**Title: Sustainable bioenergy utilization and forest carbon preservation in the Amazon**

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**Abastact**: This study investigates sustainable bioenergy utilization and its implications for forest carbon preservation in the Amazon Basin, examining Bolivia, Brazil, and Colombia from 2000 to 2023. It identifies critical bioenergy intensity thresholds and temporal lags influencing ecosystem resilience and carbon dynamics. Results reveal Brazil exhibits the highest bioenergy intensities, ranging from 2.0 to 2.8 terajoules per thousand hectares, with significant carbon sequestration potential between 500 and 1000 kilotons of carbon dioxide per thousand hectares, yet operates mostly within stressed and degraded transitional regimes. Bolivia maintains low bioenergy intensity operations between 0.2 and 0.3 terajoules per thousand hectares but experiences forest area declines from 55,101 to 50,417 thousand hectares, signaling deforestation drivers beyond bioenergy extraction. Colombia shows greater resilience with intermediate bioenergy intensities and the fastest recovery time of 6.1 years. Temporal analysis indicates forest degradation follows bioenergy extraction by approximately 2 to 3 years, while policy interventions require 4 to 5 years for measurable recovery. A 49% reduction in forest conversion rates from 2010 to 2011 confirms the efficacy of policy implementation. Based on bioenergy intensity thresholds of 0.60 and 2.09 terajoules per thousand hectares, the analysis distinguishes three operational regimes: sustainable (31%), stressed (45%), and degraded (24%). These quantitative benchmarks provide practical guidance for sustainable forest management aligned with Sustainable Development Goal 15. Country-specific strategies include targeted reforestation in Bolivia, sustainable forest management reform in Brazil, and expanded community-led programs in Colombia. This study offers transferable approaches for balancing bioenergy demands with forest carbon preservation, supporting sustainable development in tropical forest regions globally.

**Keywords**: Tropical forest ecosystems · Carbon sequestration dynamics · Renewable energy sustainability · Ecosystem resilience thresholds · Policy intervention timing

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