What factors will increase global fires in the future?

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Background

Fire occurrence and spread are affected by natural factors and human activities. The development of land management practices, changes in the proportion of cultivated and grazed land, and the building of roads have all contributed to a low fire activity compared to pre-industrial levels. In the future, land-use changes along with changes in climate and human activity will strongly affect global fire regimes. In order to prepare for these changes, it is necessary to identify how future fires will be affected by three factors: climate, land use, and socioeconomic changes.

Here, we investigate the impact of changes in climate, land use, and socioeconomic factors on future DF as well as on total fire activity. We do so by developing a DF sub model to the CLM fire model to incorporate the effects of diverse types of land-use change: wood harvesting and conversion to cropland, pastureland, and urban areas. Then, we predict future fire activity in the late 21st century (2090–2099, i.e., the 2090s).

Methods: scenario

We projected fire regimes in the 2090s by applying climate, land-use, and socioeconomic changes to our fire model. As shown in Table 1, we simulated four different future scenarios. In Scenario 1 ("All"), we applied climate, land-use, and socioeconomic changes the model. In Scenarios 2–4, we only applied one change, and the remaining factors were kept the same as in the present day. This experimental design was intended to allow us to identify the impact of each type of change.

Scenario	Climate change	Land use change	Seriocomic change
1. All	RCP 2.6 / 6.0	RCP 2.6 / 6.0	SSP 2
2. Climate	RCP 2.6 / 6.0	-	-
3. Land use	-	RCP 2.6/ 6.0	-
4. Socioeconomic	-	-	SSP 2

Methods: model

In this study, we improved the CLM fire model by expanding the scope of DF from tropical closed forests to the tropical and temperate vegetated areas. In this section, we first briefly describe the CLM fire model.

The CLM fire model represents realistic human-induced fires by parameterizing anthropogenic peat fires, deforestation fires, and agricultural fires (Lawrence et al., 2018; Li et al., 2012, 2013). Non-peat fire sub model is process based one. But the others are developed empirically.

Here, we developed deforestation fires part to deforestation and vegetation degradation fires (DF) using logistic regression.

$$Y_{i,t} = \alpha + \beta_i R_i + \gamma_{i,j}(R_i\colon X_j) + \delta_{i,t}(R_i\colon M_t)$$

Where $Y_{i,t}$ is $\ln\left(\mathrm{Ab}_{\mathrm{df}_{i,t}}/(1-\mathrm{Ab}_{\mathrm{df}_{i,t}})\right)$ for region i, and month t. α is the constant term, β_i is coefficient of the dummy for region i, and $\gamma_{i,j}$ is coefficient for interactions between the region i and X variable j ($lu_{crop}, lu_{wood}, lu_{pasture}, lu_{urban}, and\ f_{cli}$). $\delta_{i,t}$ is coefficient for the interaction term between region i and month t.

