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Comment on "Drought-Induced Reduction in Global Terrestrial Net Primary Production from 2000 Through 2009"

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Comment on "Drought-Induced Reduction in Global Terrestrial Net Primary Production from 2000 Through 2009"

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Zhao and Running (Reports, 20 August 2010, p. 940) reported a reduction in global terrestrial net primary production (NPP) from 2000 through 2009. We argue that the small trends, regional patterns, and interannual variations that they describe are artifacts of their NPP model. Satellite observations of vegetation activity show no statistically significant changes in more than 85% of the vegetated lands south of 70°N during the same 2000 to 2009 period.

Zhao and Running (*1*), hereafter ZR10, reported a reduction of 0.55 petagrams of carbon (Pg C) in global terrestrial net primary production (NPP) of 535.21 Pg C over a 10-year period (2000 to 2009), or 0.1%. They attributed this decline to a drying trend in the Southern Hemisphere that decreased NPP by 1.83 Pg C (0.34%) and that was counteracted by increased NPP in the Northern Hemisphere by 1.28 Pg C (0.24%). These minute changes raise questions about the robustness of these numbers and the reported regional patterns. The Amazonian forests are a good case study because these forests play a dominant role in trends and interannual variability (66%) reported in (*1*).

First, ZR10's estimates differ from comparably upscaled field measurements (*2*–*6*) by 28% at 14 different sites and time periods in Brazil, Colombia, and Peru (Table 1). In a majority of these cases, ZR10 underestimate field-based measurements by 31% and overestimate by 18% for the rest. Notably, they overestimate NPP by 32% for two sites at Tambopata (Peru), which suffered an intense drought in 2005 when the peak dry season (July to September) precipitation standardized anomaly was –1.51 relative to the 1998 to 2006 period. This poor model performance in tropical forests is also evident from an earlier article by the same authors [figure 8 in (*7*)], and no further evidence of model advancement is presented in (*1*). None of this imbues confidence in the small NPP trends reported not only for the Amazonian forests but also for other tropical forests; for example, in Asia, they report a similarly small decline (–0.562 Pg C) during 2000 to 2009.

Second, ZR10 gap-fill missing and atmosphere-corrupted satellite-based input data of their model—namely, leaf area index (LAI) and fraction of photosynthetically active radiation (FPAR) absorbed by vegetation—by linearly interpolating across uncorrupted observations (*7*). This results in artifacts, especially in the Amazon, where corruption from clouds and biomass-burning aerosols is pervasive [figure S13A in (*1*)]. Our analysis of the same data, properly filtered for atmosphere-corruption effects but not gap-filled, does not show similarly inflated LAI or FPAR values (fig. S2), consistent with other analyses (*8*). We thus question the credibility of ZR10's results (e.g., NPP changes of 0.1% at the global scale and 0.24 to 0.34% at the hemispheric scale), which were obtained from a poorly performing model (Table 1) driven with a mix of measurements and gap-filled input values containing apparent artifacts.

Third, the correlation between NPP and atmospheric CO_2 growth rate (CGR) anomalies [Fig. 1 in (*1*)] is spurious because both their gross primary production (GPP) down-regulation, to simulate temperature and soil moisture stresses, and autotrophic respiration modeling are overly sensitive to temperature (section S1 in ZR10). Therefore, ZR10's Fig. 1 (*1*) is a depiction of the correlation between temperature and CGR anomalies, not between NPP and CGR anomalies (fig. S1). Thus, their claim that "global terrestrial NPP is a major driver of the interannual CO_2 growth rate" is questionable.

Fourth, although ZR10 invoke a report (*9*) of aboveground biomass declines in Amazonian forests due to the 2005 drought as supporting evidence, a closer examination reveals incongruities. The biomass declines were a consequence of increased mortality of some select drought-sensitive

