Coping with possible wildfire regime shifts under a changing climate:

The need for local management

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Natural disturbance and climate change

- Given the anthropogenic-driven climate change, urgent reassessment of management strategy is necessary to consider how to cope with increased probability of future shifts in disturbance regime.

- One of the critical parts in understanding the responses of terrestrial ecosystems to changing climate is disturbance regimes (Dale *et al*. 2001, *Bioscience*; Mori 2011, *J Appl Ecol*).

Climate change and wildfires

- Wildfire is one of the most climate-sensitive events.
- Society may need to accept a perspective that the future ecosystems may be different and unprecedented (Millar et al. 2007, *Ecol Appl*)

  ….. especially for those that may become more vulnerable to widespread wildfires.

Ecosystem management in a changing climate

Problem

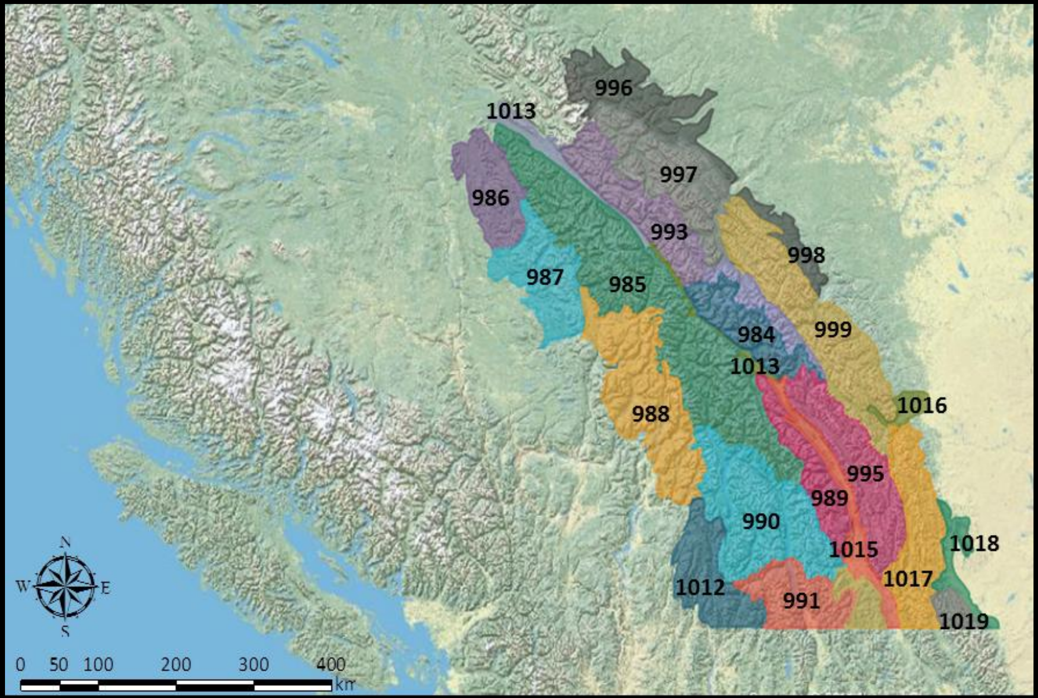
- Most of information about climate change impacts is too broad to fully inform the management of specific ecosystems (Lawler et al. 2010, *Front Ecol Environm*).
- That is, compared to accessibility of broad-scale predictions such as future increases in global mean temperature, local information is far more difficult to obtain.

Approach

- Thus, a new approach should be incorporated into our future management options, one respecting local responses of each ecosystem to climate change.

