

RothC modelling of pyrogenic carbon in the Brazilian Amazon

Dr Oscar Kennedy-Blundell
Postdoctoral research associate
University of Exeter

Prof Ted Feldpausch and Prof Richard Betts

FAPESP - Amazon PyroCarbon

Background

- Pyrogenic carbon (PyC) are resilient, high C content residues produced during the incomplete combustion of biomass during wildfires
- PyC also has the potential to improve soil fertility, suppress GHG fluxes, immobilise pollutants
- PyC can remain in soils for millennia but is often overlooked in C cycling modelling research
- PyC has had limited consideration in preceding Amazon modelling
- The RothC model has previously been used to model PyC in Australian soils (Lehmann et al., 2008)





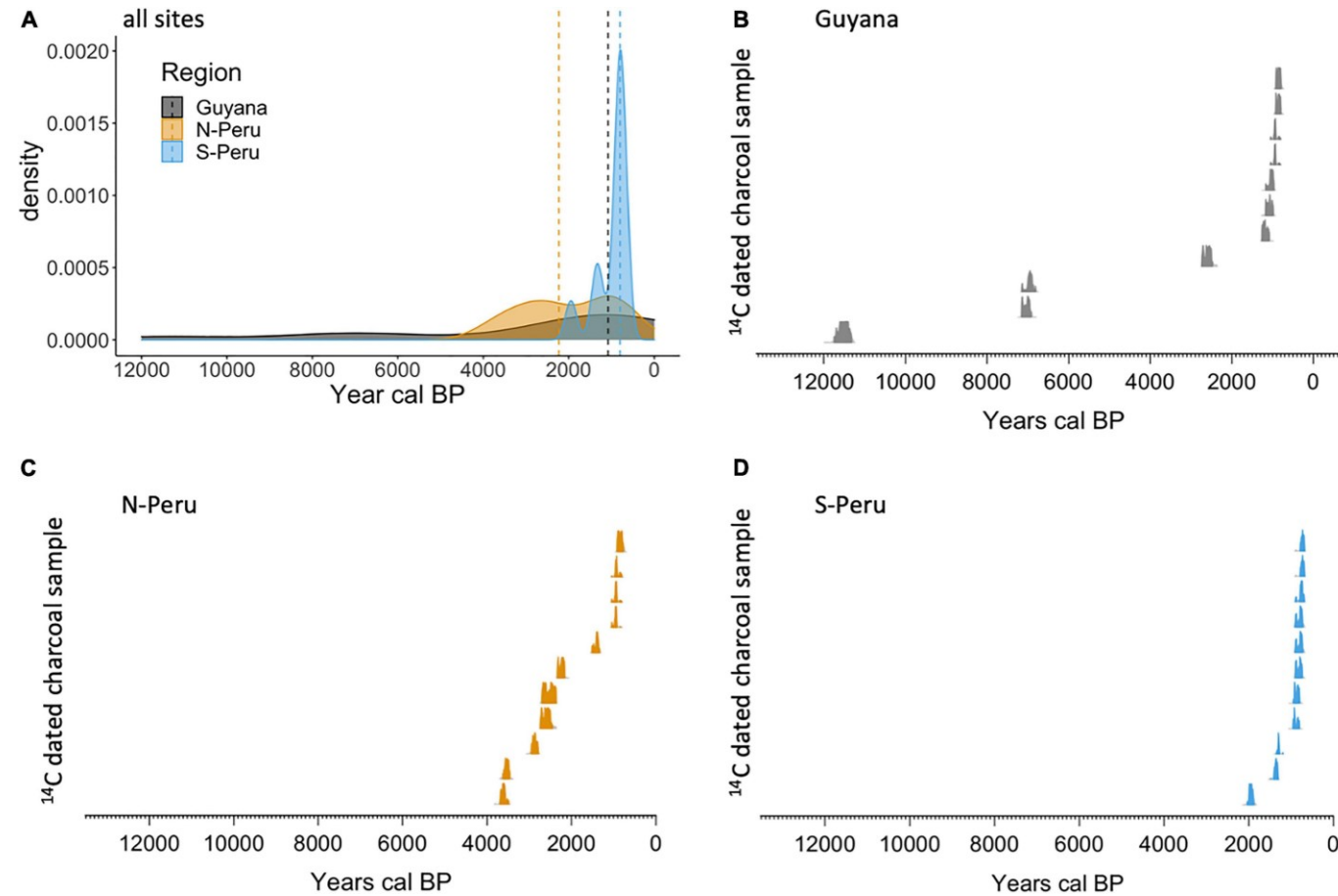
Feldpausch et al., 2022



Glaser et al., 2001

Fire recurrence

Feldpausch et al., 2022



Site	Calibrated dates (cal years BP)		Fire return interval (cal years BP)				No. of unique fire events			
	Minimum	Maximum	Mean	Median	Minimum	Maximum	Pit 1	Pit 2	Pit 3	Total
Guyana	851	11,513	2,655	2,950	208	4,510	4	2	2	5
N-Peru	842	3,606	529	484	299	838	2	2	4	6
S-Peru	728	1,944	397	455	115	621	3	1	3	4

RothC modelling

A single pool (i.e. IOM) modelling approach with set values for calculating SOC turnover in relation to vegetation cover, C inputs and meteorology.

