LEVERHULME

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Global seasonality of small-scale livelihood and cultural fire

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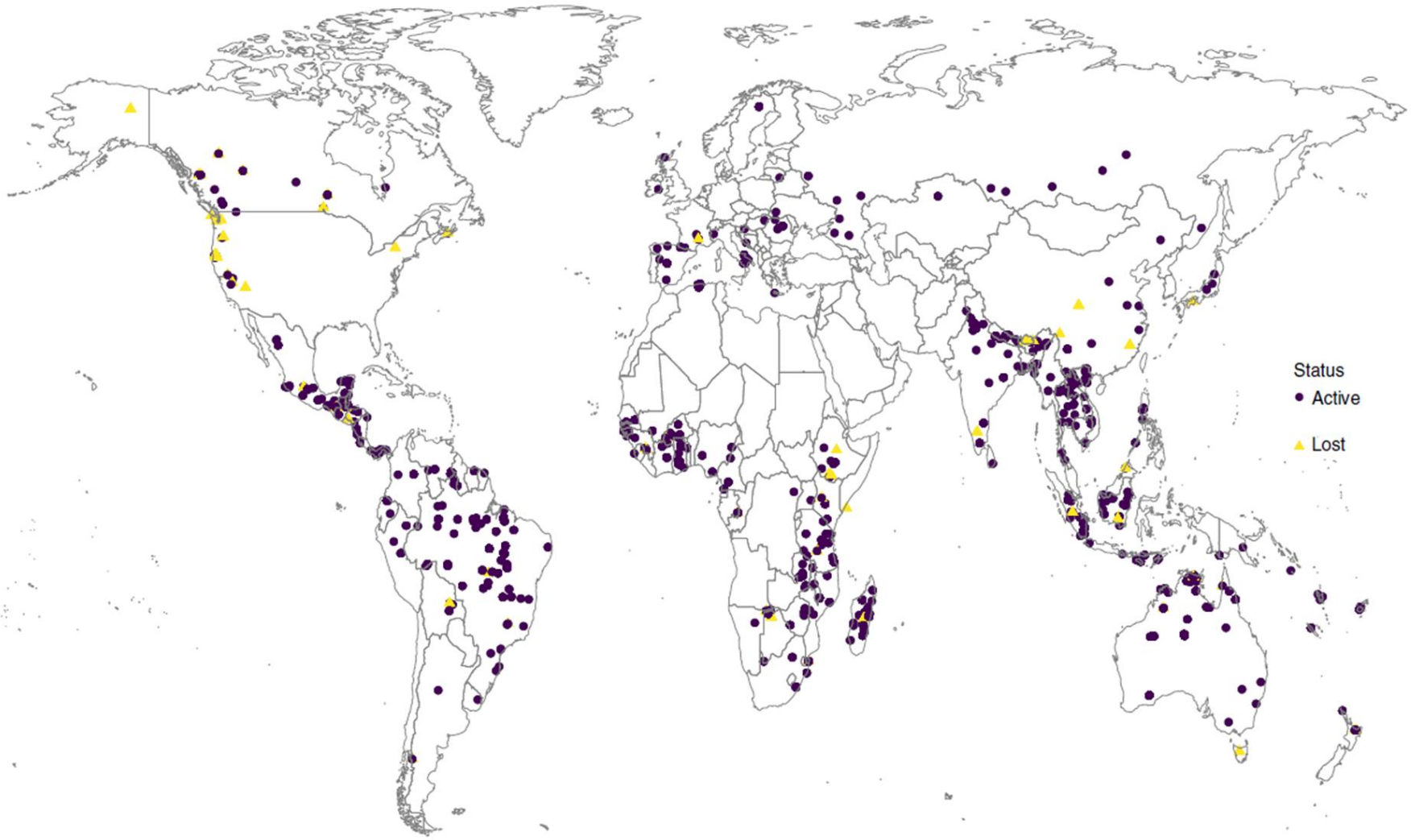
The Livelihood Fire Database (LIFE)

Data about human fire use collated from over 500 publications spanning 1990-2020.

Focus on 'small-scale livelihood' and cultural fire users.

Includes biophysical data and social data.

Fire use practices classified by fire use purpose on two tiers.

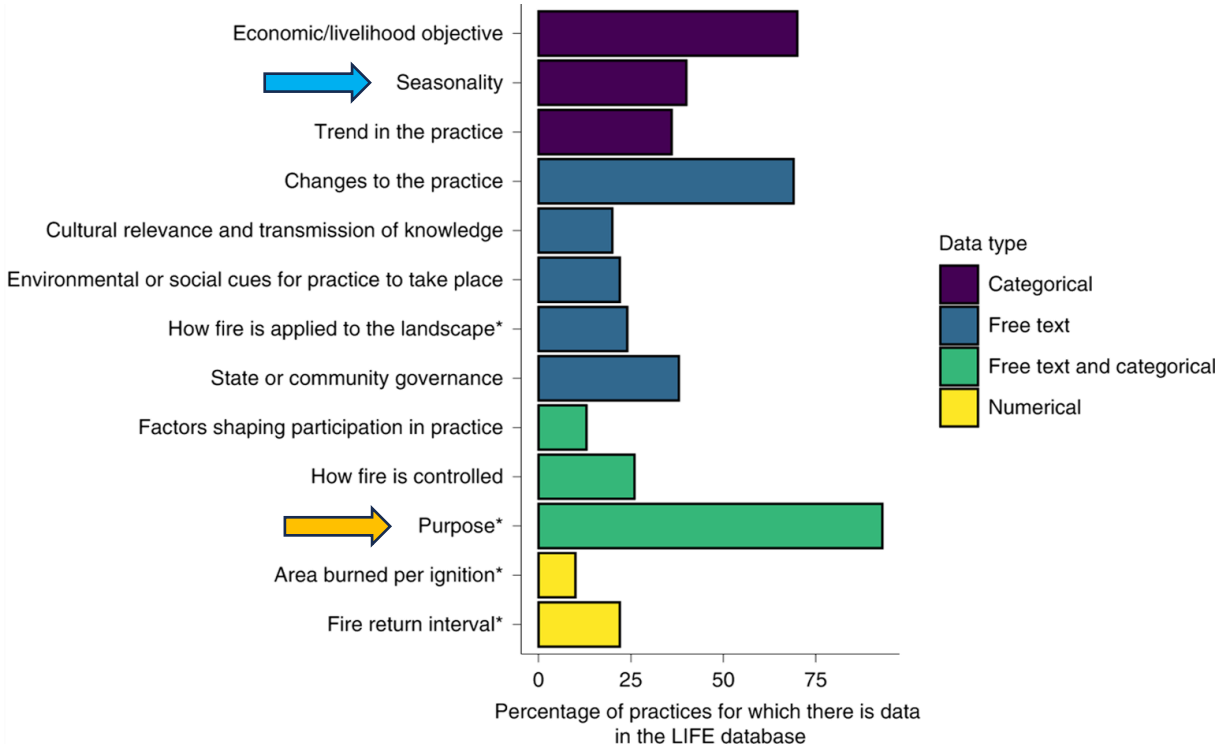


C. Smith, O. Perkins, and J. Mistry. *Nat Sustain* (2022).

In LIFE we had data on the months in which burning takes place for **617 fire use practices**, with a range of purposes.

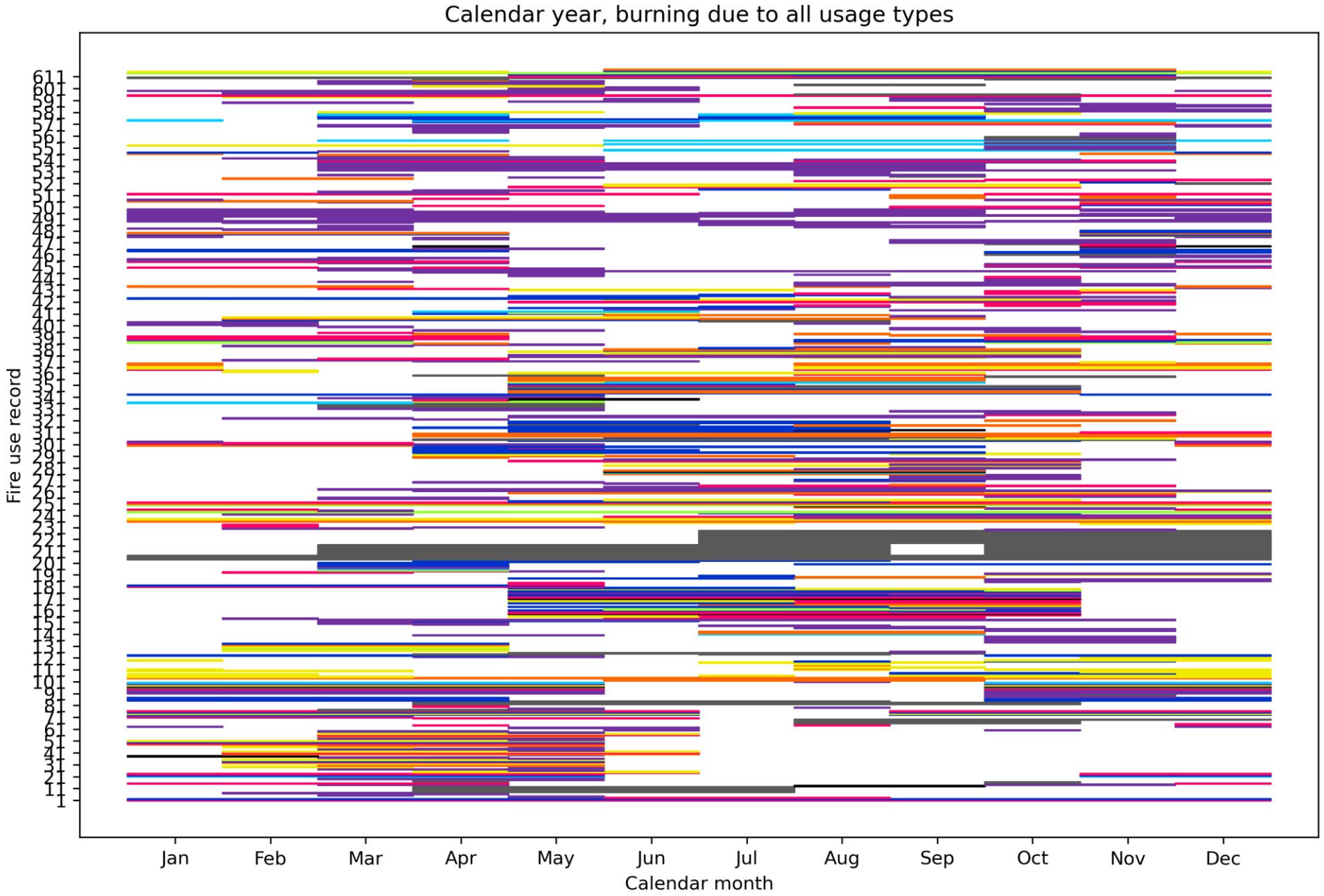
We want to be able to **look for patterns in the seasonality of burning for different burning purposes**, across the world.

But different regions on Earth have different types of seasonality (e.g. wet-dry, or spring-summer-autumn-winter), and even where patterns of seasonality are similar in different regions, the timing of the seasons within a calendar year differs.

