Modeling Wildfire Dynamics in Latin America Using the FLAM Framework

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INTRODUCTION

Wildfires significantly shape the ecological and socio-economic landscapes of Latin America, a region that holds about 50% of the world's biodiversity and 23% of its forest cover. The frequency and intensity of wildfires are expected to increase due to climate change, impacting forest cover, biodiversity, and agricultural systems. Latin America's vulnerability to climate-induced threats is uncertain, highlighting the need for comprehensive strategies such as incorporating advanced modeling and proactive measures to understand, manage, and conserve its ecological state in the face of threats posed by climate change, such as wildfires. This study used the wildFire cLimate impacts and Adaptation Model (FLAM) to understand and project the future dynamics of forests and shrublands wildfires in Latin America and its sub-regions under various climate scenarios, highlighting the urgent need for adaptive management strategies. Through historical and predictive analyses, the research aims to offer insights into wildfire trends and the efficacy of potential mitigation and adaptation strategies, focusing on the interplay between climate variables and wildfire incidence in Latin America's diverse ecosystems.

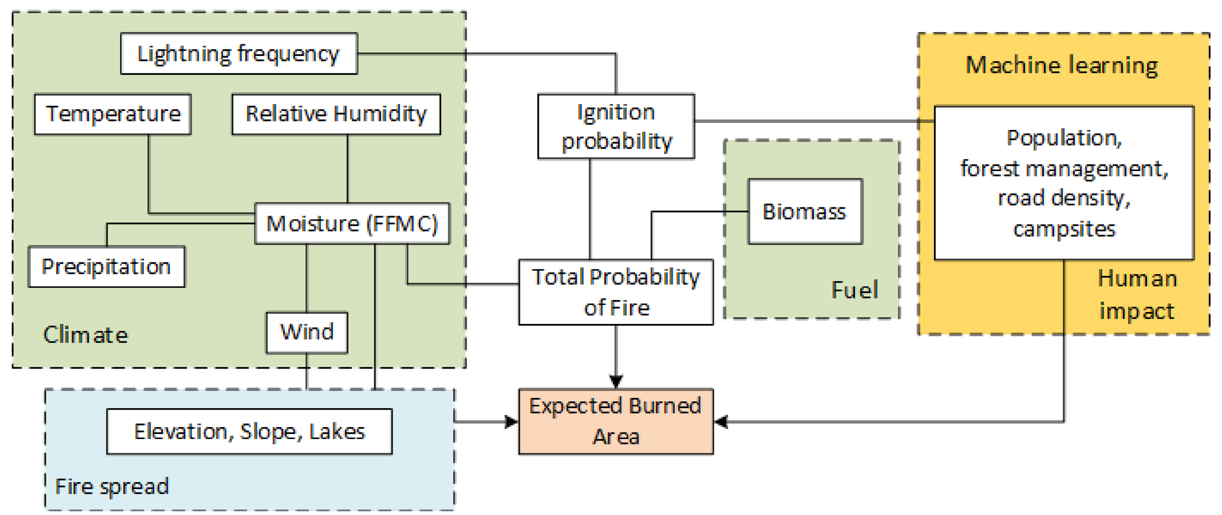
METHODS

In understanding wildfire dynamics in Latin America, historical burned areas were assessed.The same data was used in the calibration and validation process of FLAM. Using the calibrated model, we produced future wildfire burned areas until 2100 under three RCP scenarios (RCPs 2.6, 4.5 and 8.5). Adaptation scenarios were modeled by modifying suppression efficiency specifically under RCP 8.5.

FLAM captures seasonal and annual wildfire dynamics through a detailed mechanistic framework that assesses climate, fuel, terrain, and human impacts on fire behavior. It operates on a daily timestep, utilizing diverse data to model historical and future trends.