Fires are simulated at set times via altered C input with corresponding IOM inputs representing PyC.

Research questions:

1. Which modelled fire/PyC conditions show the best alignment with field observations?
2. What C cycling role does PyC play in future climate scenarios?

Methods

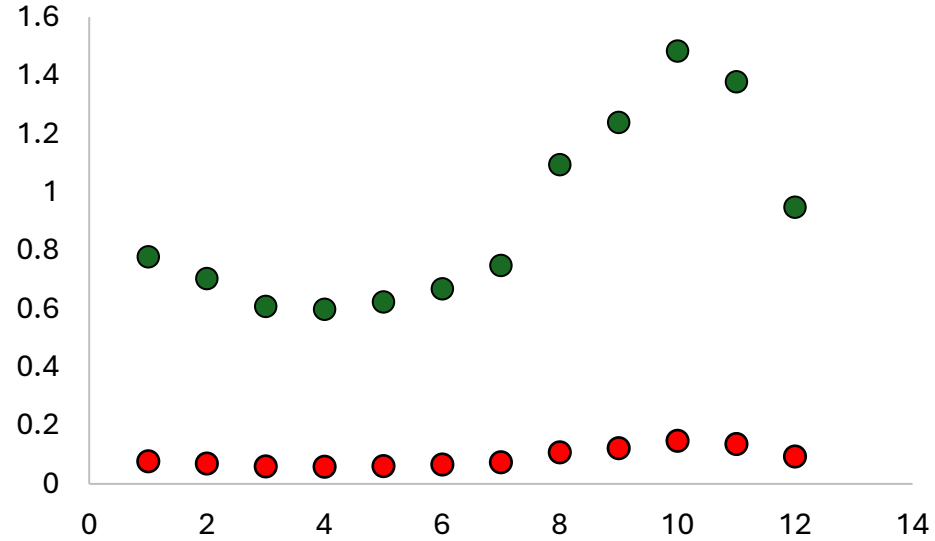
- C input as plant litter (i.e. leaves, fruit, flowers, twigs)
- Soil clay content: 5 and 35%
- West and east meteorology
- Fire recurrence: 100, 400, 850 years
- Model runs with 70% reduction in C input with fire
- PyC modelled via inert organic matter (IOM)
- PyC yields 1, 10, 25%
- PyC degradation constants vary with fire recurrence
- 1.5, 3 and 5°C future warming scenarios