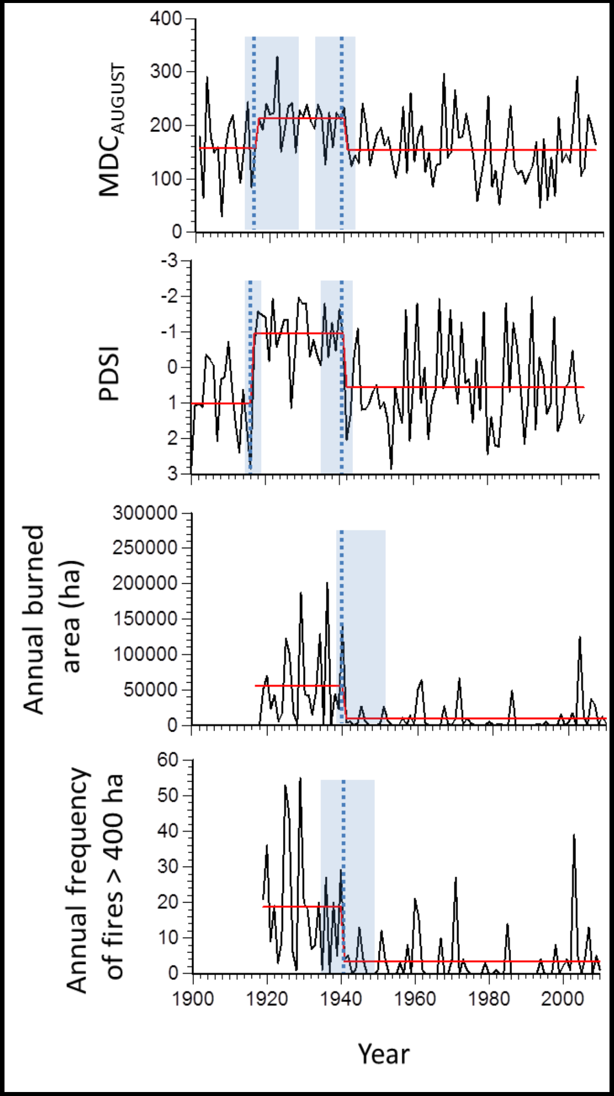
Objective

- In a mountainous ecoprovince in southwestern Canada, this study aims to evaluate the future probability of large-scale fires and possible fire regime shifts at different spatial scales.

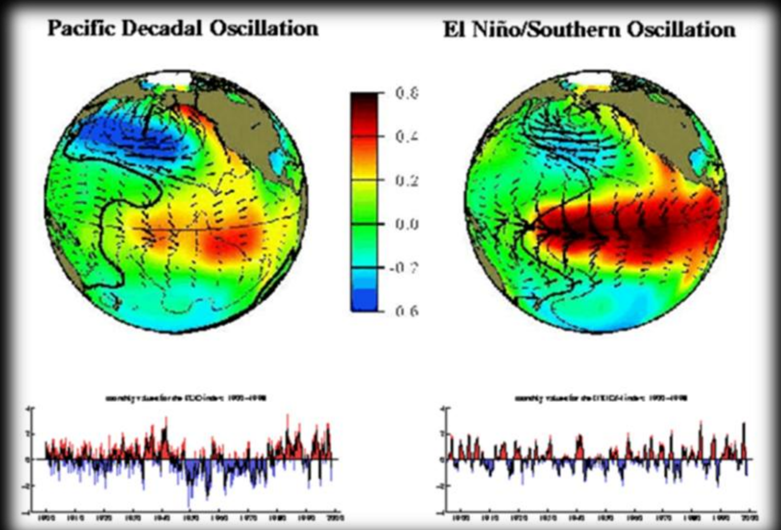


Map of the Columbia Montane Cordillera Ecoprovince in western Canada. The ecoprovince is comprised of 24 ecodistricts that are shown with polygons.