Climate change

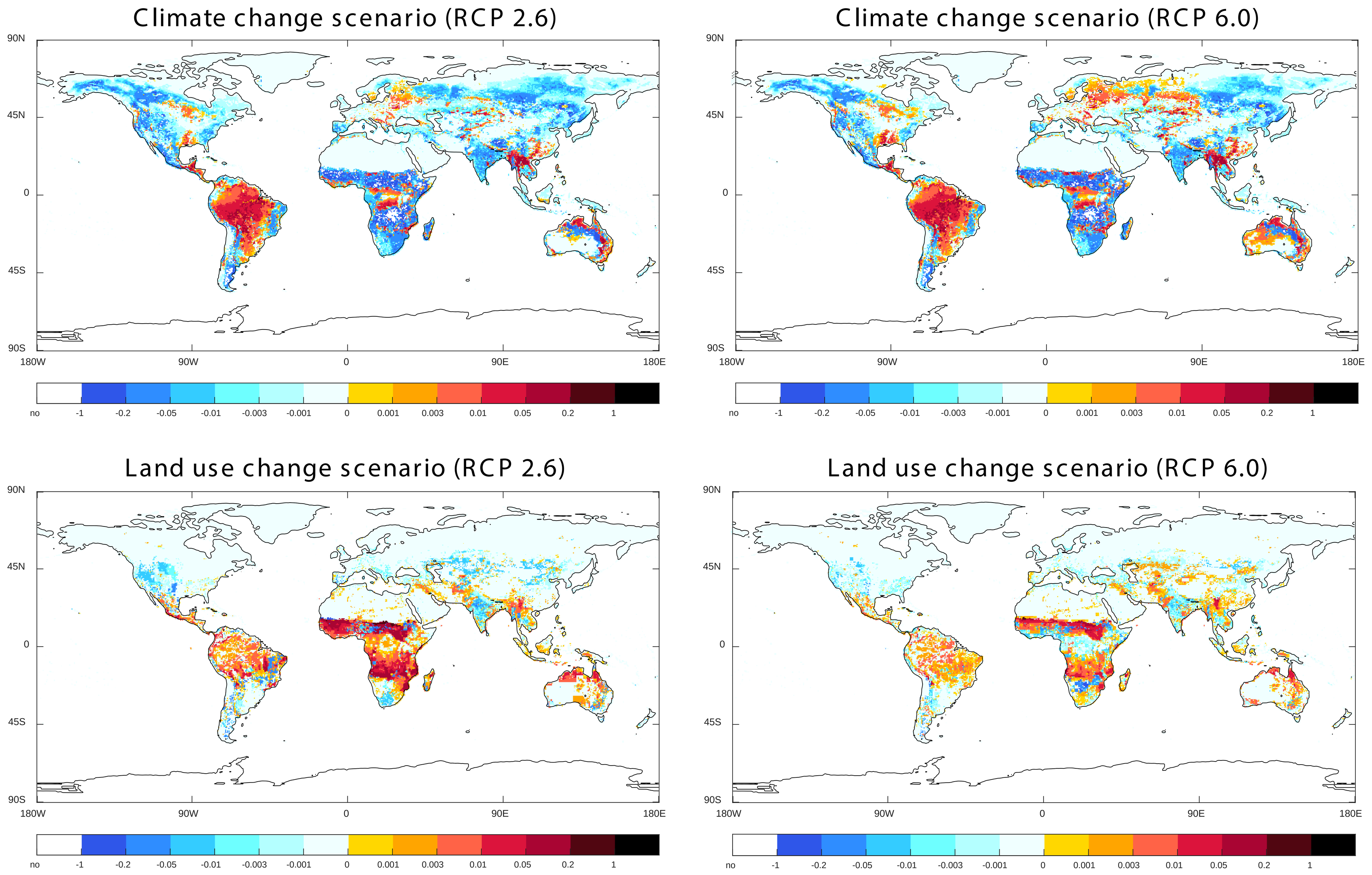
+ Area
- South America, China, Indochina, Europe, West Asia: decreasing of relativity humidity
- Decreasing of relativity humidity make the condition suitable for combustion fuel.

- Area
- North America, Boreal Russia, Africa, and Australia: increasing in soil moisture, which results in decreasing non-peat fires.
- India: increasing in precipitation (a month before planting) decrease agricultural fires for removing waste.

Land use change

+ Area
- South America: increasing of DF from wood harvest and pasture expansion
- Africa: increasing of DF due to DF from pasture expansion and increasing of agricultural fires
- West Asia: increasing of DF from wood harvest, cropland, and pasture expansion
- Indochina: increasing of DF from wood harvest, pasture, and urban expansion

-Area
- North America: reducing in DF from cropland expansion
- India: reducing in agricultural fires

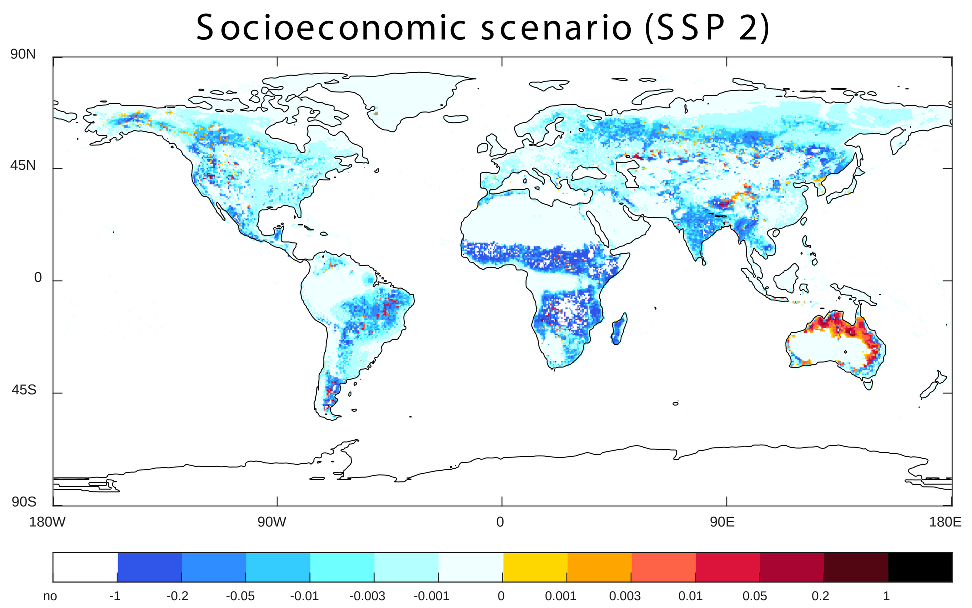


Difference (+/-) between future (2090-2099) and current (2006-2015) annual mean burned fraction
Future map is the average of four GCMs (GFDL_ESM2M, HadGEM2-ES, IPSL-CM5A-LR, and MIROC5)

Socioeconomic change

+ Area
- Australia: small increase in population density impacts on the number of fire ignition.