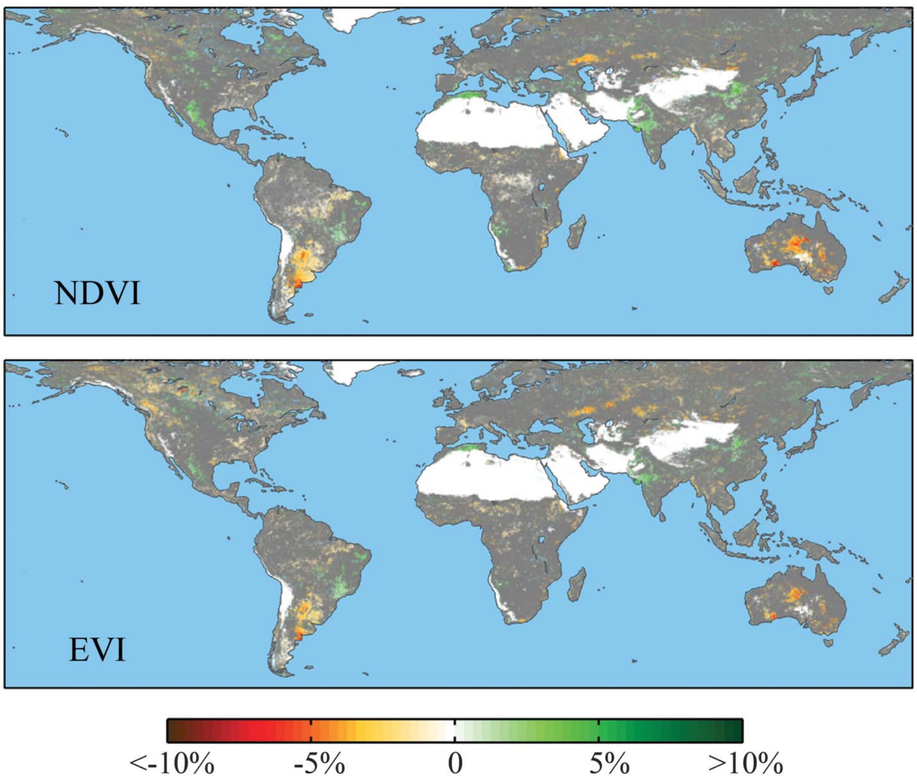

Fig. 1. Spatial patterns of statistically significant ($p < 0.05$) trends (%/year) in annual mean Collection 5 (C5) Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) at 0.05° by 0.05° spatial resolution during the decade 2000 to 2009. Cloud-, shadow-, climatology aerosol- and high aerosol–contaminated data are screened from analysis (supporting online material, section S3). Areas with statistically insignificant trends are shaded gray, and barren areas are white. These data are from the Moderate Resolution Imaging Spectroradiometer (MODIS).

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Table 1. Comparison of ZR10 (*1*) NPP estimates with comparably upscaled observations for forest sites in Brazil, Colombia, and Peru (*2*). BA712 is an Atlantic forest site in the southern state of Bahia, and the rest are in the Amazonian region. Observed NPP is field-measured NPP (supporting online material, sections S1 and S2). AGP, CAX, and TAM represent two different sites each. The average absolute difference between measured and modeled NPP reported by ZR10 (*1*) is 27.93%. The average underestimation is 31.47%, and the average overestimation is 18.48%.

		Observed NPP	Zhao and Running (*1*)	
Site	Period	(kg-C m^{-2} $year^{-1}$)	(kg-C m^{-2} $year^{-1}$)	Error (%)
KM67	2001	1.230	0.832	–32.36
KM67	2004	1.055	0.733	–30.52
ZF-2	2001	1.063	0.779	–26.72
ZF-2	2002	1.356	0.703	–48.16
UFAC	2001	1.343	0.997	–25.76
UFAC	2002	1.299	0.925	–28.79
BA712	2006	1.366	1.519	11.20
AGP (AGP-01 and AGP-02)	2004–2006	1.148	1.000	–12.28
CAX (CAX-06 and CAX-08)	2004–2006	1.396	0.737	–47.21
TAM (TAM-05 and TAM-06)	2005	1.534	2.028	32.20
ZAR-01	2004–2006	0.930	1.042	12.04

trees, whereas the forest growth rate, i.e., the NPP, did not change in 2005 relative to the pre-2005 period (*9*). The NPP declines in ZR10, however, are due to the absolute intensity of the drought, namely, vapor pressure deficit–dependent downgrading of calculated GPP and enhanced maintenance respiration due to higher air temperatures in 2005 (section S9 in ZR10). Also noteworthy is the poor performance of the ZR10 model at drought-affected sites (two at Tambopata and two at Amacayacu) (Table 1). Therefore, it is difficult to reconcile how the model could have produced the right results for the wrong reasons in response to the 2005 drought, while at the same time failing to match field measurements, some of which are from the very same drought year.

Fifth, even if we were to accept the 2005 estimates as accurate and due to the drought, ZR10's NPP estimates for the following two nondrought years are equally low and lack corroborating evidence [table S4 in (*1*)]. Actually, water balance studies, based on satellite altimeter data and precipitation observations, show significant positive hydrological anomalies in 2006 (*10*), and the 2005 drought itself was alleviated by a return to normal rainfall levels starting from October 2005 (*8*). Thus, ZR10's low NPP estimates for 2006 and 2007 are difficult to explain.

Sixth, if we accept the low 2006 and 2007 ZR10 estimates as lingering effects of the 2005 drought, the difference in NPP between the period before 2005 and the period after 2007 is only 1.1%. This suggests that the forests have recovered by their own estimates. However, ZR10 present this short-term negative anomaly, which was bracketed by periods of normal functioning, as a 10-year declining trend (–0.424 Pg C per decade), which is misleading, for it implies a progressively degenerative anomaly caused by some fundamental shift in the underlying processes for which there is no evidentiary basis.

Finally, satellite vegetation indices represent direct observations of the physiologically functioning greenness level by capturing the amount of photosynthetically active radiation absorbed by chlorophyll in green leaves (*11*). These observations do not show any large-scale declines in the greenness level of the land surface (Fig. 1); 86% of all vegetated land south of 70°N shows no trends. About 8 to 9% show declining trends in three nonforested regions: the Eurasian steppes, Argentina, and central Australia. These patterns, buttressed by trends in LAI and FPAR data (fig. S3), do not support ZR10. Their argument that model NPP fields capture reality while observations do not (section S9 in ZR10) is unwarranted for at least two reasons. First, their analysis of the same LAI and FPAR data shows gap-filling and other artifacts (compare fig. S2 with fig. S13A in ZR10). Second, published literature is replete with evidence of linkages between variations in satellite greenness index levels and climatic anomalies, several in the context of terrestrial NPP (*12*–*15*).

Based on these arguments, we conclude that the trends, regional patterns, and interannual variations reported by ZR10 (*1*) are model artifacts and that observations of vegetation activity show no significant changes in more than 85% of the vegetated lands south of 70°N during the 2000 to 2009 period.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/333/6046/1093-c/DC1
SOM Text
Figs. S1 to S3
References and Notes

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