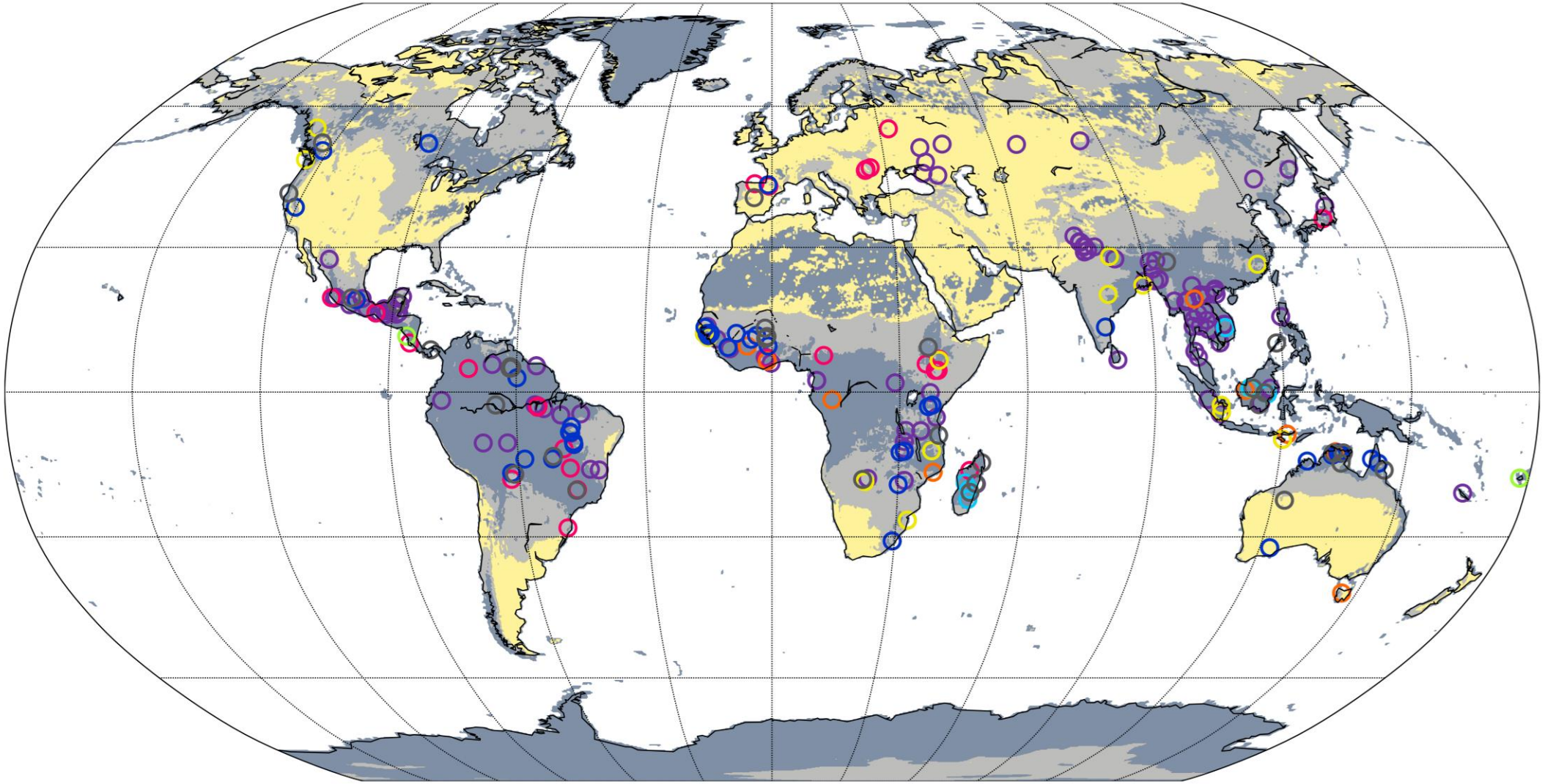


Fire use purpose		N
Higher-tier	*Lower-tier*	
Agriculture (A)	A1. Clear vegetation for swidden or semi-permanent agriculture	325
	A2. Clear vegetation for permanent agriculture	46
	A3. Clear weeds and/or crop residues during the growing season	22
	A4. Clear weeds and/or crop residues after harvest to enable planting	133
	A5. Reduce crop pests	34
Pastoralism (P)	P1. Clear vegetation to establish new pasture areas	18
	P2. Enhance forage for grazing livestock	219
	P3. Herd livestock	17
	P4. Reduce livestock pests and predators	50
Hunting and fishing (HF)	HF1. Create or improve habitat for hunted or fished species	24
	HF2. Renew forage to draw hunted or fished species into a particular area	67
	HF3. Improve visibility or access specifically for hunting or fishing	69
	HF4. Drive animals when hunting	65
	HF5. Kill, injure, or tire animals when hunting	12
Gathering (G)	G1. Enhance productivity of foraged resources	134
	G2. Ease resource collection by improving visibility or access	42
	G3. Drive wild bees away from hives for honey collection	49
Charcoal and fuelwood production (C)	C1. Produce charcoal	17
	C2. Produce or enable gathering of fuelwood	20
Movement (M)	M1. Maintain and open trails and waterways for general access	51
Human health & wellbeing (HW)	HW1. Reduce animals that are dangerous or unwanted	64
	HW2. Reduce fuel loads to reduce wildfire risk at a landscape scale	88
	HW3. Create firebreaks using fire to protect e.g., resources, farms, sacred sites	47
	HW4. Suppress a wildfire (using backing fire to fight fire with fire)	6
	HW5. Produce a more aesthetically pleasing landscape	24
Social signals (S)	S1. Communicate about current activity	17
	S2. Show disapproval or protest (arson)	53
	S3. For ritual or ceremonies	16
	S4. Assert or maintain cultural identity	113

To start with, this is what the raw case study data looks like if you just plot the calendar months that burning takes place in



So: we aggregate fire use practices based on local **seasonality cause**

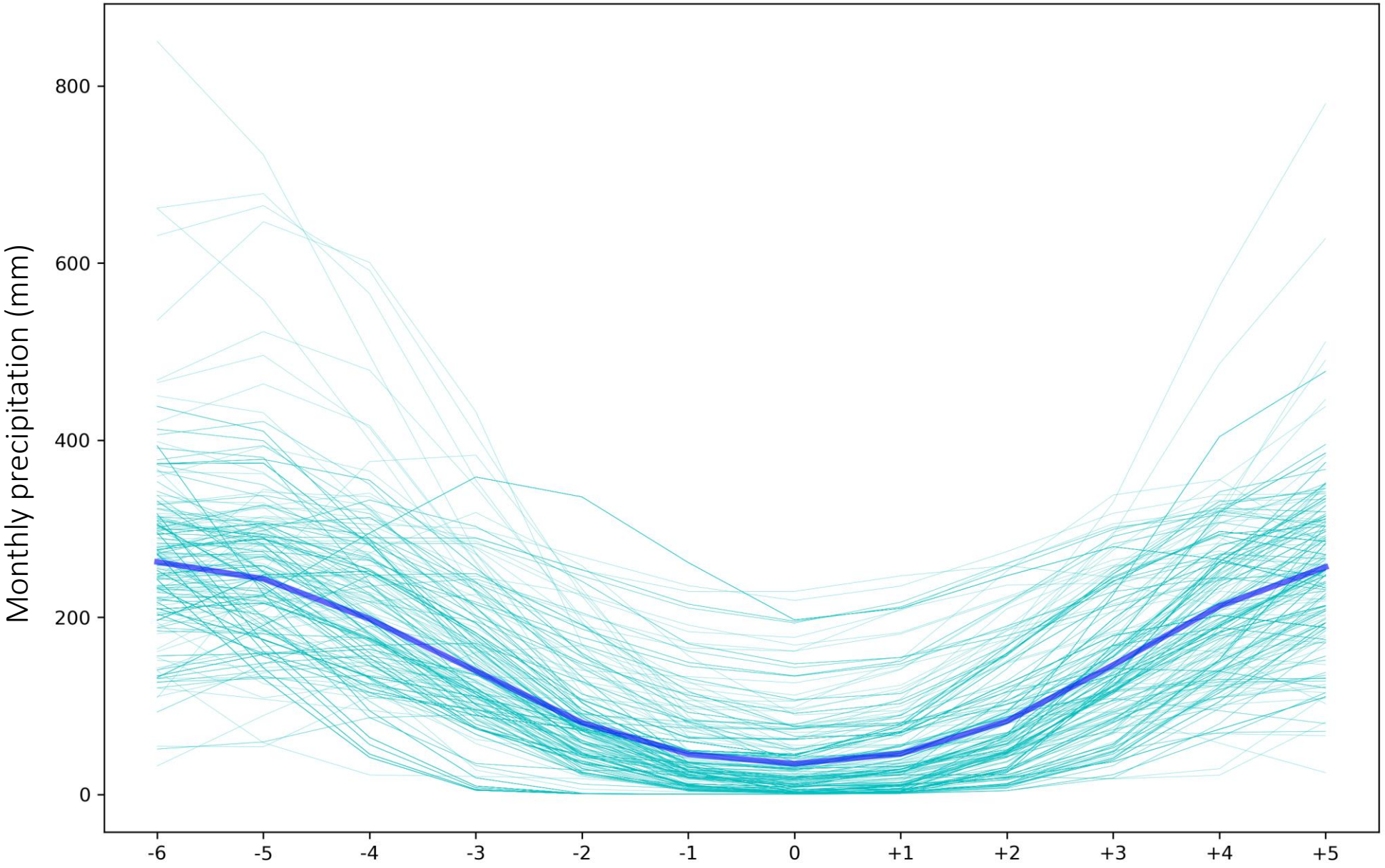


Agriculture
Pastoralism
Hunting & Fishing
Gathering
Charcoal
Movement
Health&Wellbeing
Social signals

O = case studies with data on months of burning

= precip-driven seasonality
= combi-driven seasonality
= temp-driven seasonality

Seasonality cause was determined using the metric of Feddema (*Physical Geography,* 2005), calculated on a 1990-2020 ERA5 climatology. This indicates which factor is the **main driver of seasonal variability: precipitation, temperature, or a combination of both**, based on the amplitude of seasonal variation of precipitation vs. potential evapotranspiration.



All case study locations with **precipitation-driven seasonality [446 fire use practices]**.

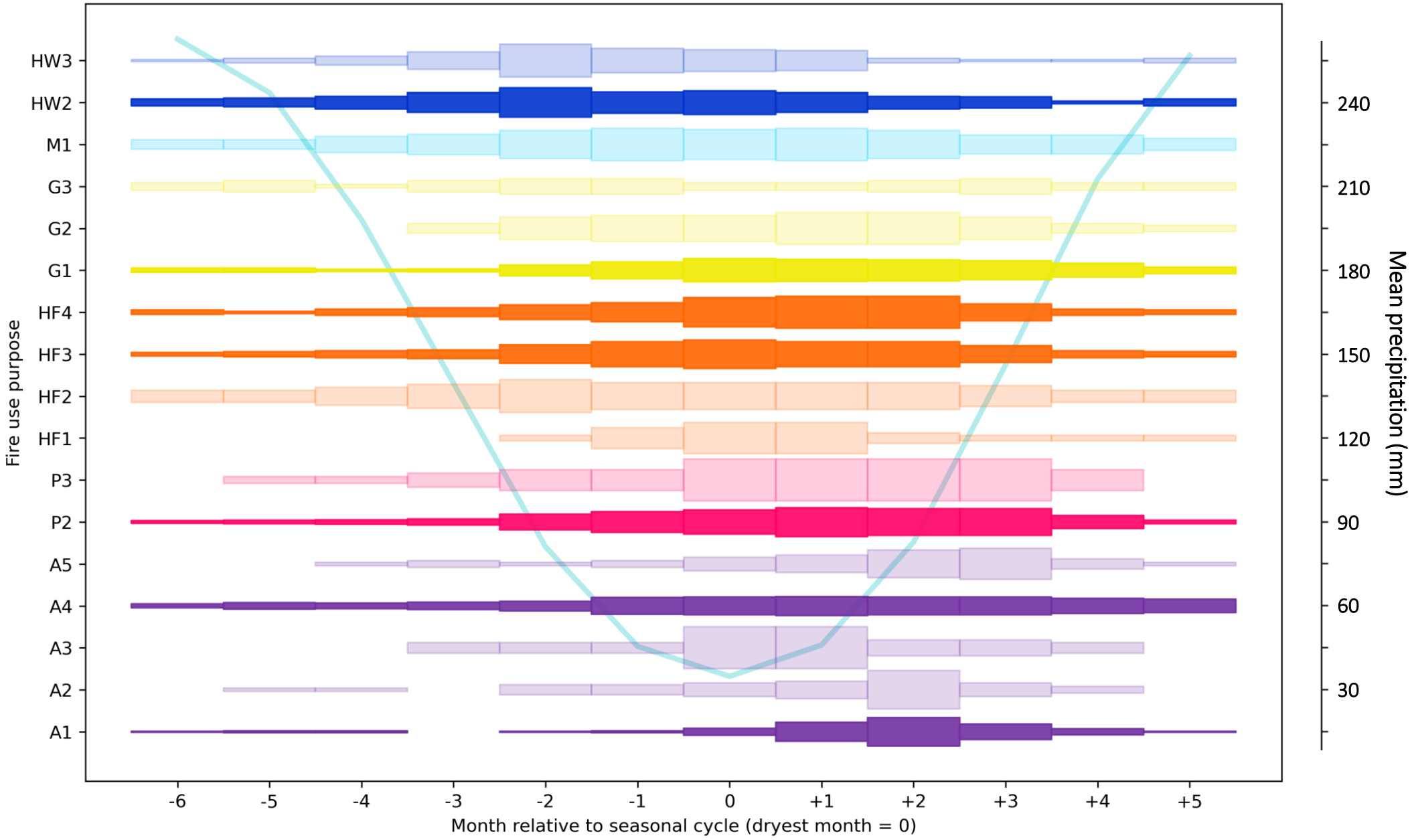
For each location, we **shift the seasonal cycle** so the **driest month** (lowest precipitation) is always in the middle.