Types of Amazon wildfire

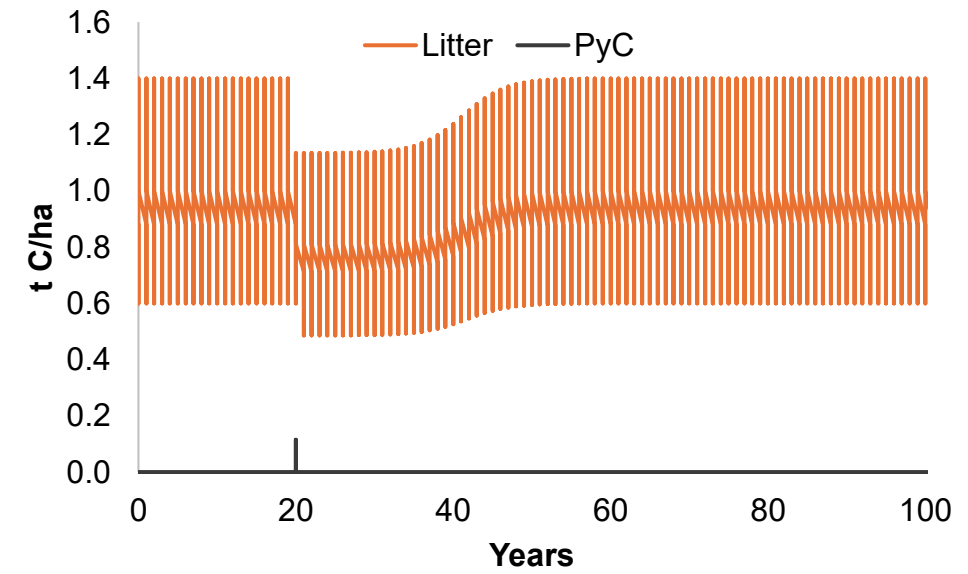
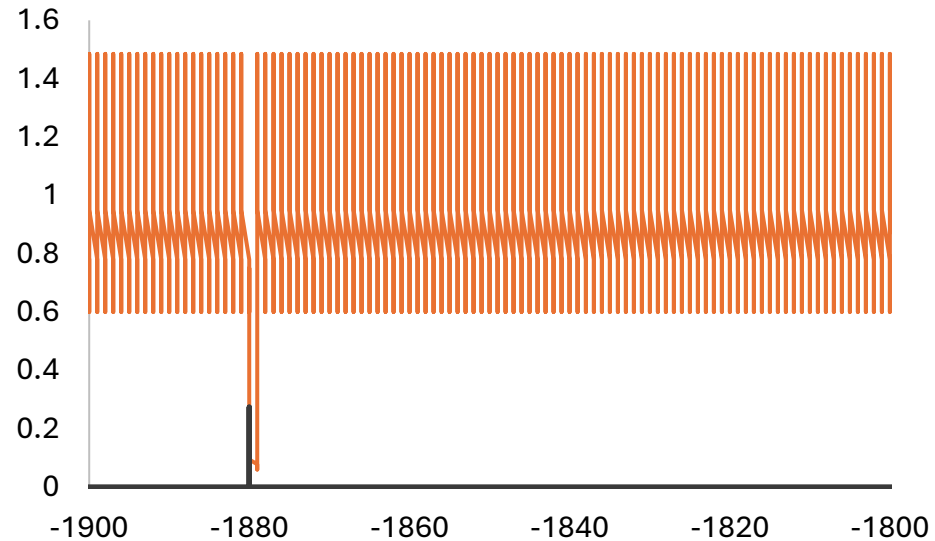
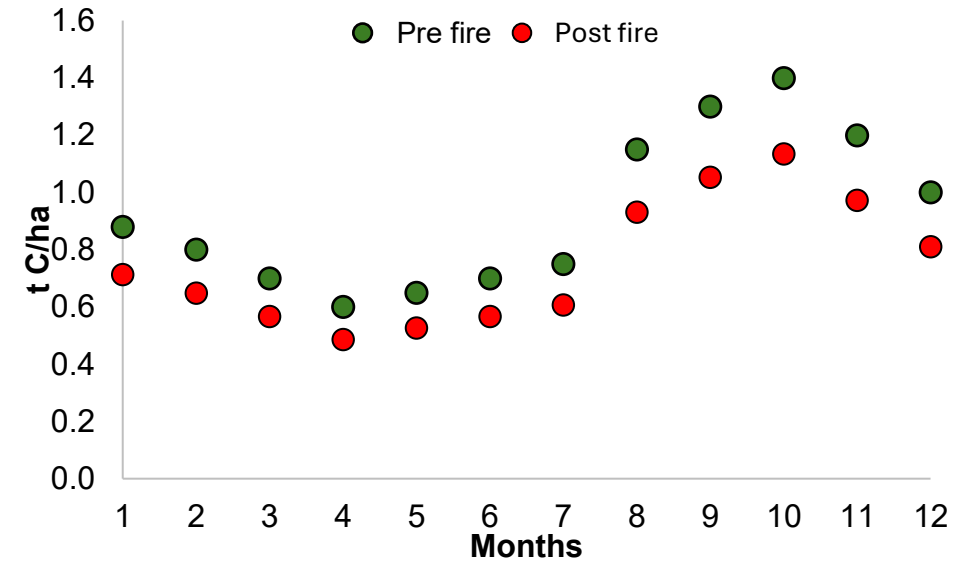


