THE UNIVERSITY OF BRITISH COLUMBIA
Faculty of Science & Faculty of Forestry

Alternative Aridity Index for Dryland Expansion Prediction Model

Ying Ren, Raunaq Nambiar, Yeonuk Kim

Introduction

"Does climate change cause drylands expansion?"

Drylands are vulnerable to climate change, but there is no agreement on the best metrics to predict their changes.

Dryland:

- Feng & Fu (2013): 1. Expanded historically;
  2. Projected to expand by the Aridity Index (AI).
- Berg & McColl (2022): Criticized the AI for:
  - Disregarded vegetation
  - Limited mechanical process connection

In our study, we propose **the Equilibrium Aridity Index (EAI)** as a viable alternative aridity metric.

Our research aims to evaluate the predictive power of the EAI in comparison to the AI in a global analysis of dryland expansion.

Methodology

Step 1 Collect 26 climate simulations from the Coupled Model Intercomparison Project Phase 6 **(CMIP6)** (Eyring et al., 2016).

Step 2 Calculate 30-year mean values of **precipitation (P)**, **potential evaporation (PE)**, and **surface flux equilibrium evaporation (SFE)** for historical (1971-2000) and future (2071-2100) periods. The future period climate is projected under a high GHG emission scenario **(SSP5-8.5).**

Step 3 Calculate the aridity index

$$AI = \frac{P}{PE}$$

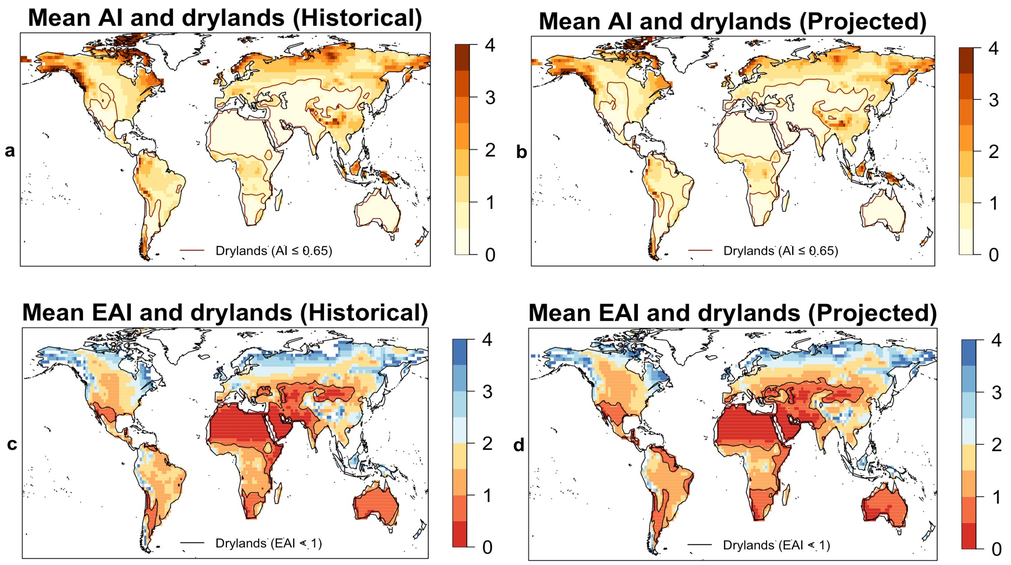
and the equilibrium aridity index

$$EAI = \frac{P}{SFE}$$

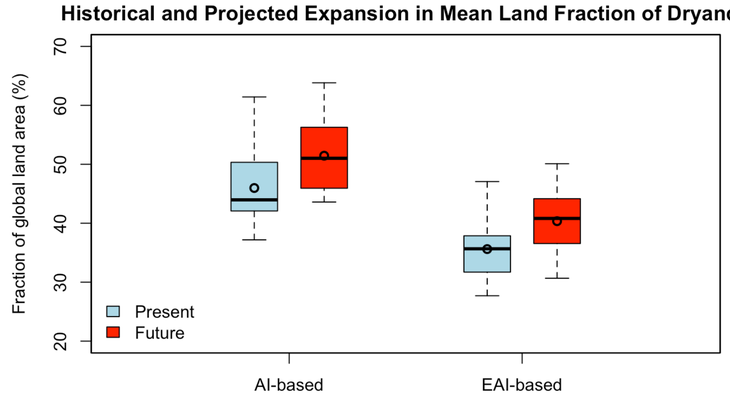
Step 4 Create AI and EAI maps with dryland classification lines (0.65 for AI, 1 for EAI)

Step 5 Statistical analysis: Future dryland fraction - historical dryland fraction (for AI and EAI), then compare them.

Results and Discussion



- The AI < 0.65 is an empirical criterion implying precipitation is lower than 65% of PE.
- On the other hand EAI <1 is a physically based criterion implying land surface cannot sustain land-atmosphere equilibrium due to limited water (Kim et al., 2021).



- The difference between the historical mean drylands and projected mean dryland fraction for both AI and EAI are **significantly different.**
- T-test: t = -3.40, p-value = 0.00134 for AI, t = -3.55, p-value = 0.000848 for EAI
- **We conclude that, while the degree of change may vary, drylands will still be globally projected to expand significantly.**

Implications

Drylands host a third of the global population and are an important pillar in global agriculture, accounting 60% of international food supplies (Wang et al., 2022).

This research is significant because it will improve our understanding of the underlying drivers of dryland expansion and inform management and conservation strategies that are necessary to preserve these critical ecosystems.

Lack of knowledge about future dryland expansion can leave policy makers ill-prepared to make informed land-use & conservation decisions.

References

Berg, A., & McColl, K. A. (2021). No projected global drylands expansion under greenhouse warming. *Nature Climate Change*, 11(4), https://doi.org/10.1038/s41558-021-01007-8

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geoscientific Model Development*, 9(5), https://doi.org/10.5194/gmd-9-1937-2016

Feng, S., & Fu, Q. (2013). Expansion of global drylands under a warming climate. *Atmospheric Chemistry and Physics*, 13(19), https://doi.org/10.5194/acp-13-10081-2013

Kim, Y., Garcia, M., Morillas, L., Weber, U., & Johnson, M. S.(2021) Relative humidity gradients as a key constraint on terrestrial water and energy fluxes. *Hydrology & Earth System Science* 25(9), https://doi.org/ 10.5194/hess-25-5175-2021 (2021).

Wang, L., Jiao, W., MacBean, N., Rulli, M. C., Manzoni, S., Vico, G., & D'Odorico, P. (2022). Dryland productivity under a changing climate. *Nature Climate Change*, 12(11), https://doi.org/10.1038/s41558-022-01499-y

Acknowledgments

This project was supported by Research Experience Program under Undergraduate Research Opportunities. We would like to thank our mentor, Dr. Yeonuk Kim, for his help and expertise in dryland expansion.