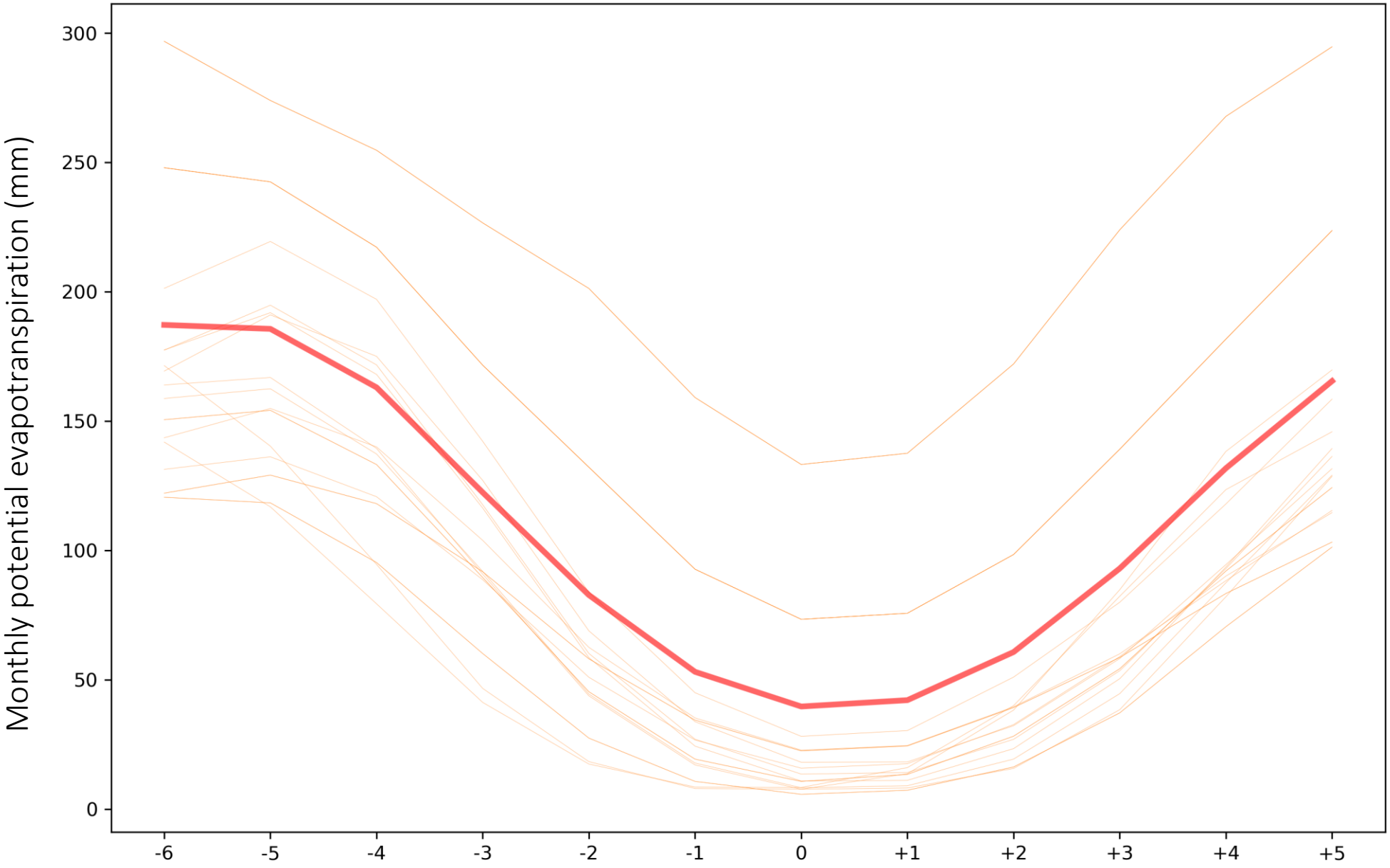
[Precipitation-driven seasonality]

Having aligned everything to a relative seasonal cycle, now we can aggregate by **fire use purpose**.

Light shading = 6-19 database entries, dark shading = 20+ entries. Categories with < 6 cases are not shown.

[P4, HW1, HW5, S4 omitted]





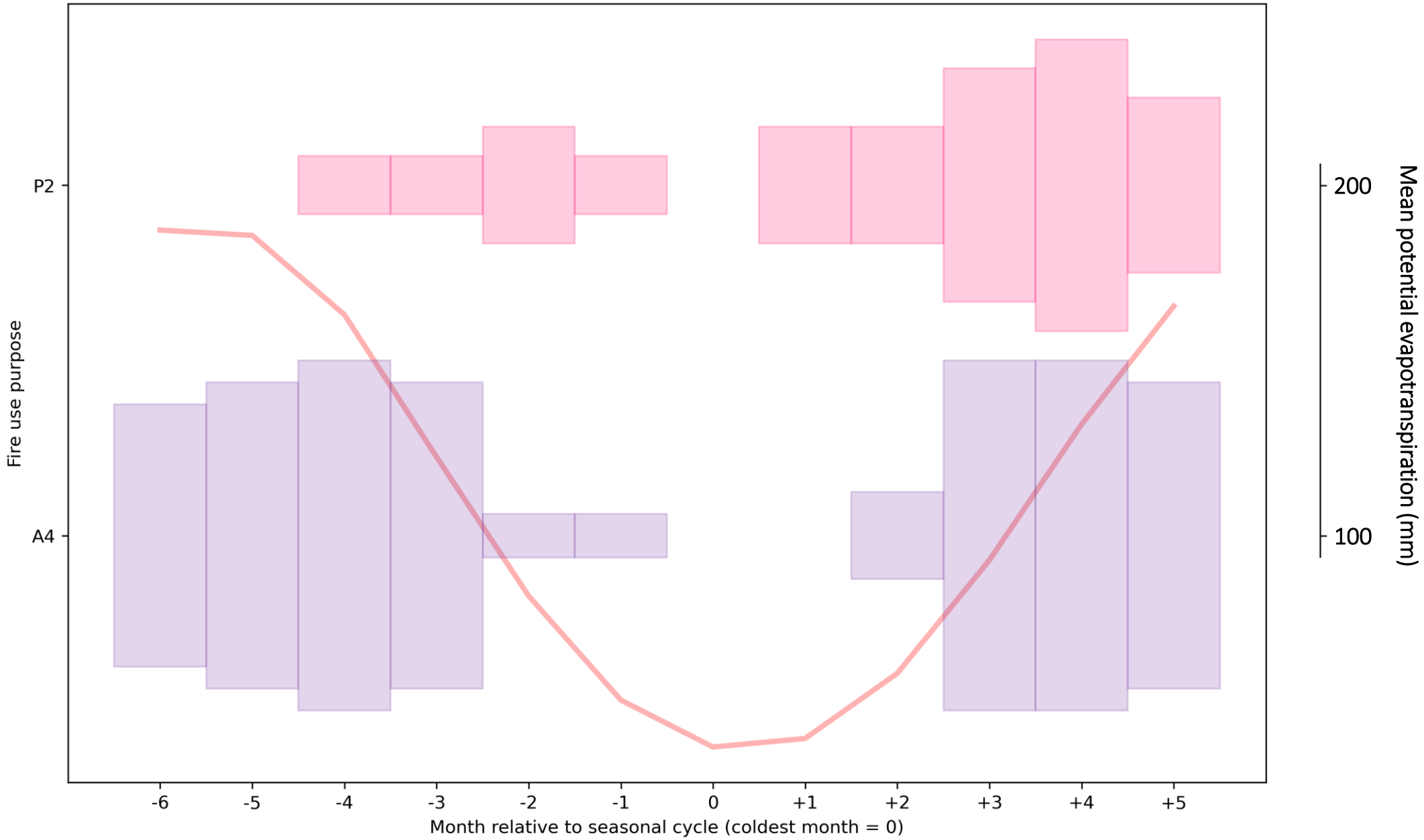
All case study locations with **temperature-driven seasonality [23 fire use practices]**.

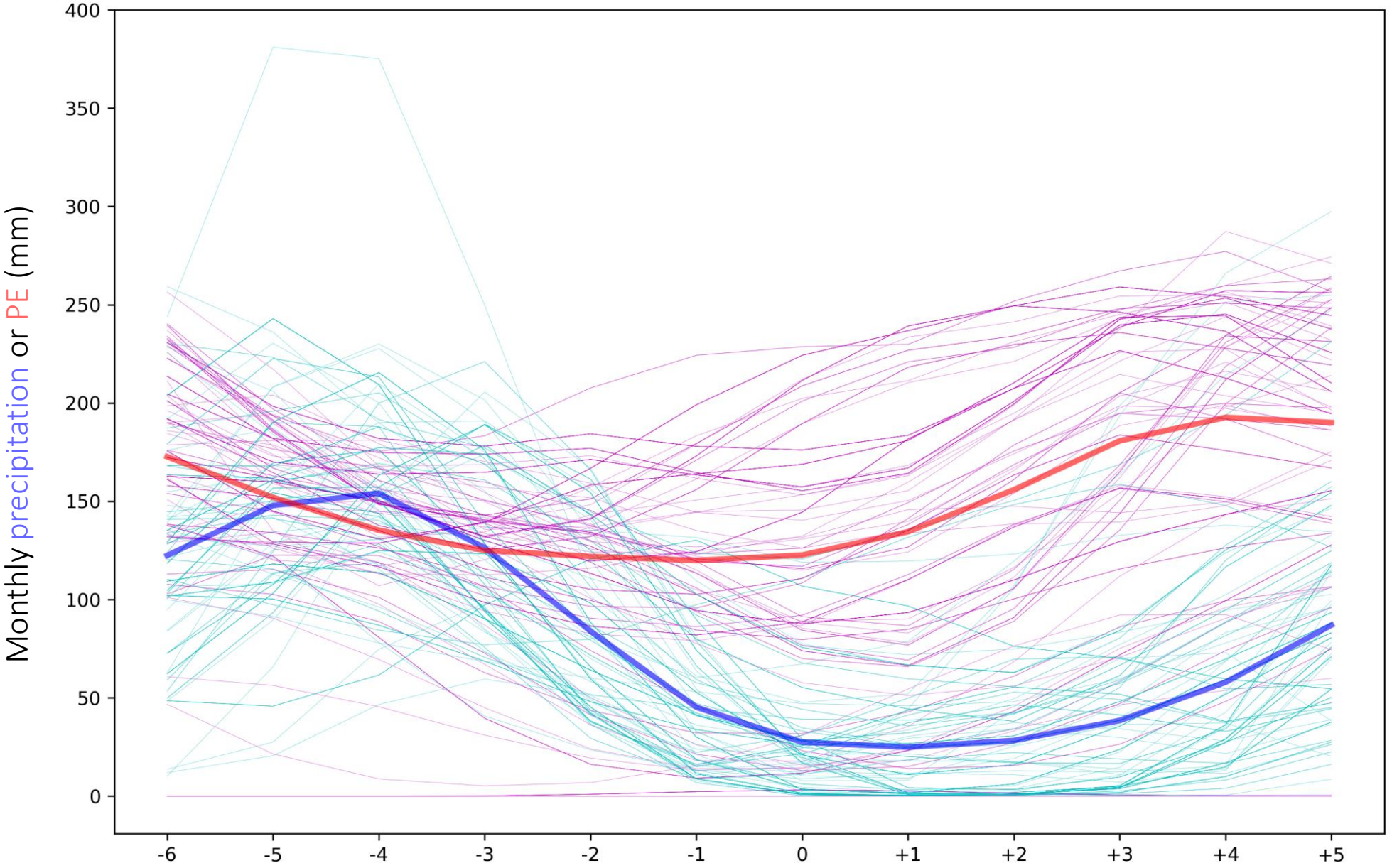
For each location, we **shift the seasonal cycle** so the **coldest month** (lowest potential evapotranspiration) is always in the middle.

[Temperature-driven seasonality]

Light shading = 6-19 database entries. Categories with < 6 cases are not shown.

[P4, HW1, HW5, S4 omitted]





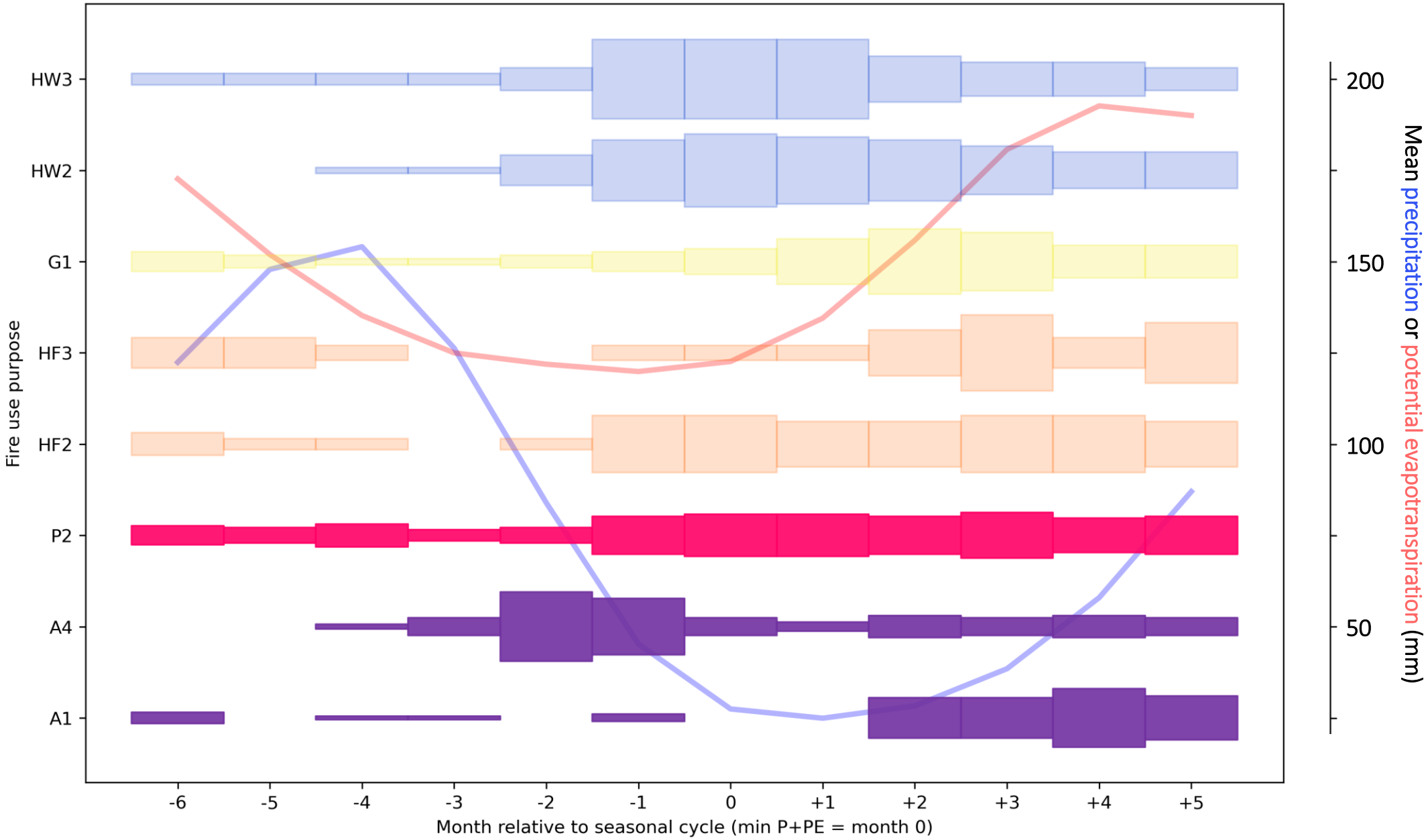
All case study locations with **combination-driven seasonality [148 fire use practices]**.

