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The Global Mass and Average Rate of Rubisco

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Photosynthetic carbon assimilation enables energy storage in the living world and produces most of the biomass in the biosphere. Rubisco (D-ribulose 1,5-bisphosphate carboxylase/oxygenase), is responsible for the vast majority of global carbon fixation, and has been previously claimed to be the most abundant protein on Earth. Here, we provide an updated and rigorous estimate for the total mass of Rubisco on Earth, concluding it is ≈0.7 Gt, more than an order of magnitude higher than previously thought. We find that >90% of Rubisco enzymes are found in the ≈$2x10^{14}$ m^2 of leaves of terrestrial plants, and that Rubisco accounts for ≈3% of the total mass of leaves which we estimate at ≈30 Gt dry weight. We use our estimate for the total mass of Rubisco to derive the effective time-averaged catalytic rate of Rubisco and find that it is ≈0.03 s^{-1} on land and ≈0.6 s^{-1} in the ocean. In comparison to the maximal catalytic rate observed in vitro at 25□, the effective rate in the wild is ≈100-fold slower on land and ≈7-fold slower in the ocean. The lower ambient temperature, and Rubisco not working at nighttime, are enough to explain most of the difference from lab conditions in the ocean, which implies that in the ocean Rubisco is working close to its maximal catalytic capacity. This is not the case for land Rubiscos, and therefore motivates future quantification of many more factors on a global scale.