**And Yet it Moves: Can Beef be Useful After All?**

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**Abstract**

The well established anomalously high resource intensity of industrial beef has prompted growing interest in alternative beef production pathways. Of those, grass feeding in particular is often invoked and portrayed as a lower impact alternative. Yet such claims are not backed by rigorous quantitative analysis. Motivated to bridge this knowledge gap, we quantify the environmental impacts of grass-fed beef and compare them to intensive beef production and a range of animal and plant alternatives. Using a numerical model that unifies standard governing equations, we evaluate the resource needs of grass-fed beef, distinguishing extensive operations on semi-arid, marginal rangelands from intensive ones in lush settings with deep, well-developed soil and accommodating topography. Comparing the resource needs of grass-fed beef to those of a wide range of plant and animal alternatives and to industrial beef, we find that at least 90% of grass-fed beef herds exhibit greenhouse gas emissions about tenfold higher than those of non-beef alternatives. We also find that grass fed beef is about 40% more emission intensive than industrial beef, and that while reasonably expected sequestration rates reduce this disparity somewhat, they leave it qualitatively intact. We also find that intensification—moving away from extensive operations on true rangeland toward intensive, industrial operations—lowers operational emissions from about 230 to 140 kg CO2eq per kg beef protein and sequestration corrected annual emissions from about 1200-1300 to 200-300 kg C per rangeland ha.