**Supplementary Information Table 1 | Calculation of $\beta_R^{GPP}$ from existing proxies.**

| Source | $CO_2(t_1)$ (ppm) | $CO_2(t_2)$ (ppm) | GPP($t_1$) (Pg C) | GPP($t_2$) (Pg C) | $\Delta CO_2$ (%) | $\Delta$GPP (%) | $\beta_R^{GPP}$ | Notes |
|---|---|---|---|---|---|---|---|---|
| Campbell et al.[1] | 297 | 395 | 100 | 131 | 33.00 | 31 | 0.94 | Integrates multiple global change factors. |
| Wenzel et al.[2] | 285 | 570 | 100 | 132 | 100.00 | 32 | 0.32 | Northern extra-tropical future sensitivity. |
| Ehlers et al.[3] | 295 | 395 | 100 | 135 | 33.90 | 35 | 1.03 | Sunlit leaves only. |

[Footnote:]

***Notes on published estimates of the response of global photosynthesis to $CO_2$*:**

Wenzel et al.[2] use atmospheric observations of the seasonal cycle of $CO_2$ to infer a GPP increase of 32% for northern extra-tropical ecosystems under a doubling of $CO_2$, equivalent to a $\beta_R^{GPP}$ of 0.32. This reflects the sensitivity of extra-tropical ecosystem photosynthesis to $CO_2$, and is therefore expected to be lower than the global sensitivity due to the temperature dependence of the effect of $CO_2$ on photosynthesis (Fig. 3a). It is also based on a doubling of $CO_2$, and due to the saturating response of photosynthesis to elevated $CO_2$ is likely an underestimate of, and not directly comparable to, the historic sensitivity.

Ehlers et al.[3] estimate the sensitivity of photosynthesis to $CO_2$ based on measurements of deuterium isotopomers in herbarium samples of natural $C_3$ vascular plant species, crops, and a Sphagnum moss species. Deuterium isotopomers provide an estimate of the photosynthesis/respiration ratio, and it's change over time. In order to translate the change in the photosynthesis/respiration ratio to a change in photosynthesis, Ehlers et al. used a model with the assumption that photosynthesis is not limited by light[3]. The resulting $\beta_R^{GPP}$ of 1.03 therefore represents the sensitivity of photosynthesis in the absence of light limitation, which is expected to be considerably higher than that of whole-ecosystem global photosynthesis due to the large contribution of shaded leaves, as $\partial Ac/\partial CO_2 \gg \partial Aj/\partial CO_2$ (see methods).

Other published estimates of the effect of $CO_2$ on global photosynthesis include correlative analyses based on eddy-covariance observations (Fernandez-Martinez et al., 2017[4]; $\beta_R^{GPP}$=1.2), oxygen isotope estimates (Ciais et al., 2012[5]; $\beta_R^{GPP}$=1.3±2.3), and modeled products (Cheng et al., 2017[6]; Cernusak et al., 2020[7]; Haverd et al., 2020[8]; Ueyama et al. 2020[9];Sun et al., 2019[10]; overall modeled $\beta_R^{GPP}$ range 0.1-1.6). We do not discuss these estimates in the main text due to the lack of causal relationship in [4], the very large uncertainty in [5], and the variety of assumptions employed in the modeled estimates [6–10].

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