Plant litter input

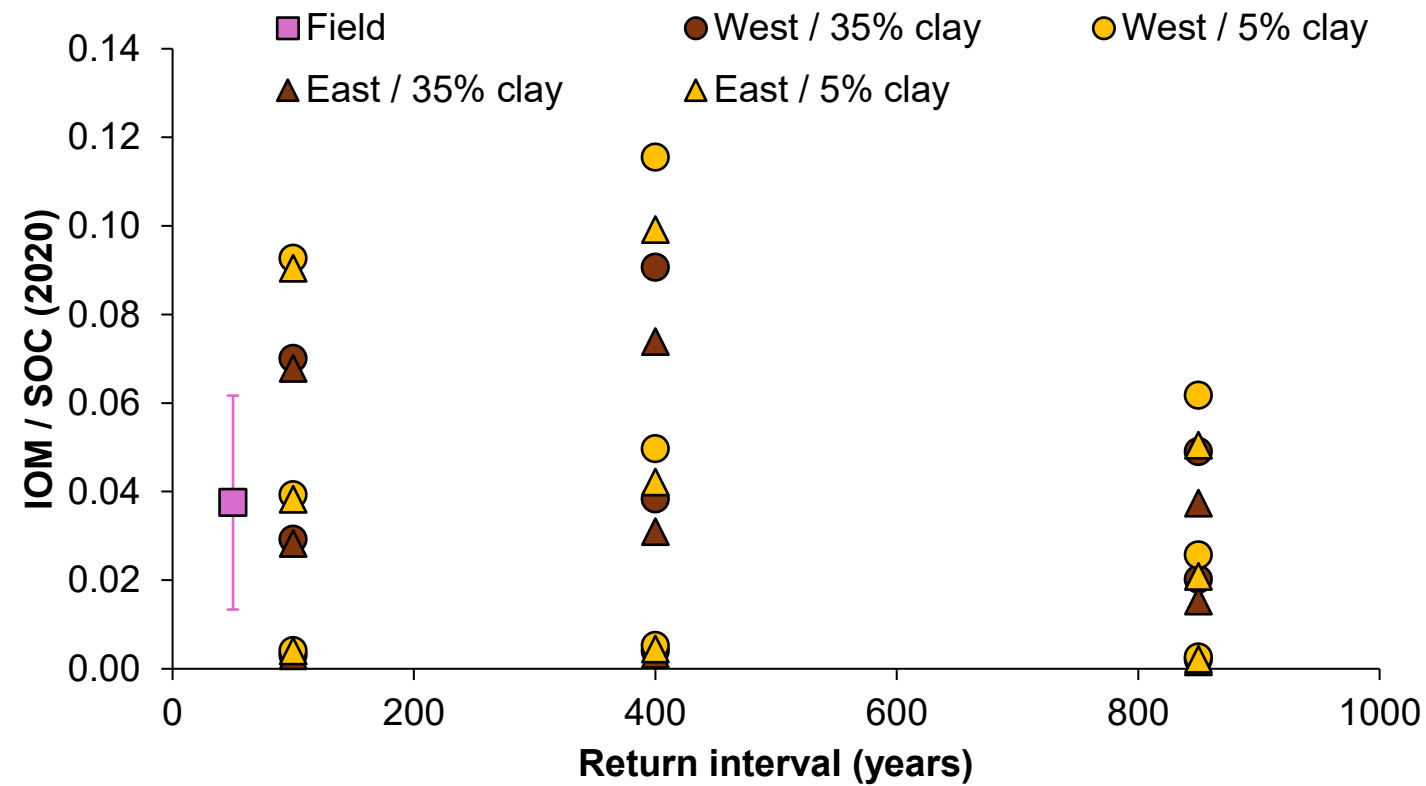
Palaeo fire, 70% litter combustion
Balch et al., 2008