For each location, we **shift the seasonal cycle** so the **overall coldest and dryest month** (lowest sum of P + PE) is always in the middle.

[Combination-driven seasonality]

Light shading = 6-19 database entries, dark shading = 20+ entries. Categories with < 6 cases are not shown.

[P4, HW1, HW5, S4 omitted]

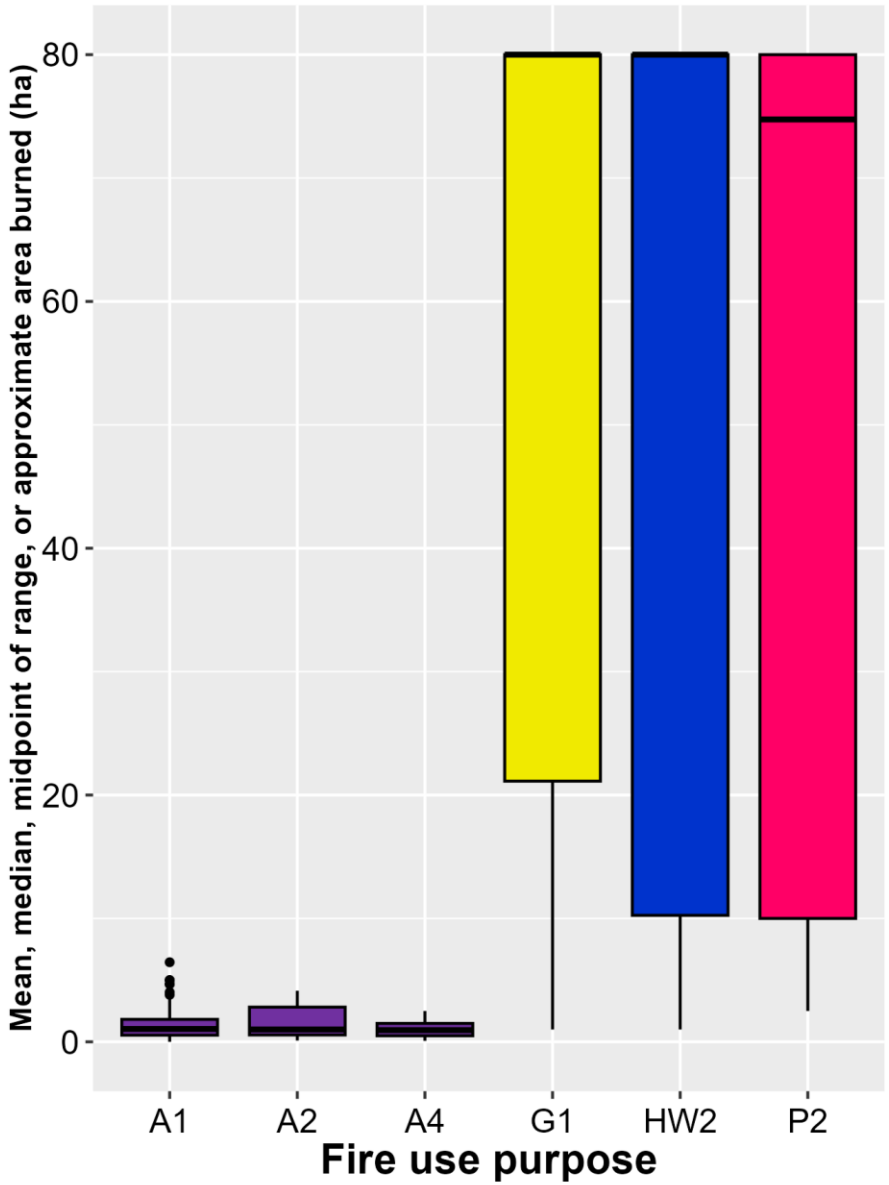


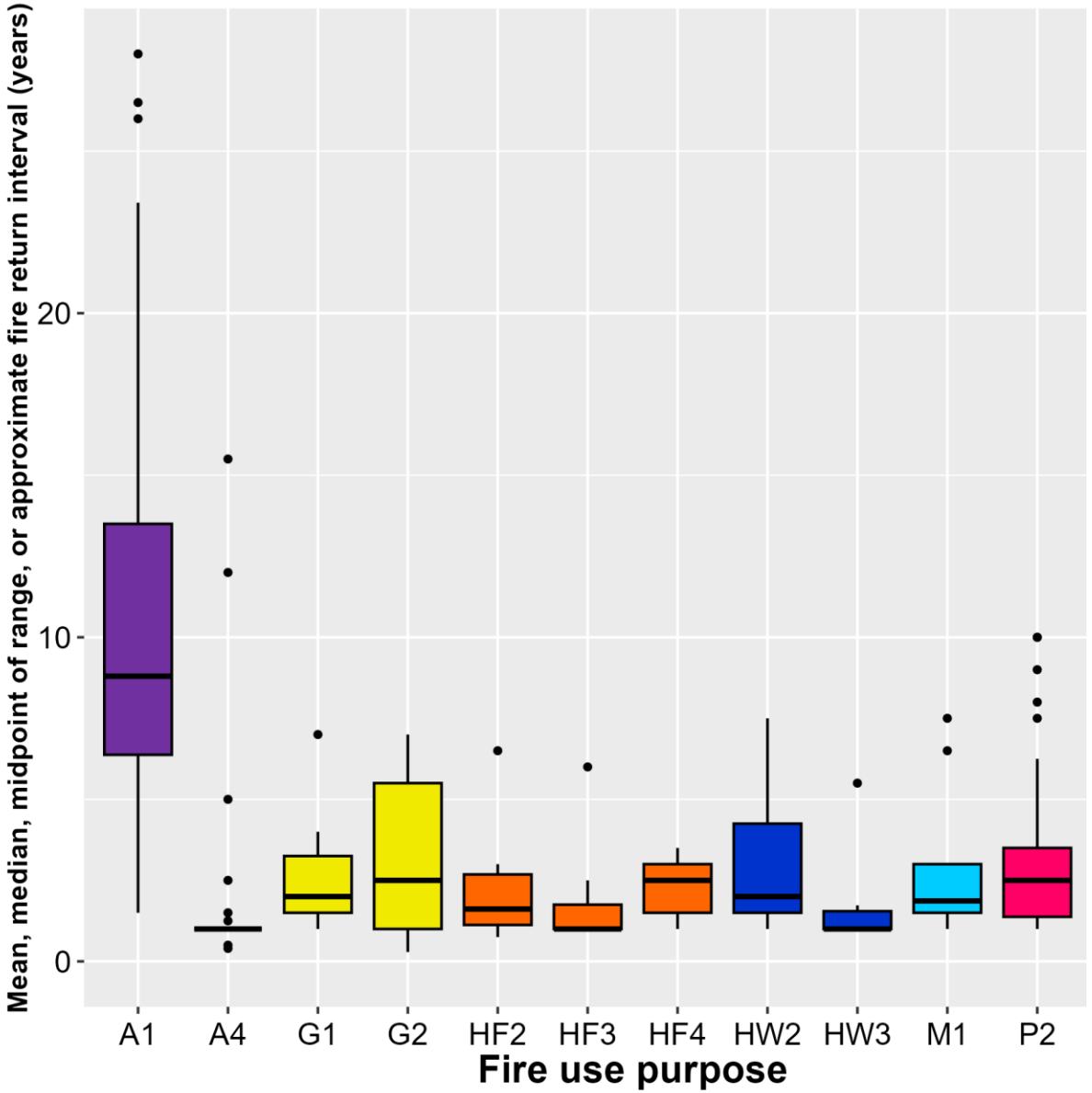
We can also link these fire use purposes to different **burned areas** and **return intervals** using LIFE data.

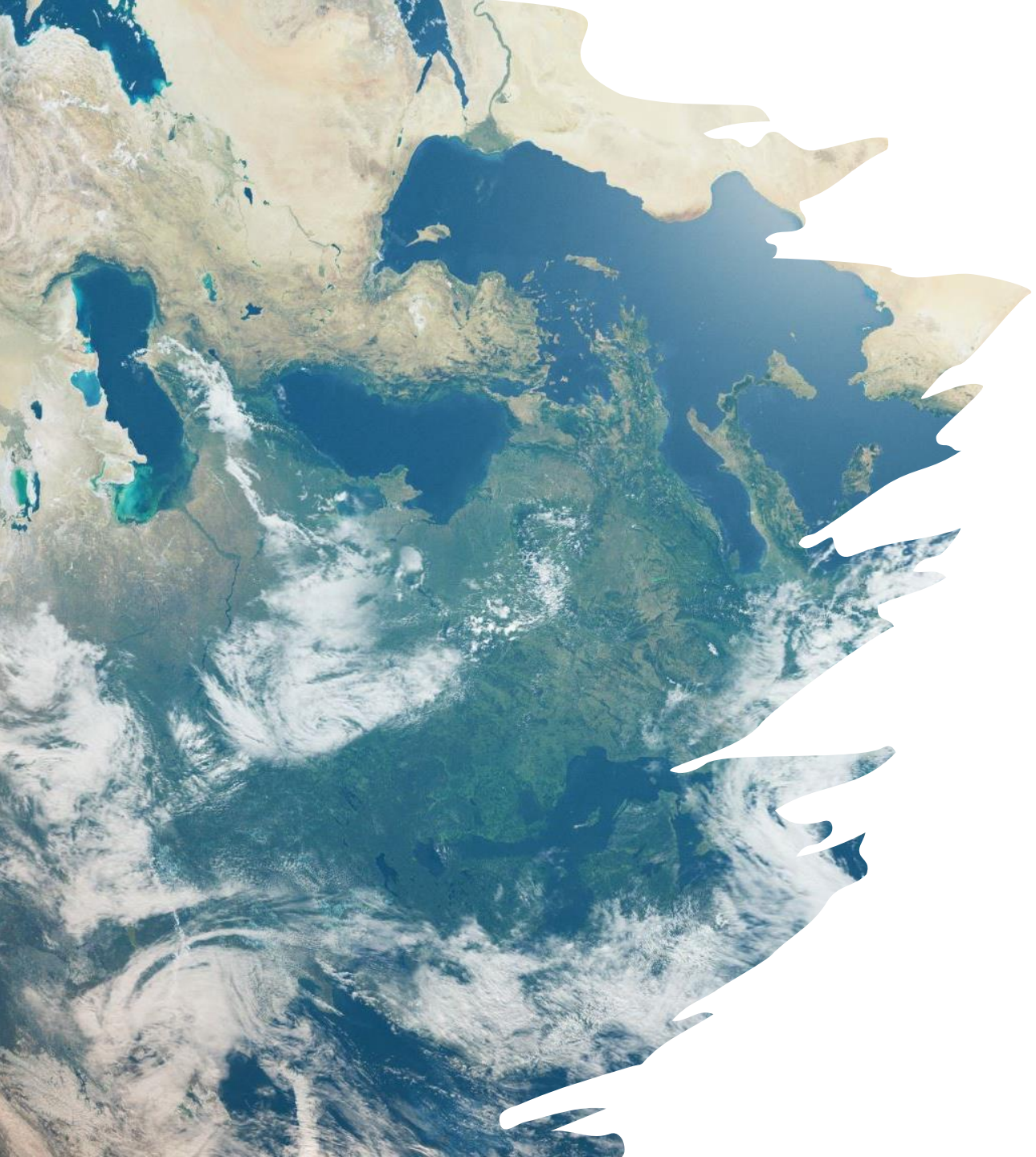
But note, even more limited data points for these variables!

