HOW GLOBAL WARMING AFFECTS TROPICAL RAINFORESTS? A PALEOGENE PERSPECTIVE

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The consequences of global warming on tropical vegetation are unknown. Today, most tropical rainforest lives at temperatures below 27.5°C (Fig. 1). Many have argued that tropical communities live near their climatic optimum (Stoskopf 1981), and that a slight increase in temperature could be deleterious to them (Tewksbury et al. 2008). Empirical examples in earth history might help us understand the behaviour of tropical biota during past climate change.

Past tropical temperatures during the Paleogene for a fossil forest in northern Colombia named Cerrejón have been estimated using leaf margin analysis (Herrera et al. 2005) and snake morphology (Head et al. 2009). Leaf margin analysis, however, can give only a minimum estimate of paleotemperature for tropical forests, because the regression models used in the method lack a modern analogue for forest at temperatures above 28°C. Snake morphology suggests a temperature of 32°C for the middle Paleocene of Colombia (Head et al. 2009), which seems to agree with other proxies as well as with global circulation models for the Paleogene (Huber 2008).

The fossil record of the tropics shows overall that tropical biotas were able to cope with high temperatures over extensive periods of time (several millions of years). Paleocene tropical forests from northern Colombia were similar in composition to modern tropical forests (Wing

![Figure 1](image-url)
et al. 2004). Most of the plant families that are abundant in the neotropical rainforest today were also abundant in the Paleocene, including legumes, Malvaceae, palms, Araceae, and Menispermaceae (Doria et al. 2008; Gomez et al. 2009; Herrera et al. 2008a; Jaramillo et al. 2007; Ramirez 2009). The forest also supported a rich fauna that included mammals, giant snakes, crocodiles, and giant turtles (Bloch et al. 2008; Cadena and Jaramillo 2006; Hasting et al. 2009; Head et al. 2009). Moreover, a subsequent warming, the long-term Eocene thermal maximum with temperatures in the tropics reaching 36–37°C, correlates with an increase in tropical plant diversity (Jaramillo et al. 2006).

In contrast, modern experimental studies have shown than plants suffer several deleterious effects under maximum daily temperatures associated with mean annual temperatures of 32–33°C. Some of those effects include a decrease in the rate of photosynthesis, a decrease in net production, an increased risk of photoinjury, and an increase in isoprene emissions (e.g. Lerdau and Throop 1999; Stoskopf, 1981). How, then, to explain the Cerrejón forest thriving at 32°C?

The solution could rely on a combination of high CO2 and elevated precipitation. The Cerrejón fossil forest lived under high precipitation regimes — about 3.2 m of rain a year (Herrera et al. 2005, 2008b) — and CO2 levels much higher than those of today (Royer 2006). Experiments in greenhouses have shown that plants deal better with high temperatures under high levels of CO2 and precipitation (Aber et al. 2001; Berry and Bjorkman 1980; Niu et al. 2008). Perhaps, then, rainforest lineages already have the genetic variability to cope with elevated temperatures if they are living in high levels of CO2 and high rates of rainfall, as during the Paleogene.

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