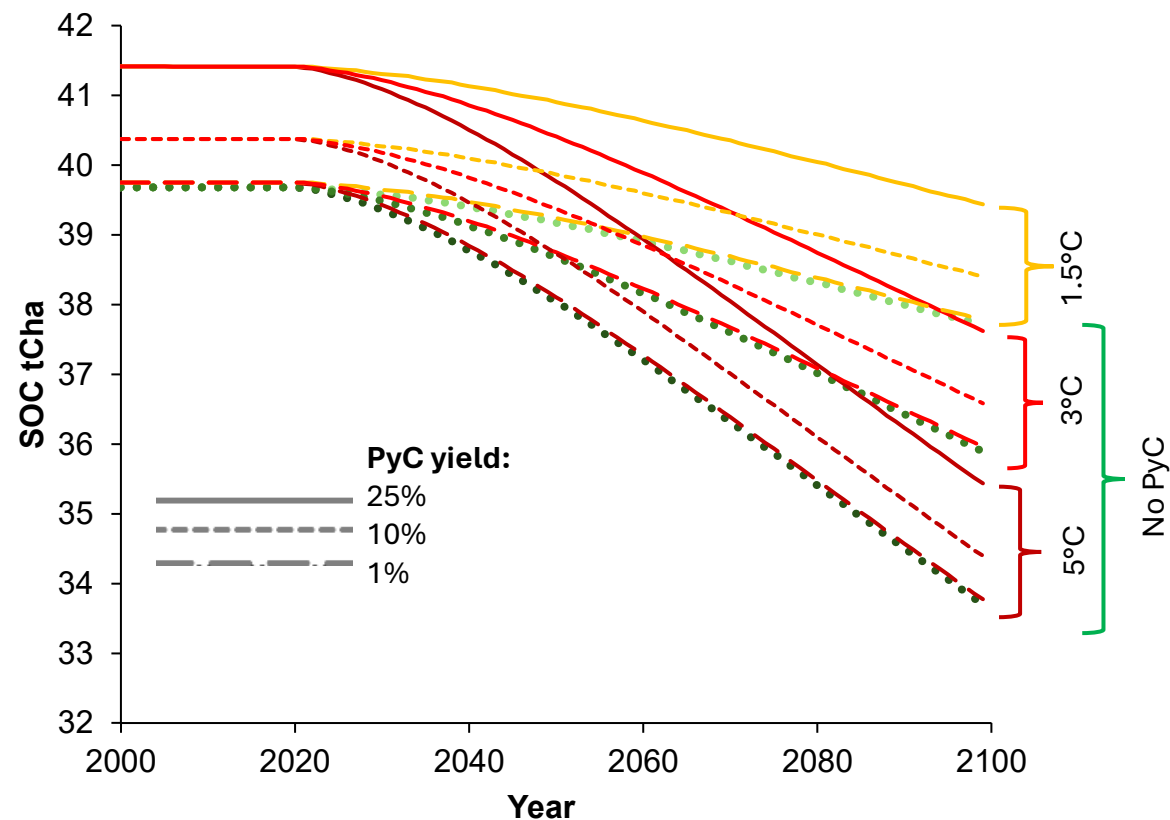
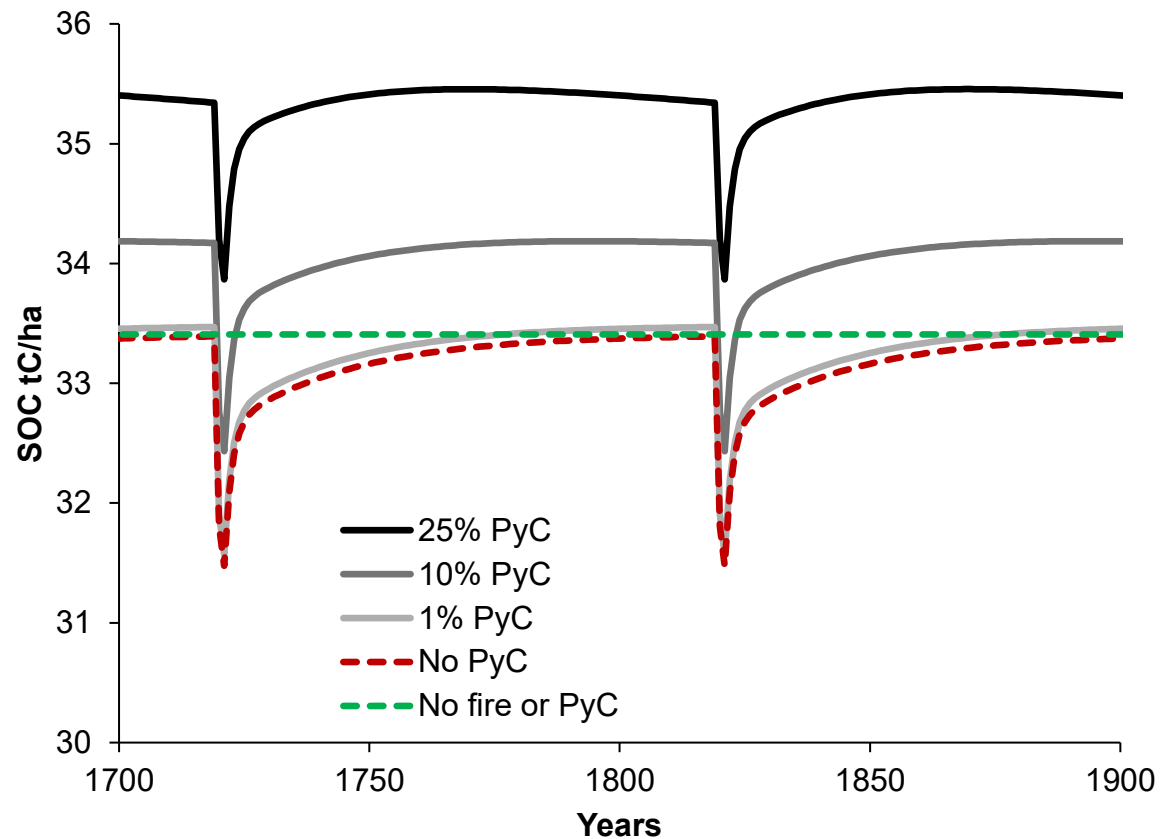
Contemporary fire, 19% AGB combustion
De Faria et al., 2020



Results



Year	Yield	West / East	Clay	Diff to field (IOM/SOC)
100	10	e	35	-0.009
100	10	w	35	-0.008
400	10	e	35	-0.007
850	25	e	35	0.000
100	10	e	5	0.001
400	10	w	35	0.001
100	10	w	5	0.002
400	10	e	5	0.005