Data Inputs:

- **Climate:** ISIMIP2b
- **Burned Area/Land Cover:** MODIS FireCCI51
- **Fuel:** Global Forest Model, Copernicus Biomass
- **Ignition:** Population data (GPW 4), HRMC monthly lightning



Schematic overview of FLAM

Adaptation scenarios were modeled through improved suppression of fires within a specific timeframe after ignition, aiding in the development of targeted management strategies. This is mathematically expressed through:

$$q_{ij} := \begin{cases} q_a, & \text{if } q_{ij} < q_a, \\ q_{ij}, & \text{elsewhere.} \end{cases} \qquad (1)$$

$$\bar{\tau} = \frac{1-q}{q}. \qquad (2)$$

Where:

$q_a^1 = 0.5$ Suppressing fire in 1 day

$q_a^2 = 0.2$ Suppressing fire in 4 days

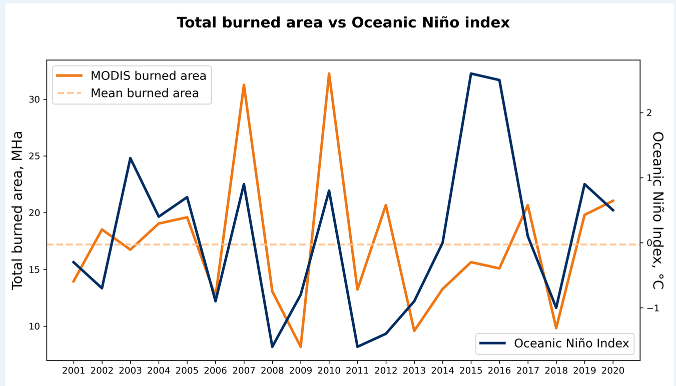
RESULTS

Trends in Historical Annual Mean Burned Areas

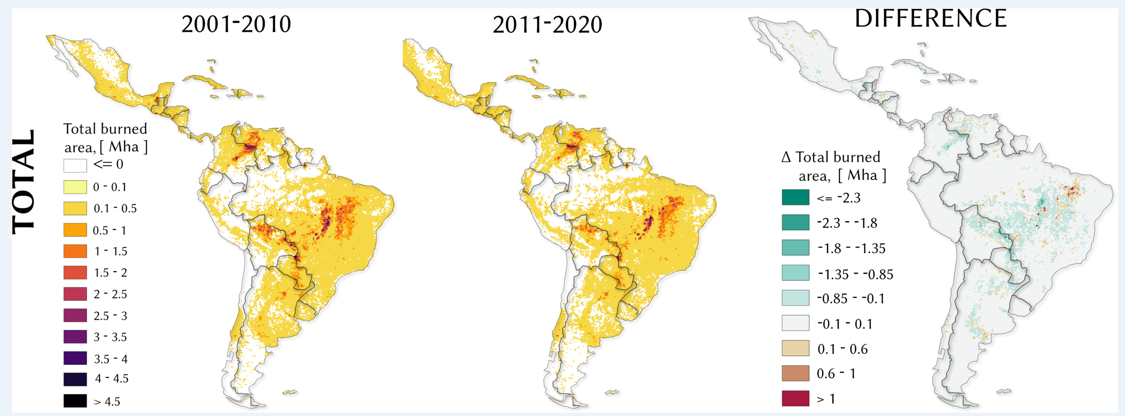
Annual Variability: Between 2001 and 2020, the annual burned area in Latin America averaged 33.8 Mha. The peaks in 2007 and 2010 have a strong correlation with El Niño Events (Pearson Correlation ~0.7)

Spatial Distribution: Shrublands and forests account for 38% and 24% of burned area. Most fires occur in shrubland regions such as Brazil's Cerrado and Bolivia, with significant fire spread to adjacent Amazonian forests.

Impact of Agricultural Practices: Prescribed burning significantly contributes to the region's fire dynamics. These burns can lead to spillover fires that affect adjacent forested areas.



Yearly burned area in Latin America and the corresponding Oceanic Niño index from 2001 to 2020

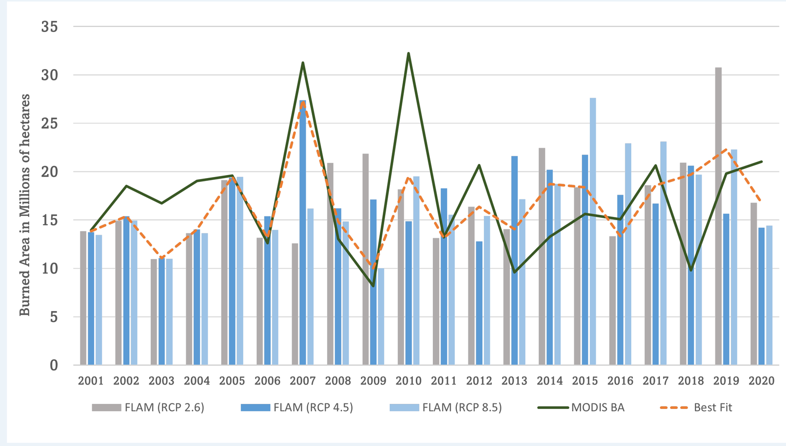


Spatial distribution of mean annual burned area (BA, in Mha) across Latin America for years 2001-2010, 2011-2020 and the difference between two decades , for all vegetation classes