Fire regime shift

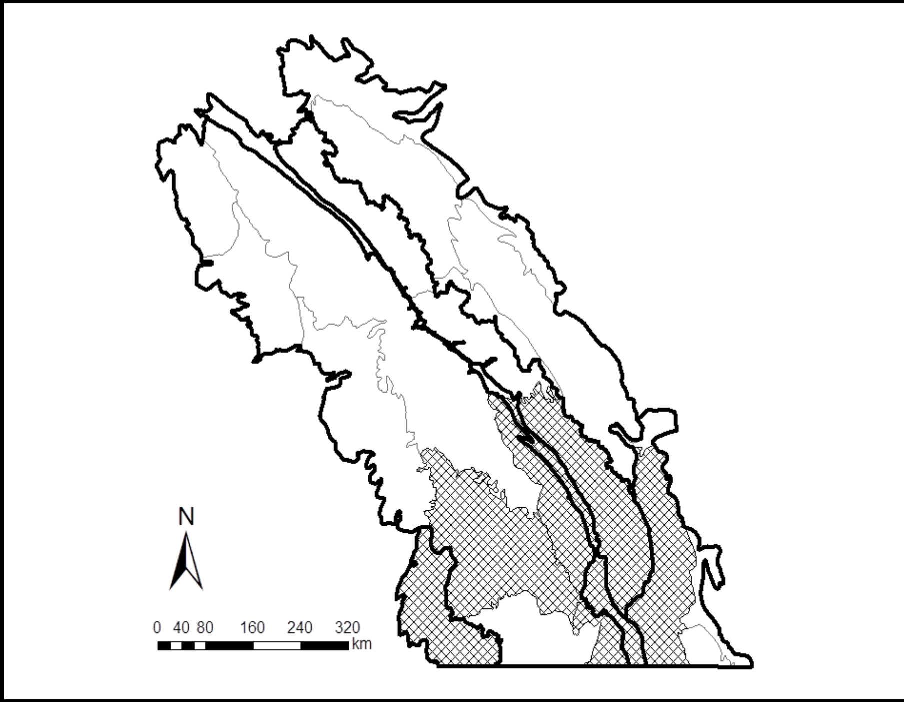


- Significant regime shifts in drought (MDC, PDSI), annual area burned (AAB), and annual frequency of large wildfires > 400ha/year in the study ecoprovince.



PDO & ENSO variations
from NASA website

Fire regime shift



- At the ecodistrict-scale, only 8 of 24 ecodistricts showed the shift in AAB around 1940, indicating wildfire regime is more heterogeneous at the finer spatial scale.

Fire modeling

- A fire prediction model that accounts for spatial heterogeneity of fire regime within the ecoprovince, based on the hierarchical Bayesian approach.

$$Y_{ij} \sim \textit{Bernoii}\ (p_{ij}) \text{ with}$$

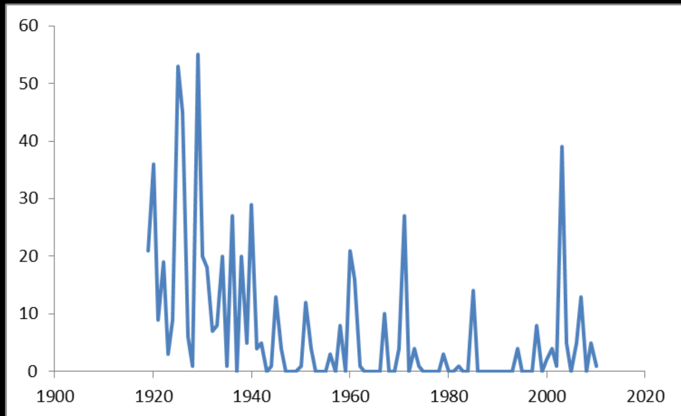
$$logit(p_{ij}) = \beta_{j1} + \beta_{j2} X_{ij}$$

where Y_{ij} and X_{ij} are probability of wildfires and the MDC_{Aug} (monthly drought code, based on weather variables estimated by ClimateWNA; Wang et al. 2012, *J Appl Meteor Climatol*) in the year *i* of the ecodistrict *j*, respectively, and β_{j1} and β_{j2} are the parameters of the ecodistrict *j*.

Rarity of stand-replacing fire episodes

Large ire frequency in the ecoprovince

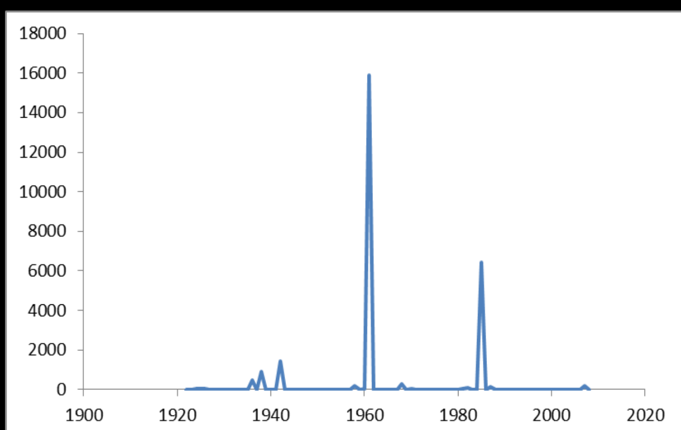
Number of large fires $(year^{-1})$



Year

Annual area burned in an ecodistrict

AAB (ha/year)



Year

Large fires are episodic.

In other words, most of years were not a large fire year.