Across all seasonality zones, we could only collect quantitative data about burned area from > 5 studies for **six of our 29 fire-use purposes**, and quantitative data about fire return interval from > 5 studies for **11 of our 29 fire-use purposes**. Of those values available, many are approximate, not based on field measurements.

Area burned (left) and **fire return interval** (right) relationships with fire use purpose. Boxplots only given for those fire purpose categories with six or more data points.







- There are relationships between **fire-use purpose** and fire return interval, burned area and seasonality.

  Understanding anthropogenic fire quantitatively will help interpret improved detection of small fires in global burned area products.

- For fire-enabled DGVMs, many models use metrics such as population density and GDP to include human influence on fire without regard to different fire use purposes and in a temporally uniform manner.

  Our results highlight variations in fire activity throughout the year **dependent on seasonal activities and climate.**

  The broad patterns in seasonality of anthropogenic fire that we identify could already be useful to improve the current representation of human activity in models via some general rules.

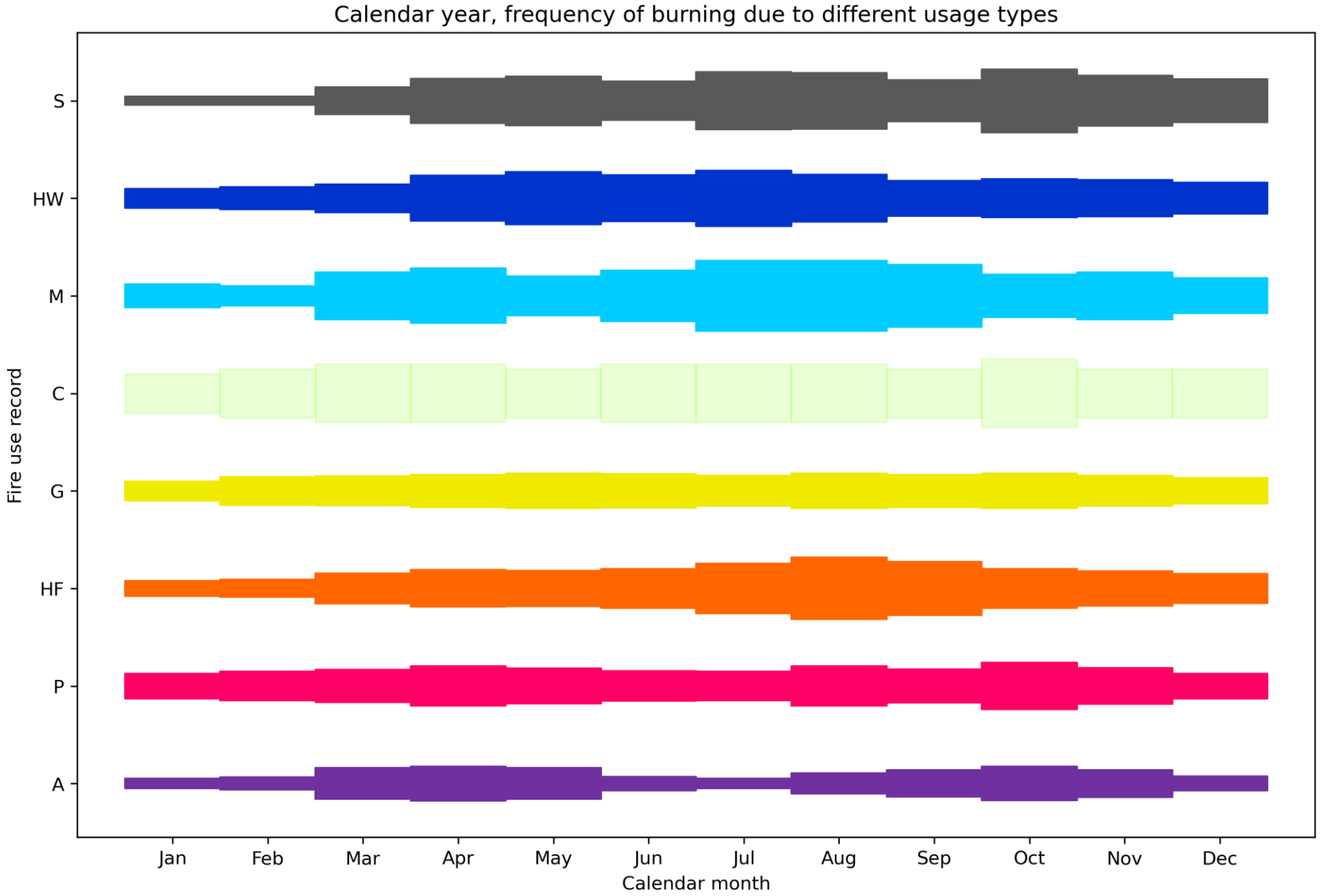
- **However**, except for agricultural and some pastoral fires, our study highlights the **limited quality and quantity of quantitative data available from case studies** regarding small-scale livelihood and/or cultural fire use. Systematic and comprehensive quantitative data on anthropogenic fires is lacking globally.

Extra slides:

Fire use purpose: Higher-tier	Fire use purpose: Lower-tier	Reason	Description	N
Agriculture (A)	A1. Clear vegetation for swidden or semi-permanent agriculture	Primary purpose	Fire clears vegetation between cycles of alternating cropping and fallow, supplying nutrients to the soil. Chopped and dried vegetation is burned in piles or fire is broadcast across the plot. In areas with low soil fertility, additional vegetation may be taken from surrounding areas, to increase organic matter supplied to the soil.	325
	A2. Clear vegetation for permanent agriculture	Primary purpose	Fire clears vegetation to establish permanent plots of perennial or annual crops, possibly after one or more cycles of swidden. Similar process to swidden clearance.	46
	A3. Clear weeds and/or crop residues during the growing season	Primary purpose	Includes various practices, e.g., burning weeds in piles during the growing season or burning sugarcane plants before harvest to facilitate faster harvesting.	22
	A4. Clear weeds and/or crop residues after harvest to enable planting	Primary purpose	In permanent or semi-permanent agriculture where annual crops are grown repeatedly on the same plot, burning after harvest clears crop residues and/or weeds to rapidly prepare for the next crop. Fire may be broadcast across the whole plot, or material is burned in piles.	133
	A5. Reduce crop pests	Primary purpose or co-benefit	Fires set for other agricultural purposes can also reduce crop pests but is sometimes used specifically for this purpose during the growing season, e.g., through removing vegetative cover used by pests.	34
Pastoralism (P)	P1. Clear vegetation to establish new pasture areas	Primary purpose	Like clearance for swidden or permanent cropping, with vegetation cut and dried before burning. May take place in areas that have previously been cropped.	18
	P2. Enhance forage for grazing livestock	Primary purpose	Burning maintains forage, in the longer term by suppressing woody growth, in the shorter term by encouraging fresh growth of grasses, forbs, and/or leafy vegetation. In extensive pastoral systems, fires extinguish where they meet previously burned areas, or natural firebreaks. In more intensive systems, artificial firebreaks may be constructed to limit fire extent.	219
	P3. Herd livestock	Primary purpose or co-benefit	Sometimes a co-benefit of burning to enhance forage, as this encourages movement of livestock. Sometimes fire/smoke are directly used to drive livestock.	17
	P4. Reduce livestock pests and predators	Often a co-benefit	Common co-benefit of fires set to enhance forage. Pests are directly burned, or their vegetative cover reduced.	50
Hunting and fishing (HF)	HF1. Create or improve habitat for hunted or fished species	Primary purpose or co-benefit	On inter-annual timescales, fire maintains habitat for hunted or fished species.	24
	HF2. Renew forage to draw hunted or fished species into a particular area	Primary purpose or co-benefit	Fire renews forage for animals, drawing them into certain areas where they can be located for hunting/ fishing on weekly to monthly timescales.	67
	HF3. Improve visibility or access specifically for hunting or fishing	Primary purpose or co-benefit	Burning clears vegetative cover rendering hunted/ fished species, or their tracks, more visible, or improves access to hunting/ fishing grounds.	69
	HF4. Drive animals when hunting	Primary purpose	Fire or smoke force animals in certain directions for hunting. Commonly practiced during communal hunts.	65
	HF5. Kill, injure, or tire animals when hunting	Primary purpose	Fire or smoke are used as a weapon during hunting.	12
Gathering (G)	G1. Enhance productivity of foraged resources	Primary purpose or co-benefit	Burning enhances the quality and productivity of foraged resources in various ways. Sometimes, fire stimulates certain phenological stages, e.g., germination, flowering, fruiting. Where plants resprout after fire this can bring more vigorous growth, or desired growth forms. Burning can also reduce competing vegetation or pests.	134
	G2. Ease the collection of a foraged resource by improving visibility or access	Primary purpose or co-benefit	Burning clears vegetation making it easier to access/ see a foraged resource.	42
	G3. Drive wild bees away from hives for honey collection	Primary purpose	Smoke drives bees away from their hives.	49
Charcoal and fuelwood production (C)	C1. Produce charcoal	Primary purpose	To produce charcoal, felled trees are buried in mounds or pits and smouldered for several days.	17
	C2. Produce fuelwood for gathering, or enable gathering of fuelwood	Primary purpose or co-benefit	Burning can produce fuelwood by provoking tree mortality or hastening drying of deadwood.	20
Movement (M)	M1. Maintain and open trails and waterways for general access	Primary purpose or co-benefit	Fire improves access by clearing trails or waterways or reducing dense vegetation across wider landscape patches (in this case improved access is likely a co-benefit of burning for other reasons).	51
Human health & wellbeing (HW)	HW1. Reduce animals that are dangerous to or unwanted by humans	Often a co-benefit	Burning reduces habitat/ vegetative cover for unwanted animals (e.g., snakes, ticks) or kills them directly.	64
	HW2. Reduce fuel loads to reduce risk of wildfires at a landscape scale	Primary purpose, or co-benefit	Progressive burning of landscape patches fragments the fuel landscape, reducing wildfire risk.	88
	HW3. Create firebreak using fire to protect e.g., resources, farms, sacred sites	Primary purpose, or co-benefit	Targeted, delimited, burning protects specific entities (settlements, farms, sacred sites, resources) from wildfire.	47
	HW4. Suppress a wildfire (using backing fire to fight fire with fire)	Primary purpose	Controlled backing fire (set against the wind or upslope) meets a wildfire front, and the fires extinguish one another.	6
	HW5. Produce a more aesthetically pleasing landscape, or for enjoyment	Often a co-benefit	In many cultures the 'cleaner' post-fire landscape is considered more beautiful and burning may be seen as an enjoyable activity.	24
Social signals (S)	S1. Communicate about current activity	Primary purpose	Fire/smoke signal to comrades about current activity, e.g., success of hunt, or broken-down vehicle.	17
	S2. Show disapproval or protest (arson)	Primary purpose	Burning in resistance to or dispute with the state, landowners, or other community members, e.g., over land access or protected areas regulations.	53
	S3. For ritual or ceremonies	Primary purpose	Burning in rituals or ceremonies occurring in the landscape outside settlements.	16
	S4. Assert or maintain cultural identity	Often a co-benefit	Burning may persist or be revived as a way of expressing cultural identity. Not usually the sole reason for burning – fire usually retains role in subsistence/ wildfire mitigation.	113

Raw data (all cases studies) broken down by higher-tier fire use purpose. Thickness of the bars denotes the proportion of cases where burning occurs in each month, for that usage purpose.