Calibration Results

Calibration shows variability under different climate scenarios (RCPs), with high accuracy in several specific years (e.g., 2001 and 2007). The Pearson correlation coefficient (R) between the best fit and observation data is 0.64.

Around 10% of areas could not be calibrated due to lack of fuel in developed regions or absence of ignition sources



Comparison of MODIS Fire CCI burned area (dark green solid line) for forest and shrubland to calibration results of FLAM under various RCP scenarios: orange dash line represents the best fitting RCP values per year obtained from FLAM

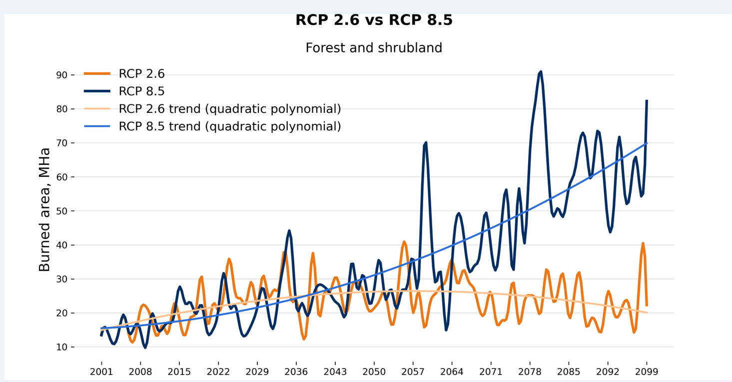
Climate Change Projections

The projected temperature will increase from 1°C to over 3°C by 2061-2080, depending on the RCP scenario. Northern South America and Mexico are expected to experience the largest temperature increases.

Precipitation patterns vary by region, with general decreases expected under RCP 8.5 by 2061-2080. The Central America-Caribbean region may see increased rainfall under RCP 2.6 but will face decreases under more severe scenarios.

The combined effect of hotter and drier conditions will likely enhance wildfire risks, particularly in areas already prone to high fire activity.

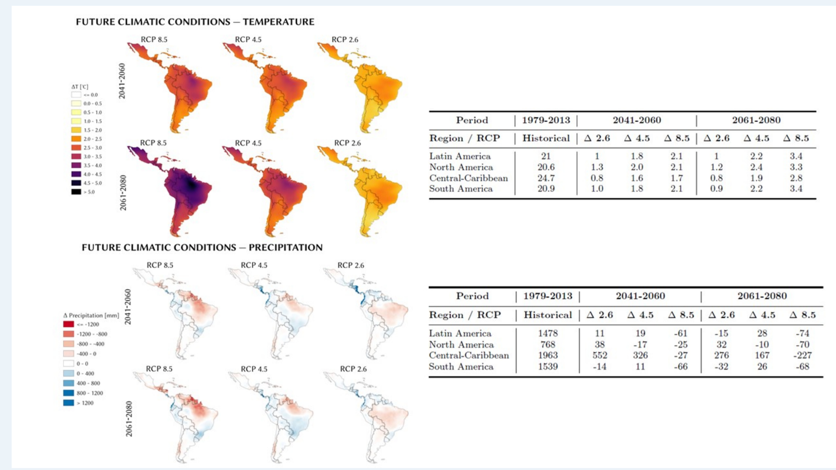
Projected burned areas in forest and shrubland across Latin America



Comparative projection of annual burned area (in Mha) for forest and shrublands in Latin America under RCP 2.6 and RCP 8.5 scenarios from 2001 to 2099.

By 2099, forests could see a 353% and shrublands a 202% BA increase under RCP 8.5, indicating severe impacts under extreme climate scenarios.

