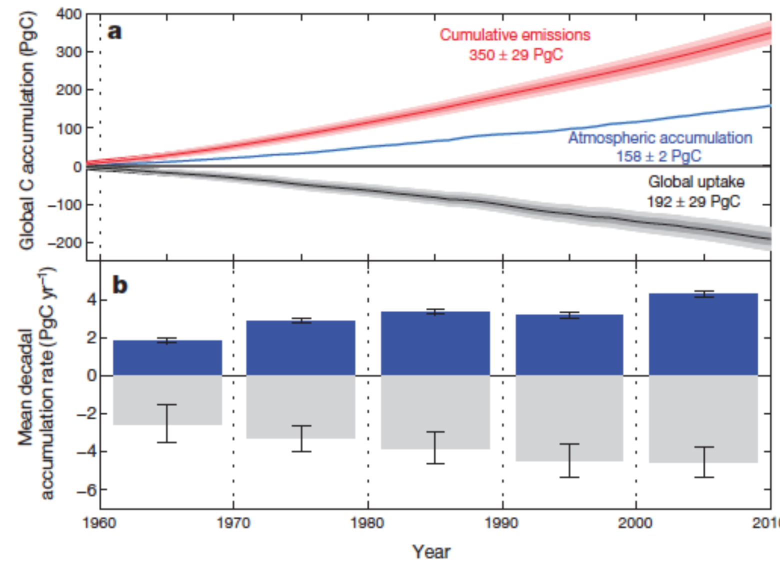
Quasi-decadal fluctuations in the global carbon budget since 1980 deduced from observations

Wei Li[1*], Philippe Ciais[1], Yilong Wang[1], Shushi Peng[1], Ashley P. Ballantyne[2], Josep G. Canadell[3], Leila A. Cooper[2], Pierre Friedlingstein[4], Corinne Le Quéré[5], Ranga B. Myneni[6], Glen Peters[7], Shilong Piao[8], Julia Pongratz[9]

(Submitted to Nature Geoscience)

Greening Trend: Carbon Connection





(Ballantyne et al., 2012)

A greener Earth could also be a increasing land sink

Greening Earth as Benefit of CO_2 Increase

THE AUSTRALIAN

Global warming: evidence high CO_2 levels good for crops, oceans

MATT RIDLEY THE TIMES OCTOBER 19, 2015 11:02AM

Patrick Moore, a founder of Greenpeace, said in a lecture last week that we should "celebrate carbon dioxide". Picture: Thinkstock Source: Supplied

France's leading television weather forecaster, Philippe Verdier, was taken off air last week for writing that there are "positive consequences" of climate change. Freeman Dyson, professor emeritus of mathematical physics and astrophysics at the Institute of Advanced Study in Princeton, declared last week that the non-climatic effects of carbon dioxide are "enormously beneficial". Patrick Moore, a founder of Greenpeace, said in a lecture last week that we should "celebrate carbon dioxide".

Are these three prominent but very different people right? Should we at least consider seriously, before we go into a massive international negotiation based on the assumption that carbon dioxide is bad, whether we might be mistaken? Most politicians today consider such a view to be so beyond the pale as to be mad or possibly criminal.

Yet the benefits of carbon dioxide emissions are not even controversial in scientific circles. As Richard Betts of the Met Office tweeted last week, the "CO_2 fertilisation effect" - the fact that rising emissions are making plants grow better - is not news and is discussed in the reports of the Intergovernmental Panel on Climate Change. The satellite data show that there has been roughly a 14 per cent increase in the amount of green vegetation on the planet since 1982, that this has happened in all ecosystems, but especially in arid tropical areas, and that it is in large part due to man-made carbon dioxide emissions.

Greening Earth: Pushback

Climate Science Denialist Matt Ridley Criticised By Same Scientist He Sourced On Greening Planet Claims

By Graham Readfearn • Monday, October 19, 2015 - 19:07

A scientist whose research has been used by prominent climate science denialists Lord Matt Ridley and Rupert Murdoch to claim carbon dioxide is good for the planet has hit back at the "selective presentation" of his work.

Professor Ranga Myneni, of Boston University, has been researching satellite data showing how the extra carbon dioxide in the atmosphere from burning fossil fuels is contributing to increased plant growth across the planet.

In an article published in the Murdoch-owned The Times and reproduced in Murdoch's The Australian, Ridley said 30 years of satellite data showed plant growth had risen by 14 per cent across the world.

I asked Lord Ridley on Twitter about the source for his satellite data and he pointed me to a 2013 presentation by Professor Myneni.

Myneni told DeSmog the presentation Lord Ridley had cited had not been peer reviewed and was "work in progress" but hoped it would appear as two scientific articles, one of which was in review at the journal Nature Climate Change.

He said his analysis of satellite data covering the last 30 years did show a 13 to 14 per cent increase in vegetation growth. He said some of this could be attributed to increased levels of carbon dioxide, but changes in the way land was management was also a factor.

Myneni, in Norway for a meeting of ecologists to discuss vegetation changes in remote regions, said "in the context of being good versus bad" he was "worried about how this work is being interpreted".

Greening Earth: Correct Perspective