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Lots of 0 data (no fire year) with a few 1 data (fire year)

Fire modeling

$$Y_{ij} \sim \textit{Bernoii}\ (p_{ij}) \text{ with}$$

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where Y_{ij} and X_{ij} are probability of wildfires and the MDC_{Aug} (monthly drought code, based on weather variables estimated by ClimateWNA; Wang et al. 2012, *J Appl Meteor Climatol*) in the year *i* of the ecodistrict *j,* respectively, and β_{j1} and β_{j2} are the parameters of the ecodistrict *j*.

Suppose $\beta_j = (\beta_{j1}, \beta_{j2})$ is the vector matrix of regression parameters, which are generated from a common multivariate prior with mean μ_β and a variance-covariance matrix *V* expressed as

$$\beta_j | \mu_\beta, R \sim Normal(\mu_\beta, V),$$

where *R* is the precision matrix. Then, we assign the vague prior to the hyperparameters as follows;

$$\mu_\beta \sim c,\ V \sim invWishart(S^{-1}, v),$$

where *c* is mean of the mean vector μ_β and $invWishart(S^{-1}, v)$ denotes the inverse-Wishart distribution with scale matrix *S* and degrees of freedom *v*.

Fire modeling

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$$\mathit{logit}(p_{ij}) = \beta_{j1} + \beta_{j2} X_{ij}$$

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- We are interested in combining the individual regression parameters in a way that reflects the somewhat common fire behavior of all ecodistricts.

Objective

- In a mountainous ecoprovince in southwestern Canada, this study aims to evaluate the future probability of large-scale fires and possible fire regime shifts at different spatial scales.

- The model will be applied to show future scenarios of wildfire vulnerability at the scale of ecodistricts.

- Based on these scenarios,
  we discuss flexible approaches to cope with inherent variability and uncertainty under the changing climate.

Model evaluation

Table 2 Results of the diagnoisis regressions

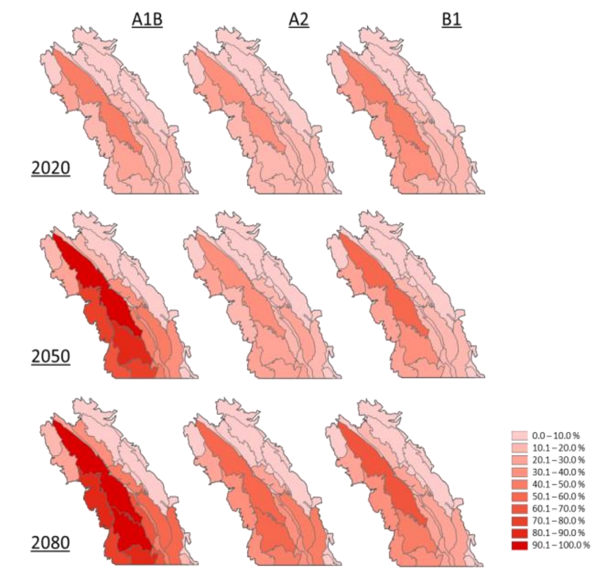
Model	Large fire category	Period		
		1930s	1960s	1990s
Non-CAR	Major wildfires	0.81	0.62	0.74
	Large wildfires	0.94	0.77	0.64
	Very large wildfires	0.94	0.65	0.45
CAR	Major wildfires	0.87	0.52	0.62
	Large wildfires	0.95	0.51	0.59
	Very large wildfires	0.69	0.49	0.08

R-square values between the observed frequency and the probability of widespread wildfires in the past three periods are shown for the two models.

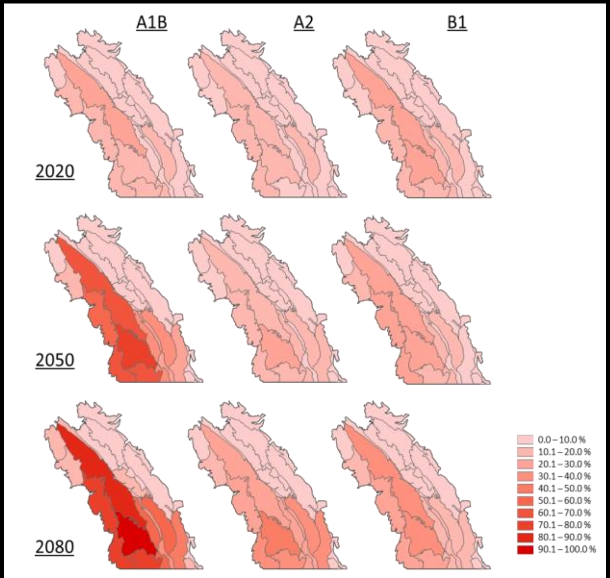
The model was effective (~94 % of the variances were explained).