	Fire recurrence		PyC yield		West / East		Future		Clay	
	<i>p</i>	$\omega 2$	<i>p</i>	$\omega 2$	<i>p</i>	$\omega 2$	<i>p</i>	$\omega 2$	<i>p</i>	$\omega 2$
DPM	<0.001	0.11	1.000	-	0.397	-	0.852	-	1.000	-
RPM	<0.001	0.020	0.994	-	<0.001	0.681	<0.001	0.006	<0.001	0.024
BIO	<0.001	0.005	0.845	-	<0.001	0.309	<0.001	0.003	<0.001	0.548
HUM	0.745	-	0.710	-	<0.001	0.334	<0.001	0.003	<0.001	0.577
IOM	<0.001	0.038	<0.001	0.716	0.014	0.002	1.000	-	0.852	-
SOC	0.763	-	<0.001	0.012	<0.001	0.417	<0.001	0.004	<0.001	0.472

Key observations

RQ1 – field vs modelled

- All 1% PyC runs were markedly lower than field values (contemporary field observations may not be representative of Amazon fire over time)
- 850yr fire recurrence with 25% PyC yield results in the closest match to field observations
- 400yr fire recurrence with 25% PyC yield results in the most SOC and IOM compared to runs with fire but no PyC

RQ2 – future contribution of PyC

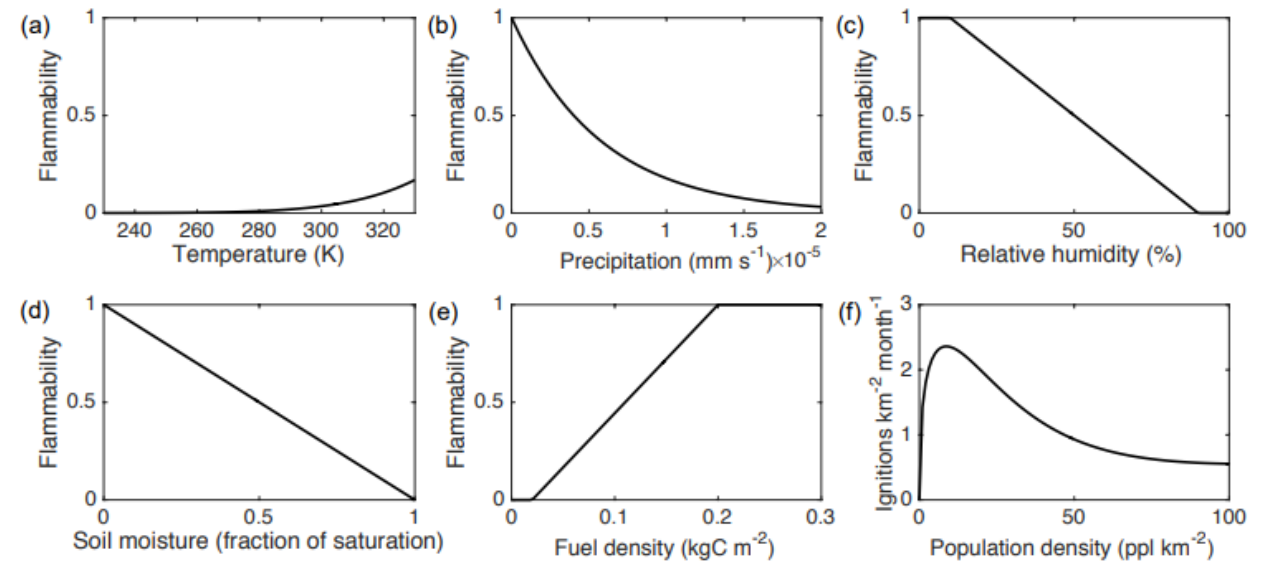
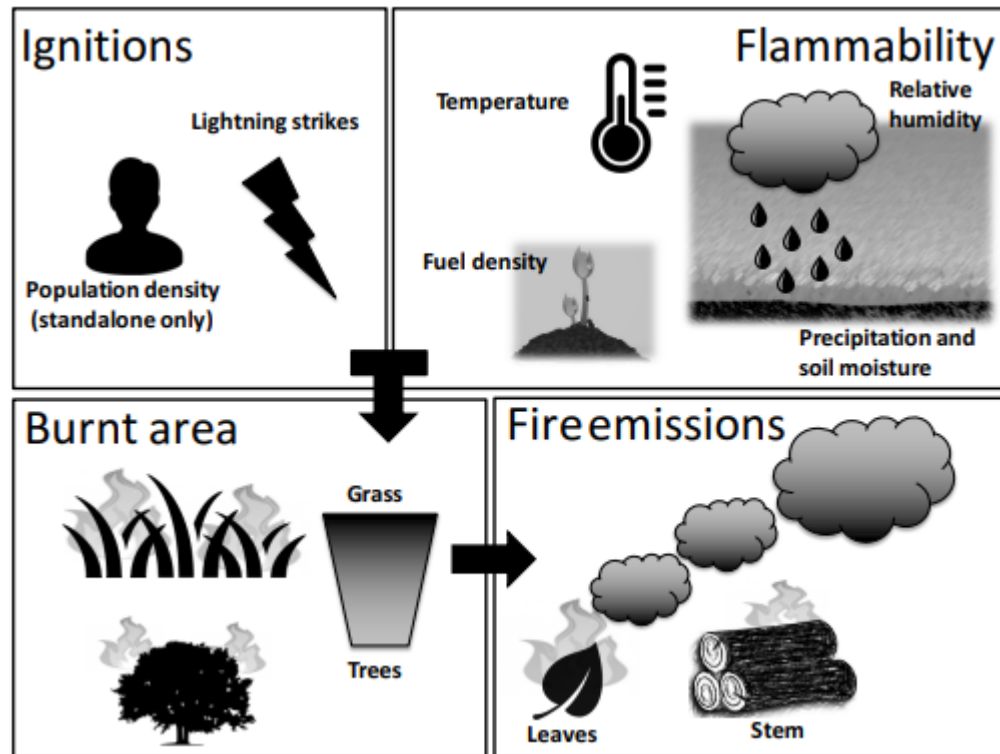
- IOM was not significantly affected by future warming scenarios
- Higher PyC yields resulted in higher SOC across all warming scenarios
- Low PyC yields (i.e. 1%) results in negligible difference to 0% PyC yield runs