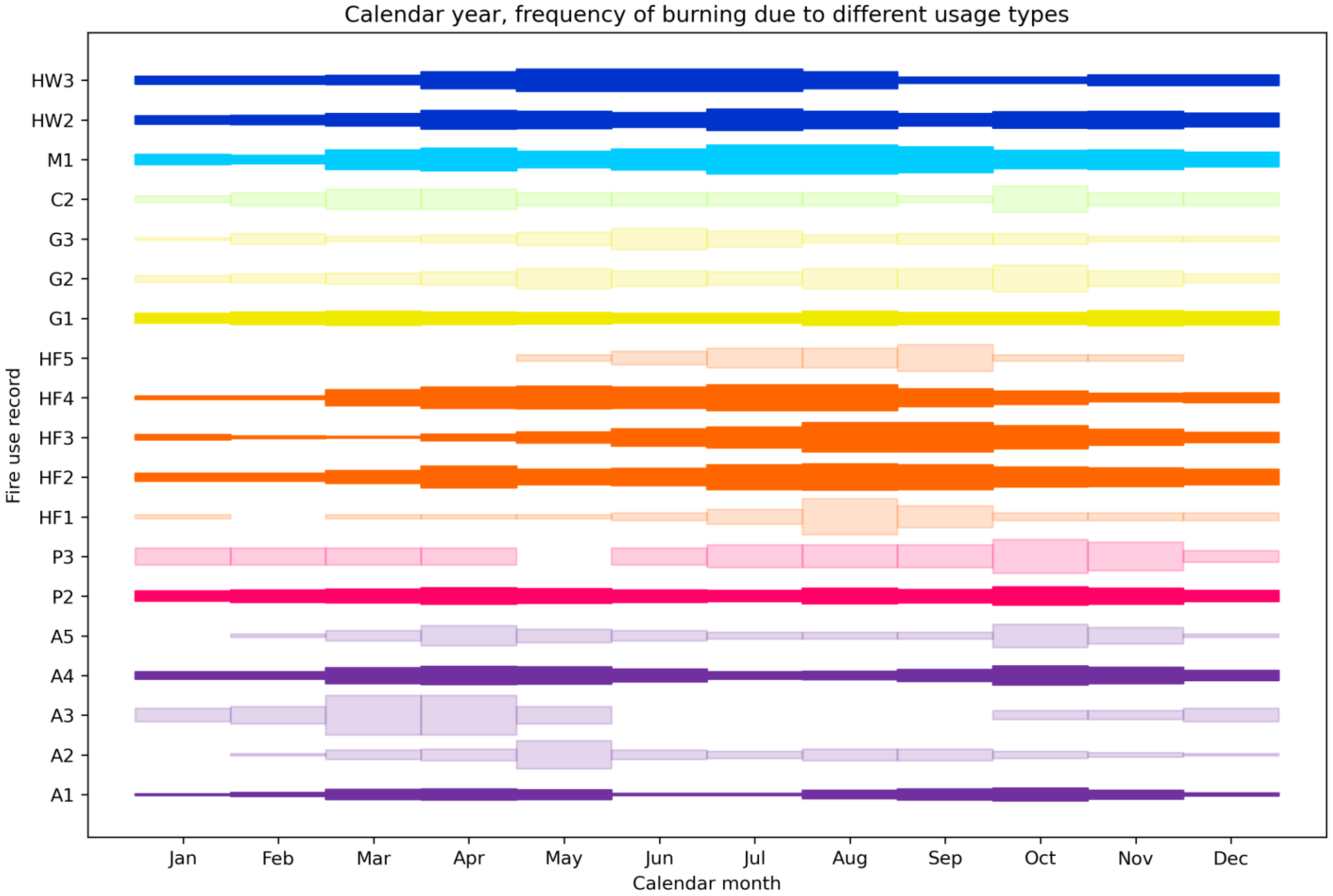
Light shading = 6-19 database entries, dark shading = 20+ entries. Categories with < 6 cases are not shown. If a particular database entry has more than one FUPU1 category then it is counted in both categories.



Raw data (all cases studies) broken down by second-tier fire use purpose. Thickness of the bars denotes the proportion of cases where burning occurs in each month, for that usage purpose.

Light shading = 6-19 database entries, dark shading = 20+ entries. Categories with < 6 cases are not shown. If a particular database entry has more than one FUPU2 category then it is counted in both categories.

[P4, HW1, HW5, S4 omitted]

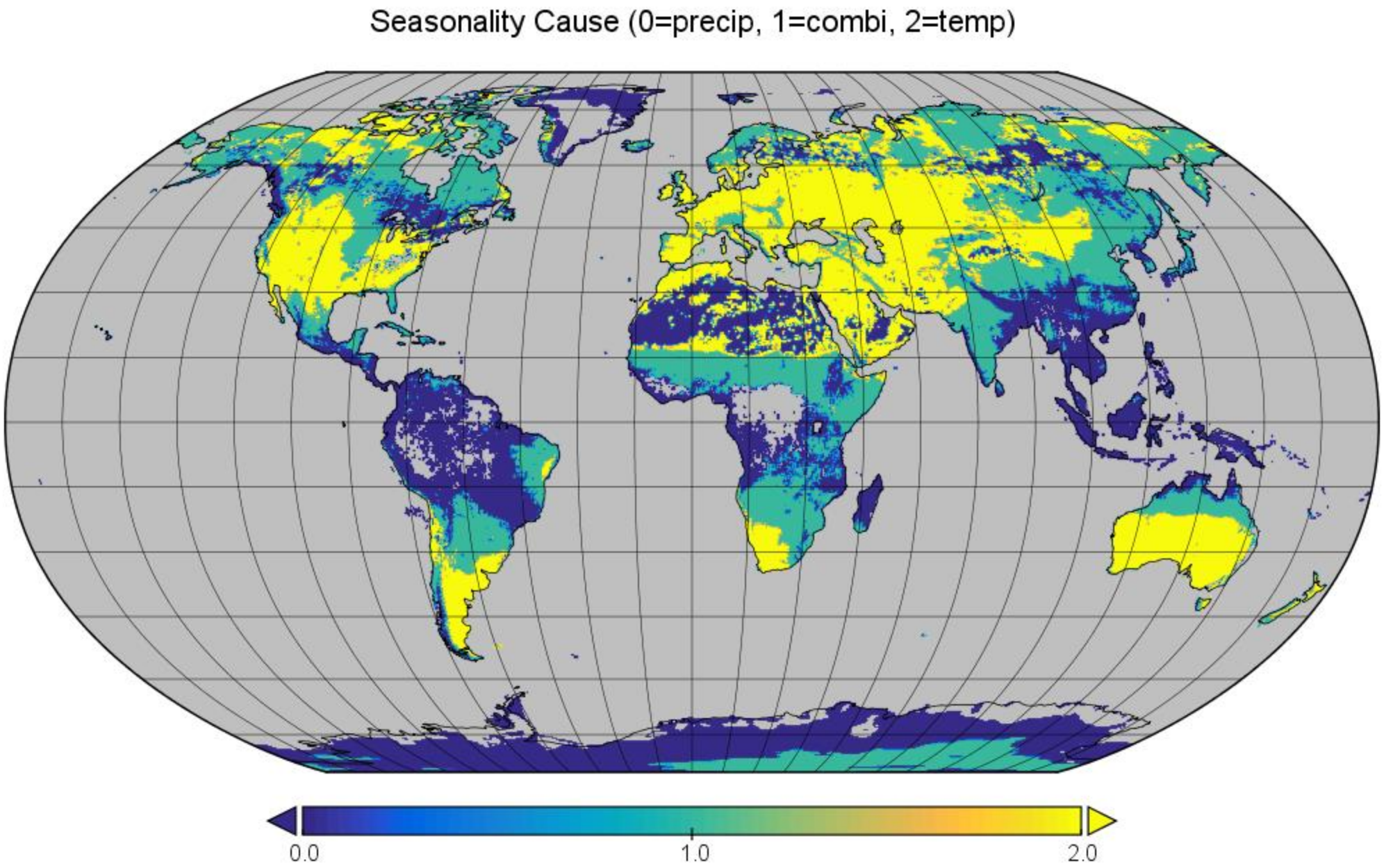


As the basis for the seasonality climate zones analysis, we calculating the Feddema (2005) **seasonality cause** metric for a **31-year (1990-2020) monthly climatology of ERA5** reanalysis data. This metric indicates which factor is the main driver of **seasonal variability** – precipitation, temperature, or a combination of both.

When the seasonal range of PE is much bigger than the range of P, the seasonal cycle is temperature-driven

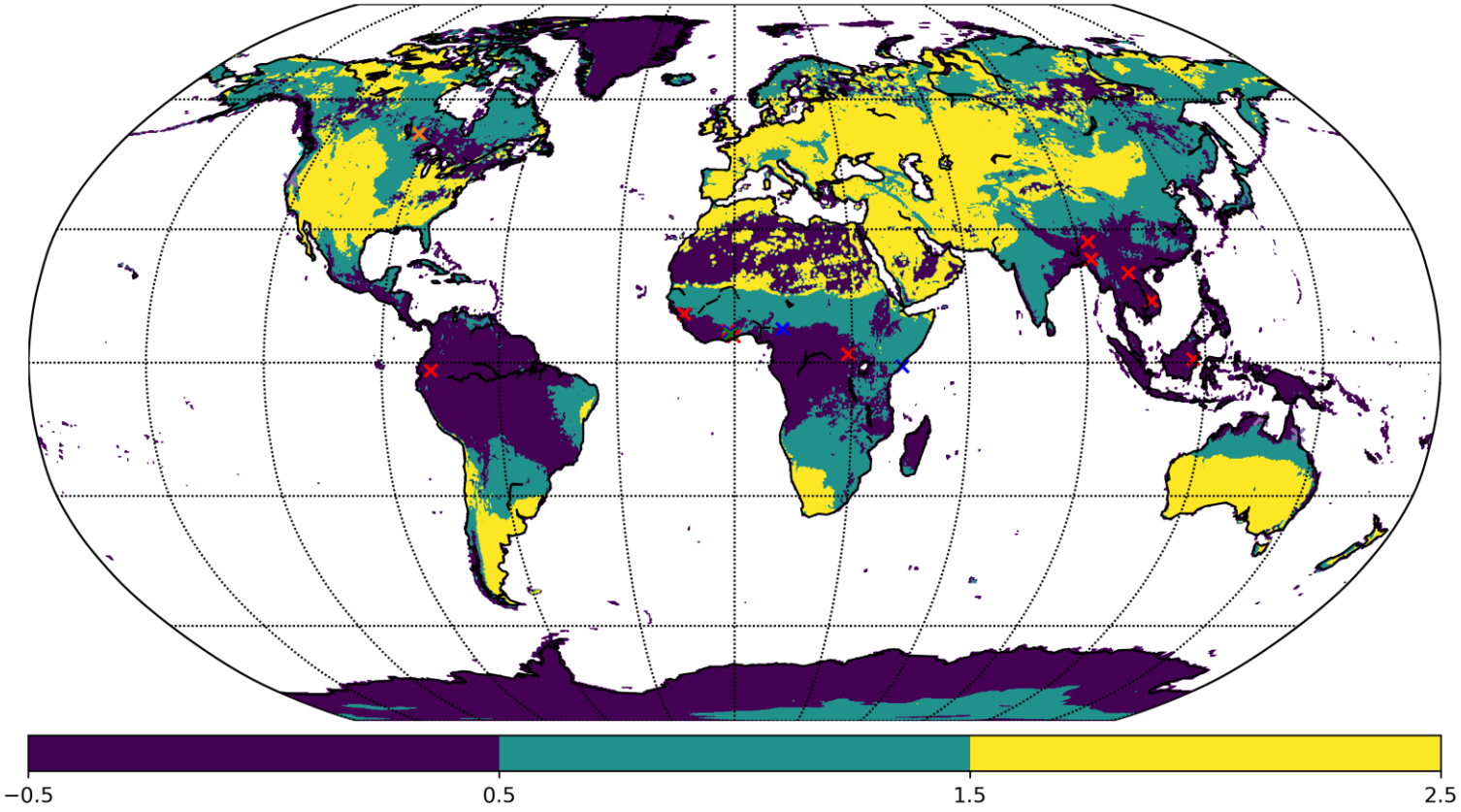
Vice versa, when the seasonal range of P is much bigger than the range of PE, the seasonality is precipitation-driven

When both PE and P have a similar seasonal range, then the seasonal cycle is driven by a combination of both temperature and precipitation variation over the year.



N.B. There are ~ 40 fire use practices in locations where ERA5 PE ≈ 0, corresponding to 19 different locations (since some records are different fire uses from same case study).

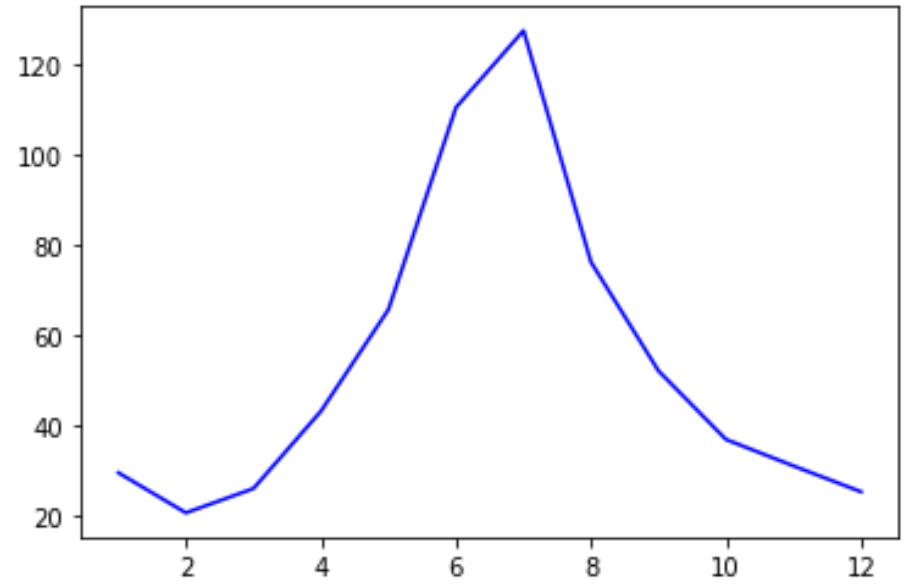
For these locations the seasonality was re-classified by eye following inspection of the precipitation and surface air temperature seasonal cycles (because ERA5 potential evapotranspiration is suspect in these locations).