Fire hotspots are found in the Amazon and other high-incidence zones predicted to face prolonged and severe wildfires due to intensified climatic conditions.



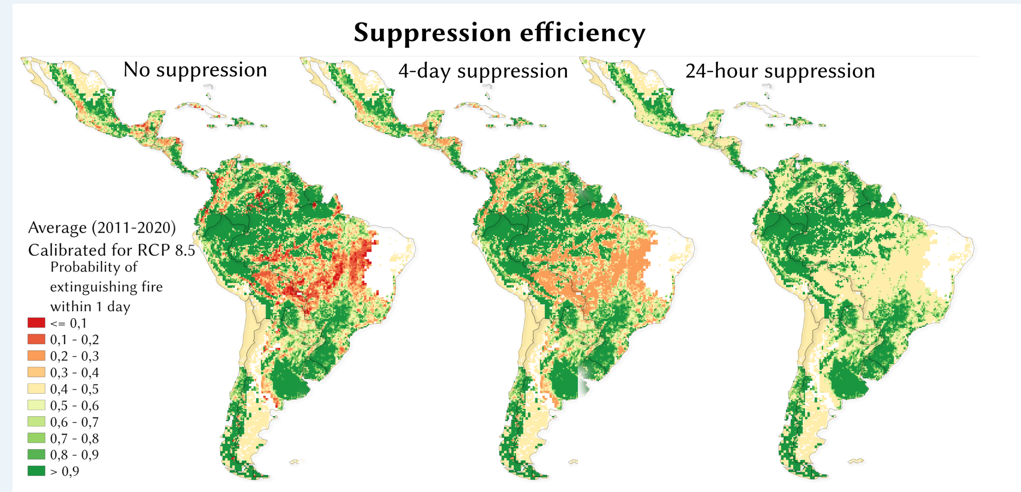
Changes (ΔT) in annual mean temperature [◦C] and (ΔP) Precipitation (mm/yr) on future scenarios with respect to CHELSA (HadGEM2–AO) historical data (from 1979 to 2013)

Identified hot spots and adaptation measures

Adaptation strategies greatly reduce wildfire spread and size. Implementing these measures can significantly reduce burned areas by up to 82%. These adaptations are increasingly effective as climatic conditions worsen under scenarios like RCP 8.5, highlighting the crucial role of proactive fire management strategies in mitigating future wildfire risks.

Period	No Adaptation	increased q		Difference	
		4-day	24-hr	4-day	24-hr
Historical	17.2				
2021-39	23.03	14.68	4.27	-8.35	-18.76
2040-2059	29.36	18.21	5.15	-11.15	-24.21
2060-2079	43.05	26.51	7.25	-16.54	-35.80
2080-2099	62.41	38.51	10.68	-23.90	-51.72

Comparison of mean annual forest burned Area (Mha/yr) projected by FLAM for RCP 8.5 without adaptation and scenario with increased suppression efficiency (q).



Suppression efficiency in RCP 8.5: no suppression scenario (left figure) and scenarios with a 4-day suppression (central figure) and a 24-hour suppression (right figure).

CONCLUSION AND NEXT STEPS

- The FLAM model has effectively captured the wildfire trends and effects of climate change to wildfire dynamics across Latin America.
- Projected temperature increases and variable precipitation changes raises the risk of wildfires, as higher temperatures and reduced precipitation create fire-prone conditions.
- Findings emphasize substantial increases in future burned areas, particularly under severe climate scenarios like RCP 8.5, with notable impacts on forests and shrublands.
- The study highlights the potential of adaptation measures, such as enhanced suppression efficiency, to significantly mitigate these risks.
- The analysis of spatial and temporal patterns in observed burned areas in Latin America serves as a foundation for understanding past and current fire dynamics, which is essential to develop reliable models to predict and manage future fire risks. This further helps in developing effective strategies for adaptation and mitigation.

For future research:

- The study currently does not account for changes in land use and human interventions, which are crucial factors influencing wildfire occurrence and severity.
- Utilizing a variety of climate models can provide a more robust comparison of projections and help generate an ensemble of potential future climate scenarios, leading to more accurate wildfire risk assessments.

ACKNOWLEDGEMENTS

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For more information about FLAM, please visit: http://www.iiasa.ac.at/flam or scan the QR above

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