-Area
- America, Africa, Russia, India, and Indochina increases in GDP increase fire suppression, which leads to fire decreases.
- Boreal region: decreased population reduces the number of fire ignition.



RCP 2.6 vs. RCP 6.0

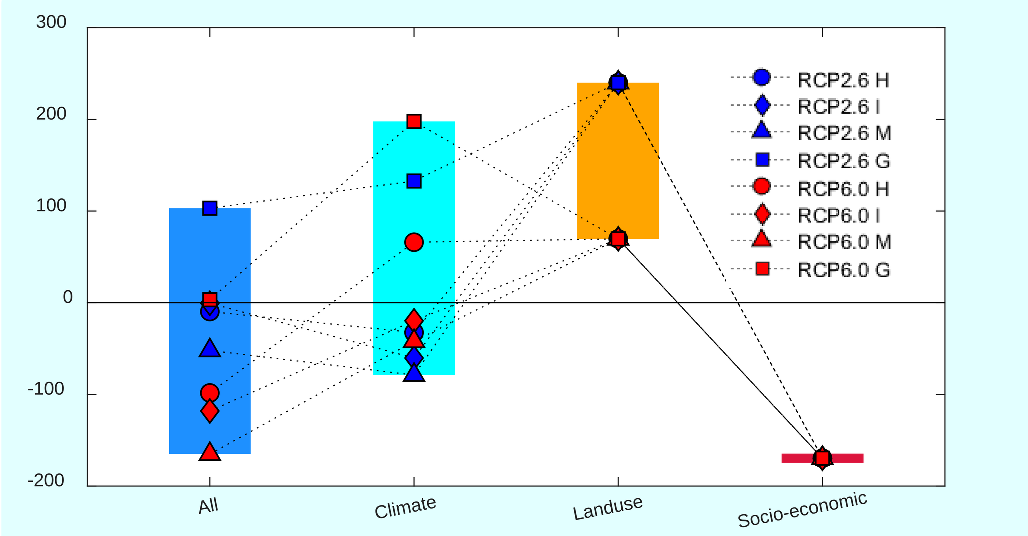
Climate change scenario
RCP 2.6 (-9.1 Mha/yr) < RCP 6.0 (+51.2 Mha/yr)

The most influential factor of climate change is relative humidity. And relative humidity is decreased in RCP 6.0, which results in more increasing in fires.
Changed relative humidity will decrease burned area 172 and 220 Mha/yr under RCP 2.6 and RCP 6.0.

Land use change scenario
RCP 2.6 (+241 Mha/yr) > RCP 6.0 (+70.3 Mha/yr)

DF from wood harvest will more increase under RCP 6.0 scenario in North America, South America, Africa, and Asia (China, Indochina).
DF from cropland will more increase under RCP 6.0 scenario in South America and West Asia.
But, DF from pasture expansion will much more increase under RCP 2.6 scenario in North America, South America, Africa, and Australia.