Future changes in drought and wildfires

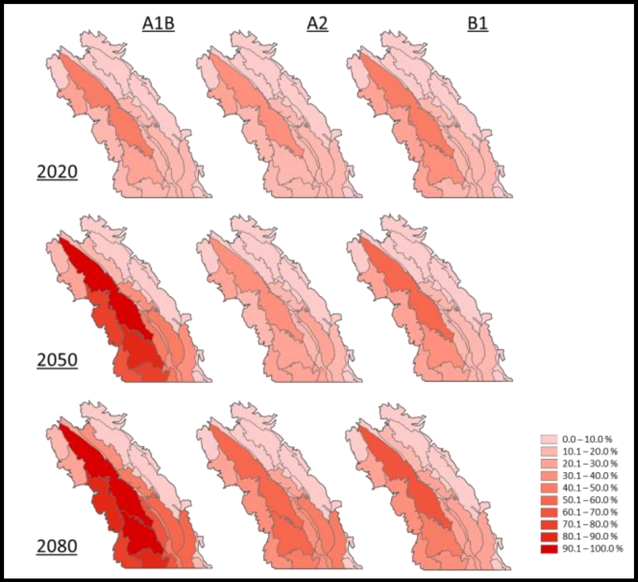
AAB > 400 ha/year



AAB > 1000 ha/year



AAB > 0.5% of total burned areas in the fire database



- More fire-prone conditions are predicted by 2050s.
- High probability of broad-scale shifts in fire regime in the near future under the A1B scenario.

Wildfire susceptibility is highly scenario-dependent.

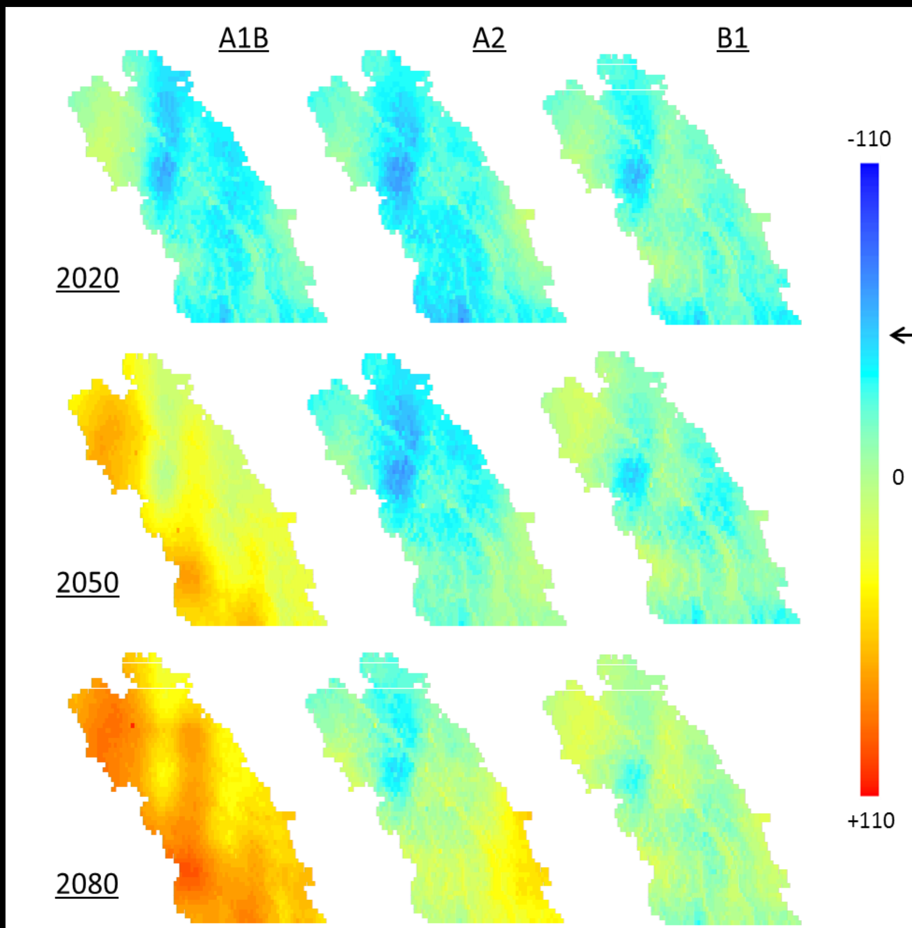
Drought code

- The study ecoprovince is one of the most diverse regions in Canada, biologically, meteorologically and geophysically.