Not accounting for PyC means that 10's MtC may be unaccounted for (e.g. ~76 MtC in 2024)

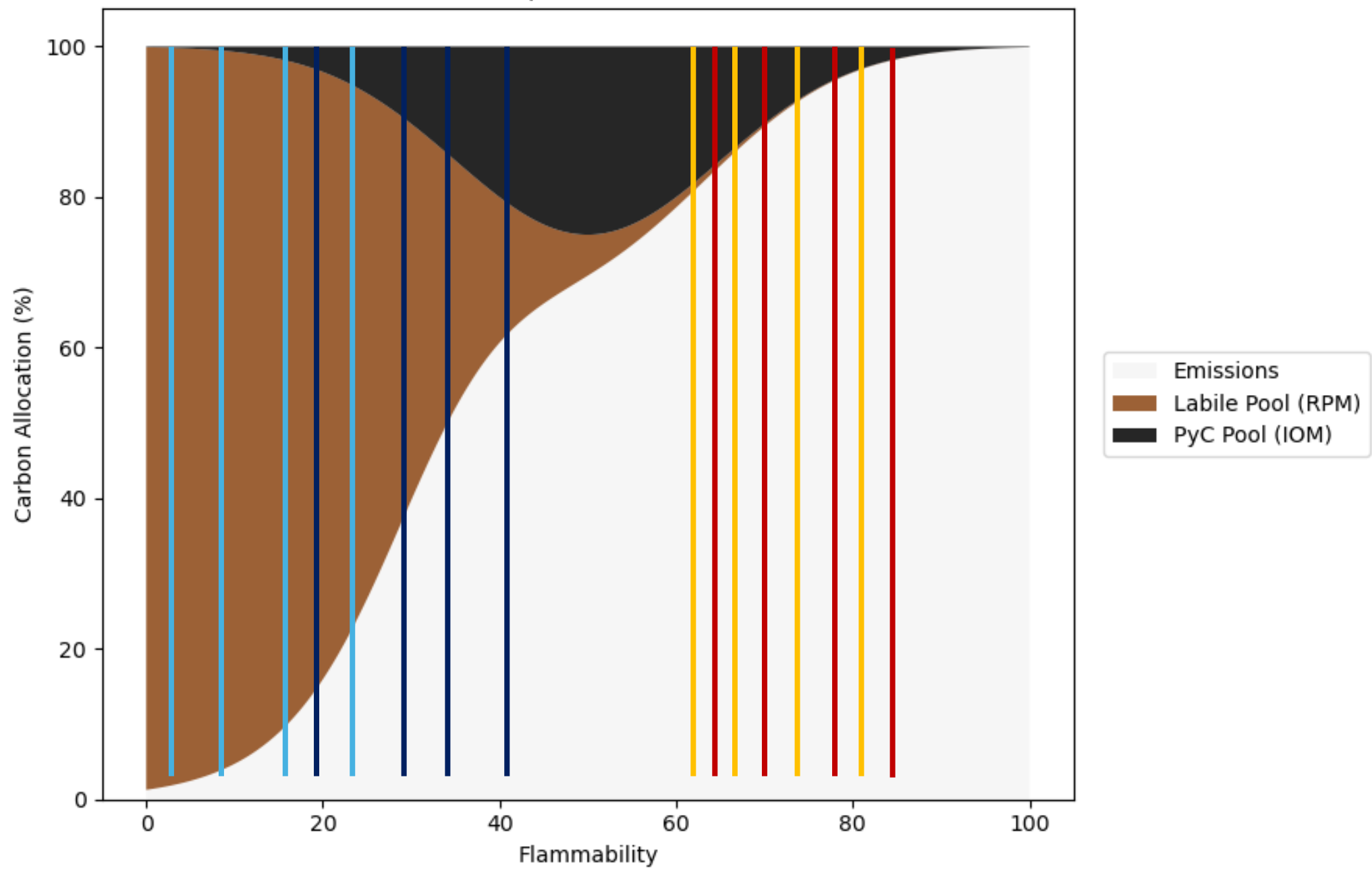
Future JULES developments

- JULES will be adjusted to produce PyC yields in relation to model conditions (e.g. fuel flammability), rather than being modelled at set values
- Possible 3 pool modelling approach (e.g. RPM, HUM, IOM)
- Differing PyC composition for different biomass types (e.g. woody vs non-woody PFT components)

INFERNO – flammability



2 pool model



References

- Balch, J.K., Nepstad, D.C., Brando, P.M., Curran, L.M., Portela, O., de Carvalho Jr, O. and Lefebvre, P., 2008. Negative fire feedback in a transitional forest of southeastern Amazonia. *Global Change Biology*, 14(10), pp.2276-2287.
- Barlow, J., Gardner, T.A., Ferreira, L.V. and Peres, C.A., 2007. Litter fall and decomposition in primary, secondary and plantation forests in the Brazilian Amazon. *Forest Ecology and Management*, 247(1-3), pp.91-97.
- De Faria, B.L., Marano, G., Piponiot, C., Silva, C.A., Dantas, V.D.L., Rattis, L., Rech, A.R. and Collalti, A., 2020. Model-based estimation of Amazonian forests recovery time after drought and fire events. *Forests*, 12(1), p.8.
- DeLuca, T.H., Gundale, M.J., Brimmer, R.J. and Gao, S., 2020. Pyrogenic carbon generation from fire and forest restoration treatments. *Frontiers in forests and global change*, 3, p.24
- Fearnside, P.M., de Alencastro Graça, P.M.L. and Rodrigues, F.J.A., 2001. Burning of Amazonian rainforests: burning efficiency and charcoal formation in forest cleared for cattle pasture near Manaus, Brazil. *Forest Ecology and Management*, 146(1-3), pp.115-128.
- Feldpausch, T.R., Carvalho, L., Macario, K.D., Ascough, P.L., Flores, C.F., Coronado, E.N.H., Kalamandeen, M., Phillips, O.L. and Staff, R.A., 2022. Forest fire history in Amazonia inferred from intensive soil charcoal sampling and radiocarbon dating. *Frontiers in Forests and Global Change*, 5, p.815438.