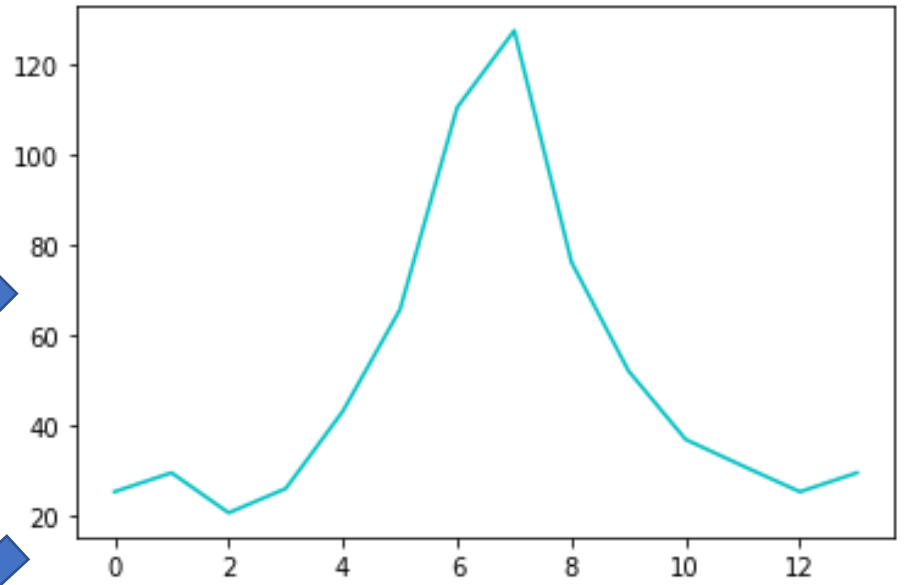
Fire use purpose	*All case studies*	*Precipitation-driven seasonality*	*Temperature-driven seasonality*	*Combination seasonality*
Agriculture (A)	262	200	8	54
Pastoralism (P)	94	63	6	25
Hunting and fishing (HF)	90	65	5	20
Gathering (G)	87	61	3	23
Charcoal & fuelwood production (C)	10	8	0	2
Movement (M)	25	18	4	3
Human health & wellbeing (HW)	96	64	8	24
Social signals (S)	68	48	5	15
TOTAL	732	527	39	166

[Note that where multiple purposes were given for the same fire use practice, it is counted in both categories, which is why the total adds up to more than the number of fire use practices with seasonality data in LIFE (= 617)]

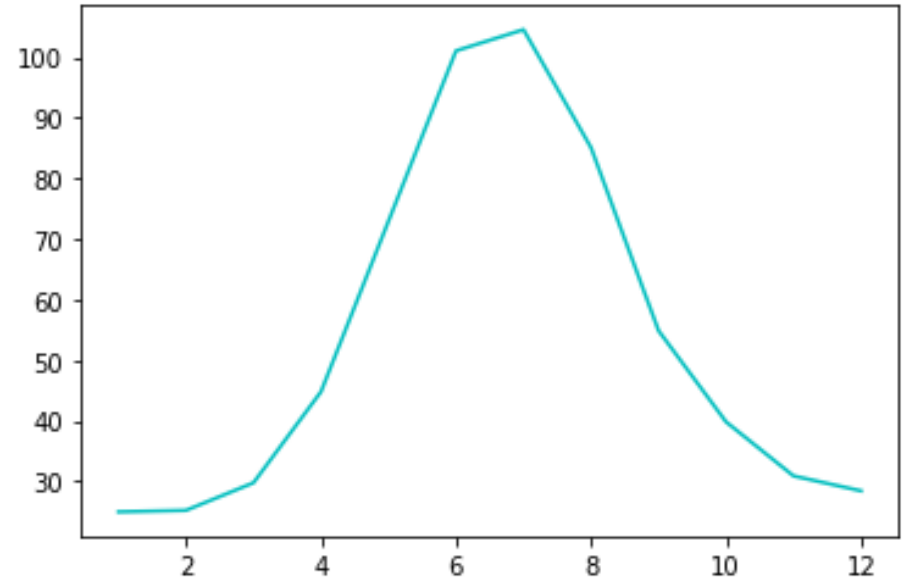
Climatological seasonal cycle at a gridpoint with precip-dominated seasonality



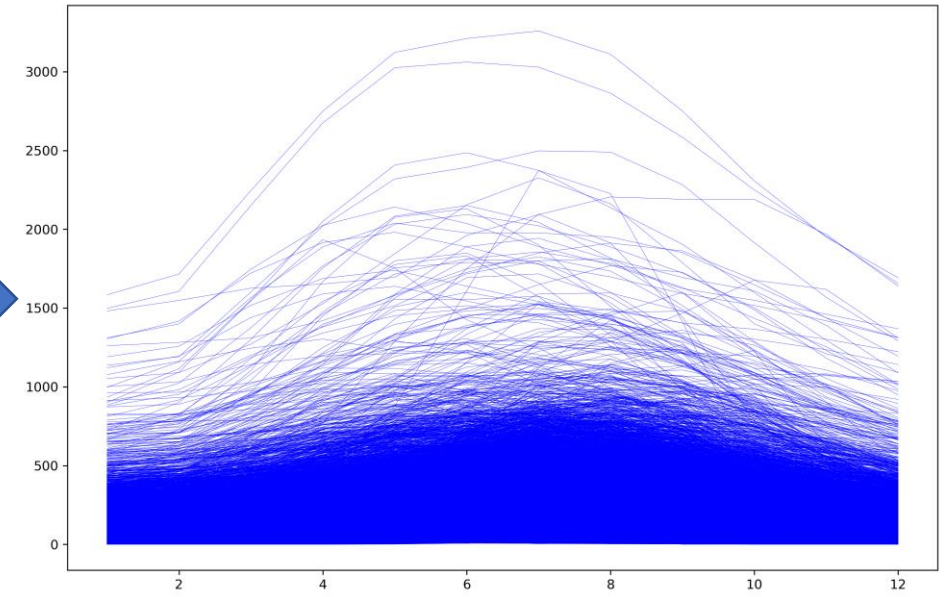
Wrap around first and last months



Smooth with a 3-month centred running mean



Shift seasonal cycle at every gridpoint so that it starts with the driest month



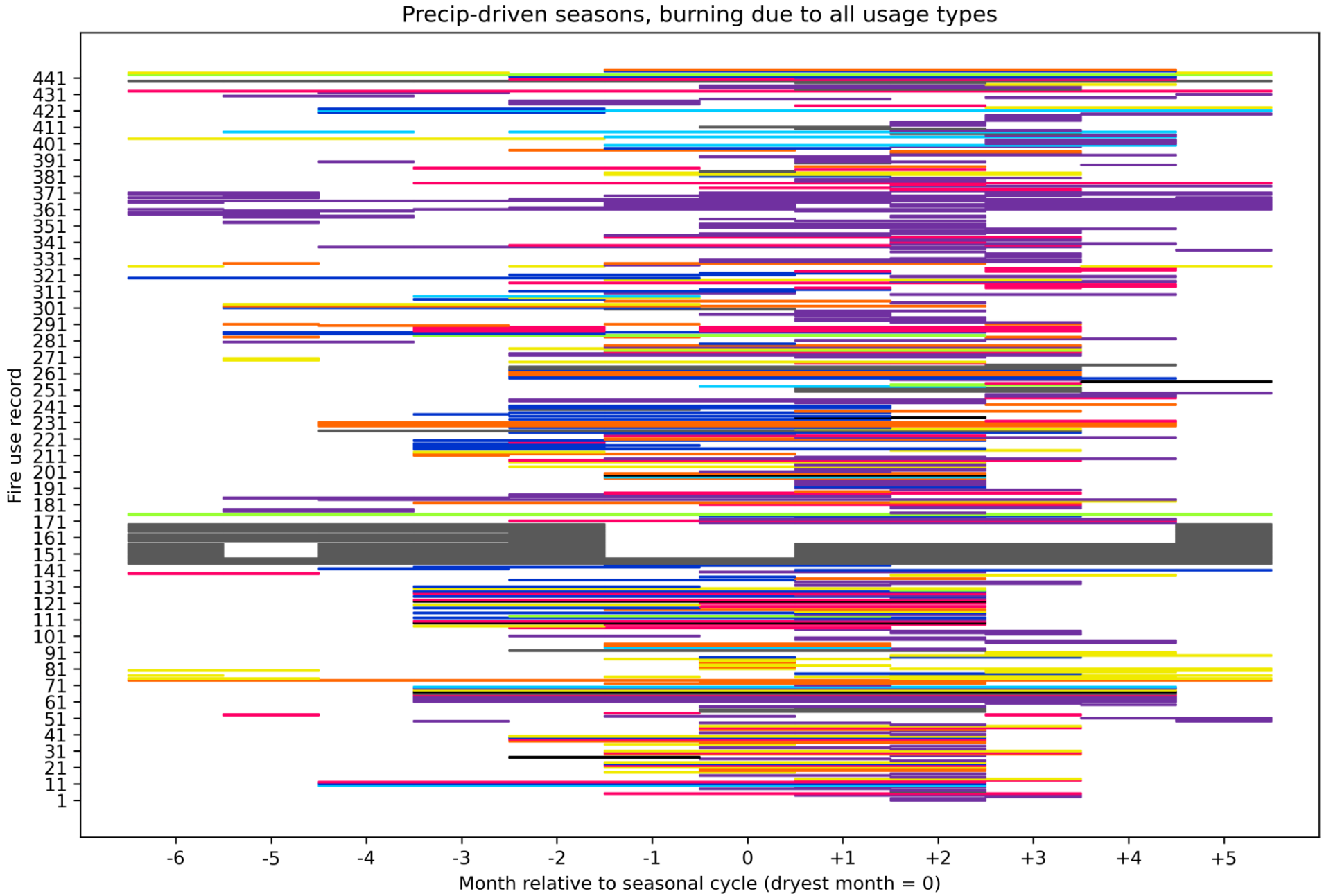
We want to define a 'start month' for the seasonal cycle at each gridbox (0.25° × 0.25°) in the ERA5 climatology. These diagrams show the process for a precipitation-driven gridbox (seasonality cause = 0), which generally applies in locations with a distinct dry season and wet season:

We take the monthly precipitation timeseries, smooth it by applying a 3-month running mean, and then define the **season start as being the month with the lowest precipitation**

We then **shift the monthly timeseries at every precipitation-driven gridpoint so that it always starts with the driest month**

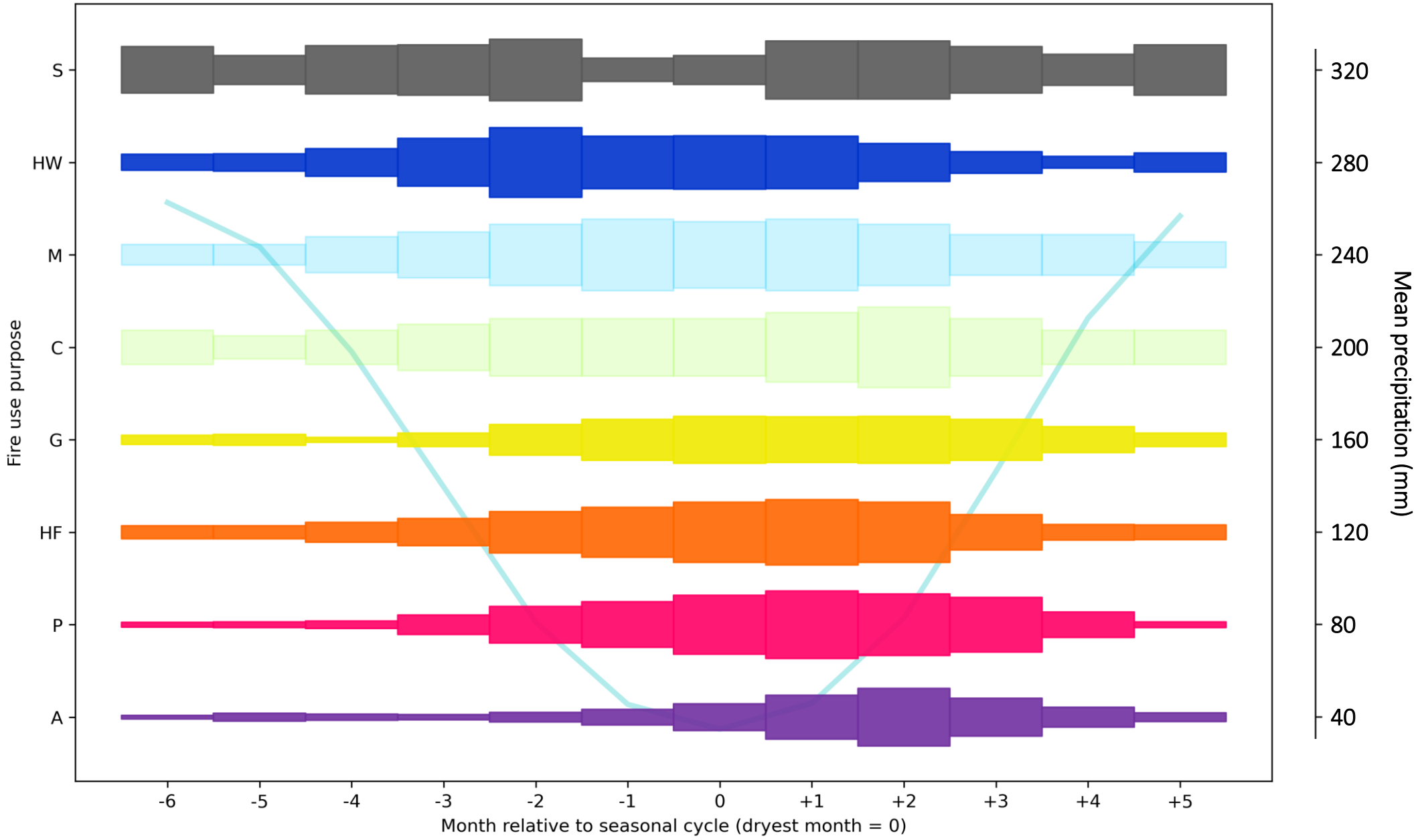
The bottom right plot shows the shifted precip timeseries for every applicable land point in the world, showing that it works pretty well and all the points have a very similar seasonal cycle pattern once shifted to be in phase with each other

Months that burning takes place in, but this time only for 446 fire use practices in locations with **precipitation-driven seasonality**, and with the months shifted so that the timing of burning is always shown relative to the **driest month**.