- In spite of this complexity, the model developed based on the summer DC (cumulative moisture deficit by late summer) showed the high predictability of large-scale wildfires.

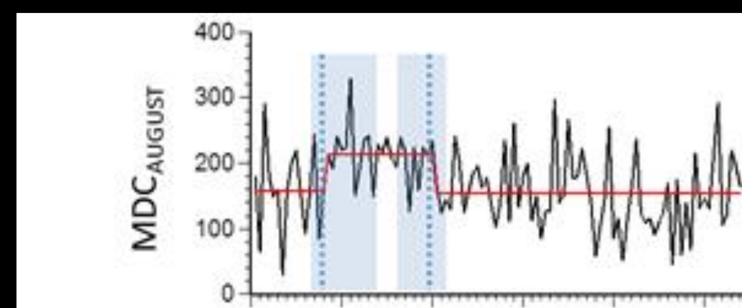
  ….. suggesting that, although the DC does not fully account for some hydroclimatic conditions such as snow accumulation, it is useful to estimate the wildfire risks even in this region with complex mountainous terrains.

Changes in drought severity for each scenario



Drought level in 1940-2009

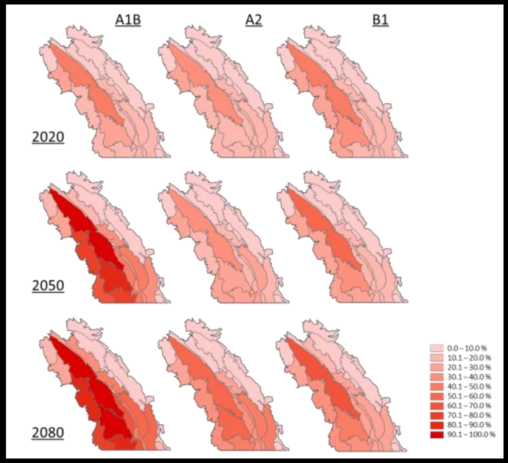
Drought level in 1916-1939

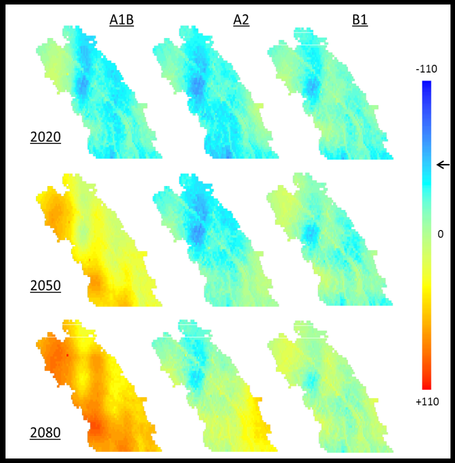


High probability of fire regime shift

Future changes in drought and wildfires

- Under the A1B scenario, the priorities of fire management should be urgently paid to western ecodistricts, which are more prone to severe droughts and fires.
- In these areas, proactive fire management such as fuel treatment would be far more effective than reactive approach such as fire suppression, if land management is primarily oriented to reduce risks of catastrophic fires.





Future changes in drought and wildfires

- Thus, urgent decision is needed whether natural wildfires that may spread at the unprecedented scale in the drier future are permitted, although this is difficult to decide.

- Note that, scenario-driven management is not necessarily ideal.

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- Scenario-informed decision is important.

Fire-prone future

- The present results are not consistent with the projection of global wildfire trend (i.e., the A2 yielded the warmest future with more wildfires reflecting the strongest anthropogenic pressures; Pechony & Shindell 2010, *PNAS*).
- Such inconsistency between local and global scale again implies the need of localized adaptation to fire-prone future.

Scenario-dependence

- The large discrepancy between the A2 and B1 indicates the high uncertainty of future responses at the local scale.

  e.g., Some ecodistrcits might experience wildfire regime shift by the 2080s under the A2, while such probability in these ecodistricts is very low under the B1 scenario.

- These areas need special consideration, because of high uncertainty.

Thank you for you attention!

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