- Glaser, B., Haumaier, L., Guggenberger, G. and Zech, W., 2001. The Terra Preta phenomenon: a model for sustainable agriculture in the humid tropics. *Naturwissenschaften*, 88(1), pp.37-41.
- Keiluweit, M., Nico, P.S., Johnson, M.G. and Kleber, M., 2010. Dynamic molecular structure of plant biomass-derived black carbon (biochar). *Environmental science & technology*, 44(4), pp.1247-1253.
- Lehmann, J., Skjemstad, J., Sohi, S., Carter, J., Barson, M., Falloon, P., Coleman, K., Woodbury, P. and Krull, E., 2008. Australian climate–carbon cycle feedback reduced by soil black carbon. *Nature Geoscience*, 1(12), pp.832-835.
- Mangeon, S., Voulgarakis, A., Gilham, R., Harper, A., Sitch, S. and Folberth, G., 2016. INFERNO: A fire and emissions scheme for the UK Met Office's Unified Model. *Geoscientific Model Development*, 9(8), pp.2685-2700.
- Preston, C.M. and Schmidt, M.W., 2006. Black (pyrogenic) carbon: a synthesis of current knowledge and uncertainties with special consideration of boreal regions. *Biogeosciences*, 3(4), pp.397-420.
- Santín, C., Doerr, S.H., Preston, C.M. and González-Rodríguez, G., 2015. Pyrogenic organic matter production from wildfires: a missing sink in the global carbon cycle. *Global Change Biology*, 21(4), pp.1621-1633.
- Santín, C., Doerr, S.H., Jones, M.W., Merino, A., Warneke, C. and Roberts, J.M., 2020. The relevance of pyrogenic carbon for carbon budgets from fires: Insights from the FIREX experiment. *Global Biogeochemical Cycles*, 34(9), p.e2020GB006647.
- da Silva, W.B., Périco, E., Dalzochio, M.S., Santos, M. and Cajaiba, R.L., 2018. Are litterfall and litter decomposition processes indicators of forest regeneration in the neotropics? Insights from a case study in the Brazilian Amazon. *Forest Ecology and Management*, 429, pp.189-197.