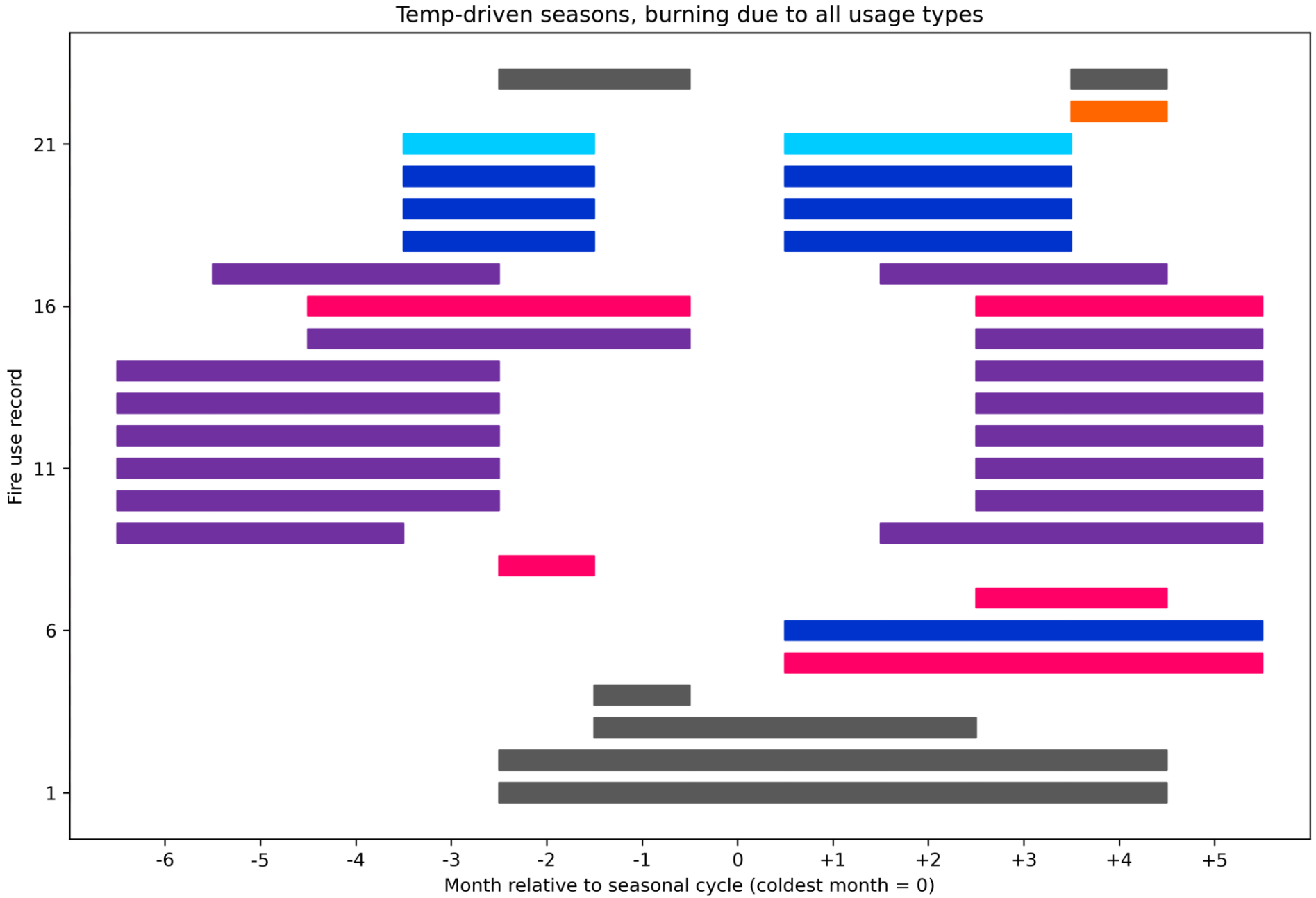
Seasonal distribution of different higher-tier fire use purposes for locations with a precipitation-driven seasonal cycle.

Light shading = 6-19 database entries, dark shading = 20+ entries. Categories with < 6 cases are not shown. If a particular database entry has more than one fire use category then it is counted in both categories.



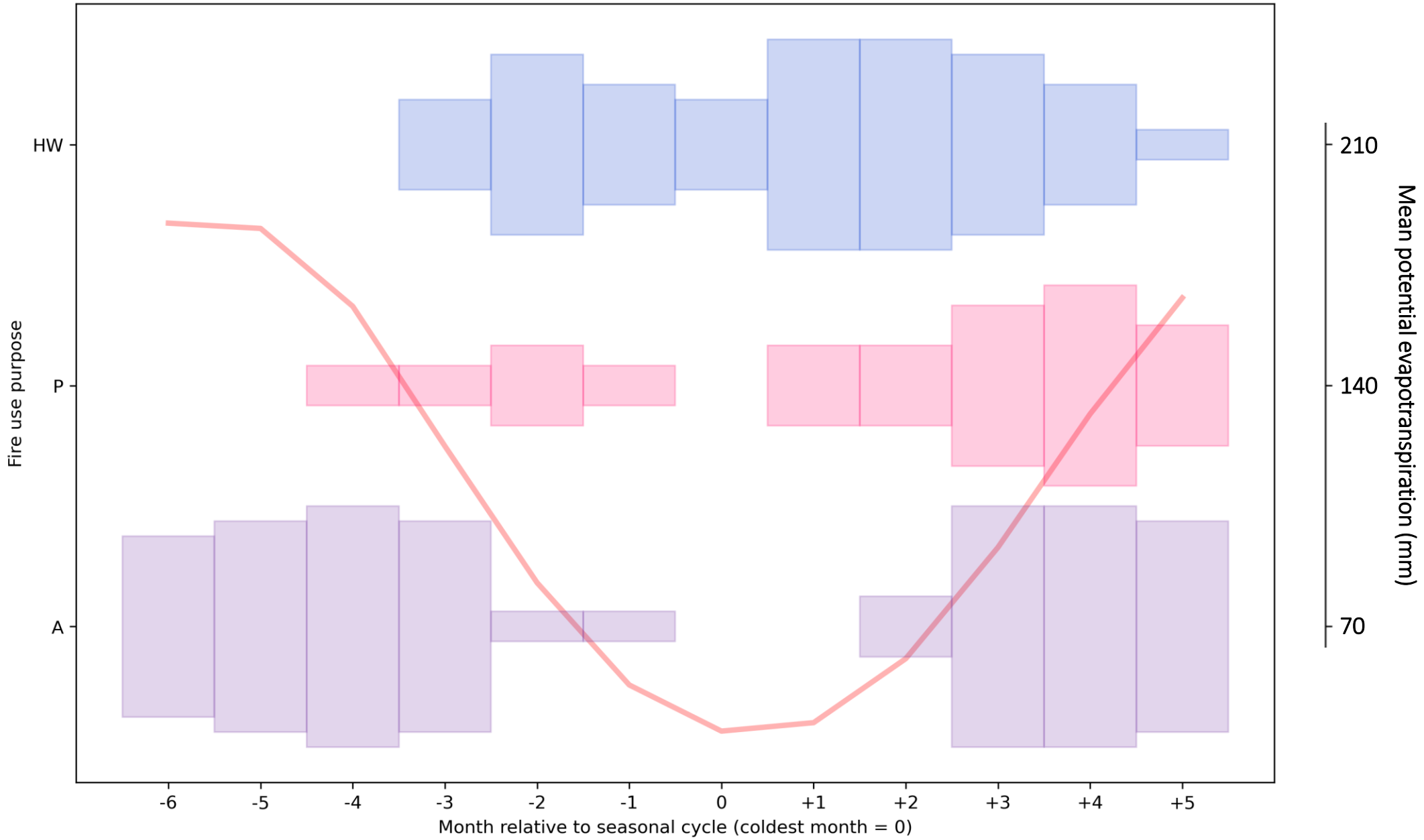
All fire use practices in temp-driven seasonality zones, with the months shifted so the coldest (lowest PE) month is always in the middle.

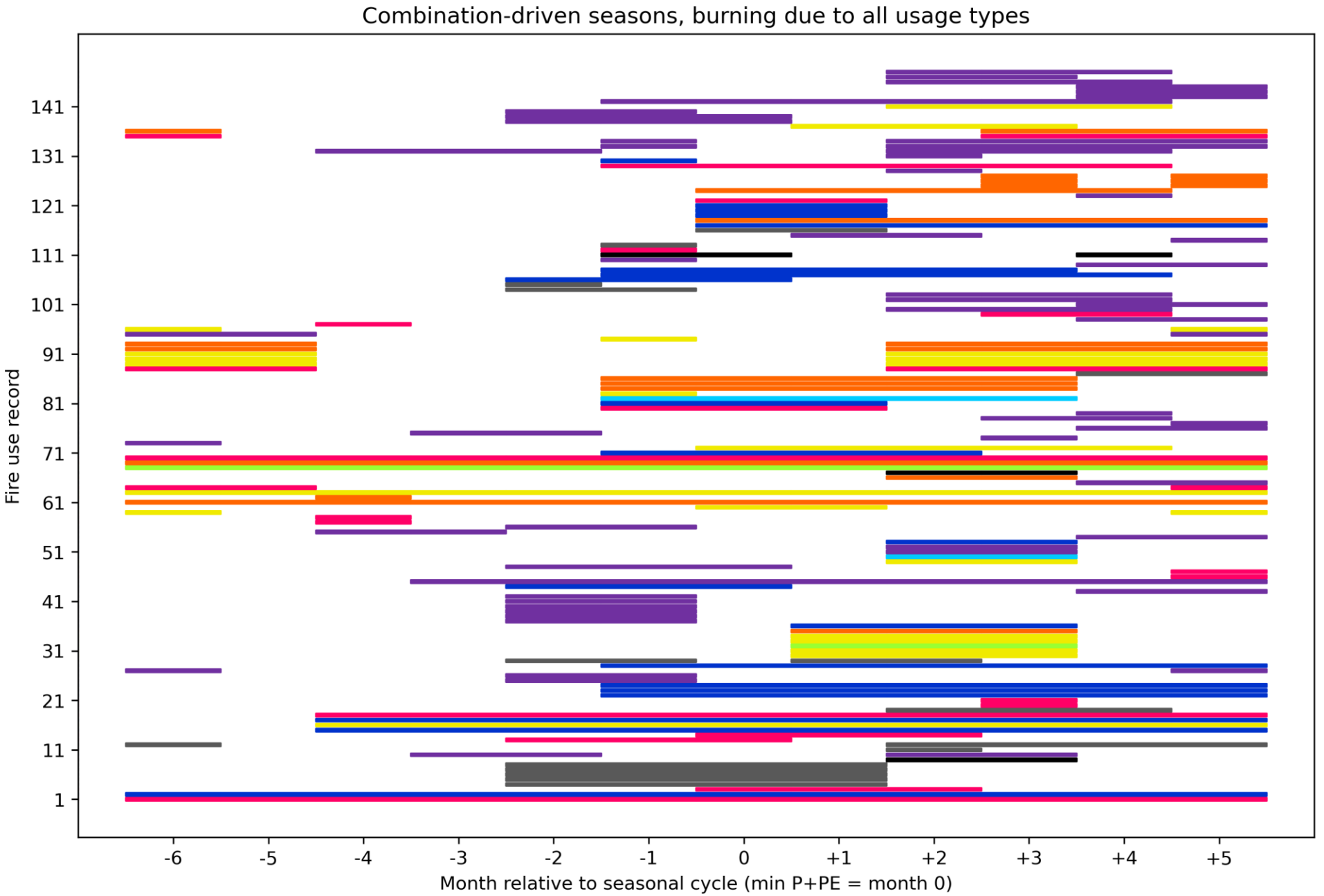
23 records total.



Seasonal distribution of different high-level fire use purposes for locations with a temperature-driven seasonal cycle.

Light shading = 6-19 database entries, dark shading = 20+ entries (N/A here). Categories with < 6 cases are not shown. If a particular database entry has more than one fire use category then it is counted in both categories.





Finally, all fire use practices in combination seasonality zones, shifted so the the lowest (P+PE) month is in the middle.

148 records total.

Seasonal distribution of different high-level fire use purposes for locations with a combination-driven seasonal cycle.

Light shading = 6-19 database entries, dark shading = 20+ entries. Categories with < 6 cases are not shown. If a particular database entry has more than one fire use category then it is counted in both categories.