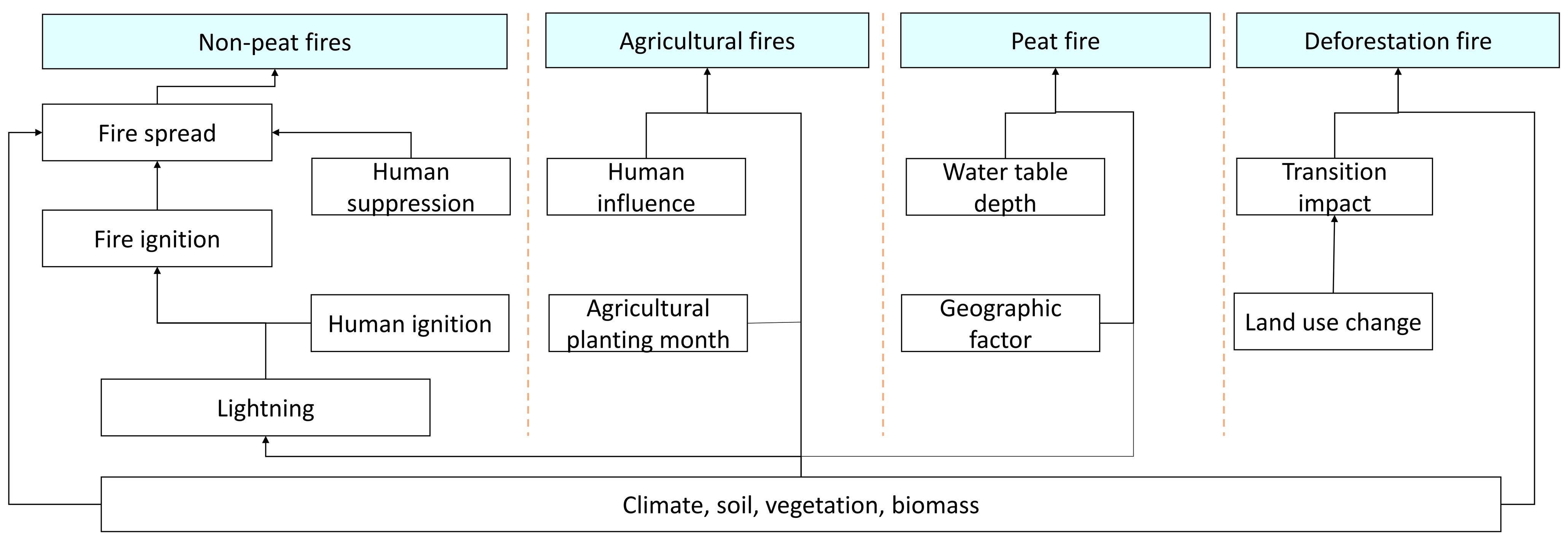
Total global fires



Total global burned fraction change (-/+ Mha/yr)

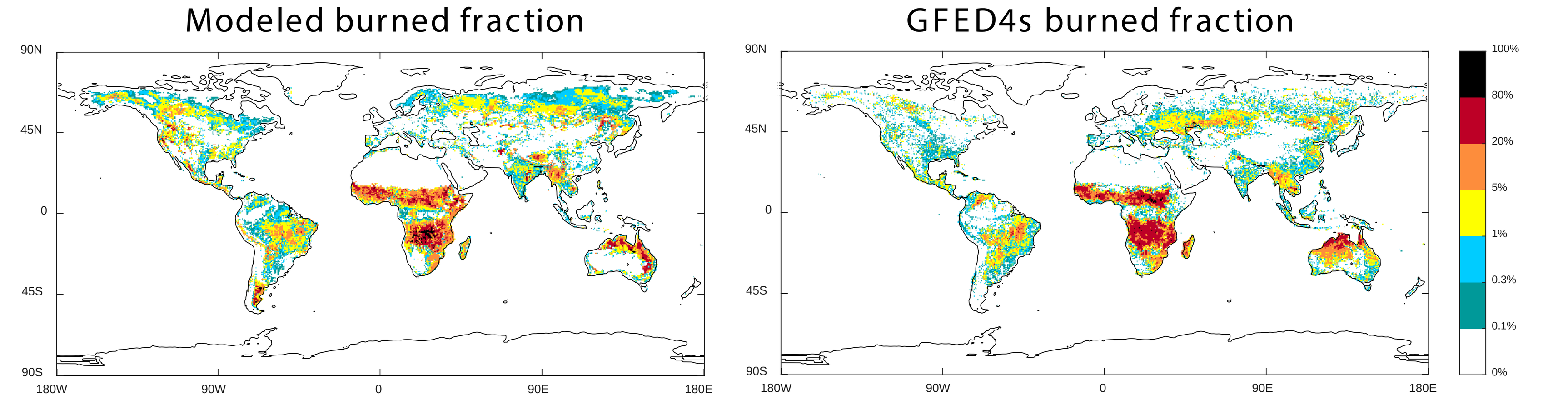
- Future fires in 2090s under RCP 2.6/6.0 and SSP 2 show declines in most GCM.
  - ✓ Only one GCM (GFDL_ESM2M) under RCP 2.6 has increased prediction due to pasture expansion.
  - ✓ Under RCP 6.0 scenario, climate change and land use change factors increase the fires. But, socio-economic factor (GDP and population density) decrease fires.
- There is a large uncertainty between GCMs.
- All three factors (climate, land use, and socioeconomic) have great impact on future fires.

Results: future prediction



Structure of CLM fire model. Fire scheme described in Li et al. (2012; 2013)

Our analytical approach was the following: To improve the performance of the modified fire model, we used a genetic algorithm (GA) optimization technique to determine the best parameter values based on the satellite-based product, Global Fire Emissions Database version 4.1 (GFED4s) (small fires included in GFED 4.1 (Giglio et al., 2013; van der Werf et al., 2017)).



The model error for the total burned area is -0.002 and the seasonal interannual coefficient is 0.8 This results show good performance of global fire model.

Results: model evaluation

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