Please find our responses given in bold blue text below after each individual comment or section provided by the reviewer.

Dear authors,

This paper is an important contribution to understanding the biogeochemical impacts of fire on phosphorus fate and mobility. The study employs a robust methodological approach, including NMR and XANES analyses, to investigate how burn severity and vegetation type influence phosphorus composition and mobilization. The findings are relevant for understanding post-fire nutrient cycling and have implications for both terrestrial and aquatic ecosystems.

Response: Thank you for your favorable review of our manuscript.

Major Comments:

1. Providing information on the geological and soil characteristics of the study site, including soil type and pH, would help contextualize phosphorus dynamics. Additionally, details on climate conditions such as rainfall, temperature, and seasonality would improve the interpretation of post-fire phosphorus mobilization and retention. If the bedrock is limestone, it could increase soil calcium concentrations and pH, reducing bioavailable phosphorus and promoting the formation of Ca-bound phosphorus (Ca-P). This may influence the phosphorus speciation in the original soil, affecting the composition of the phosphorus pool from which the organic samples were taken. If available, correlating soil properties with phosphorus fractions could further strengthen the study.

   Response: This study was designed to examine changes across land cover archetypes across the Pacific Northwest, not a specific site study. This is notably a laboratory experiment and simulates P mobilization by leaching chars with artificial rainwater and does not include study of soils or in-situ leachates from litter/overland flow. We will clarify these points throughout the introduction and method section to increase clarity on our study design and limitations.

2. **Soil Phosphorus Pools and Pre-Fire Conditions:**

   It would be valuable to include data on the total phosphorus concentration in the soils from which the organic matter was sourced. Since the initial phosphorus pools in the soil can influence post-fire phosphorus mobilization and retention, this information could provide important context for interpreting the results. If this data is available, correlating soil phosphorus status with the observed trends would further strengthen the study.

Response: The organic matter burned here was plant material (i.e. litter), not soils. The initial pools of P in the study can be considered that of the unburned plant materials presented throughout the manuscript. We will clarify our description of the study design in response to this and the previous comment.

3. **Use of the Term “Total P Concentration”** (Line 99 and elsewhere):

   The term "total P concentration" is unclear. It would be helpful to clarify whether this refers to the sum of all phosphorus fractions or a specific measurement of P concentration. Consistently defining this term throughout the text would improve clarity.

   Response: Total P is derived from ICP-OES measurements. We will clearly state this in the methods and upon first usage.

Specific Comments:

- **Line 65:** Expand on the impacts of climate change on fire regimes. The statement that fires are expected to increase in intensity and severity could be strengthened by elaborating on the mechanisms driving this trend, as climate change is expected to exacerbate fire risk.

  Response: We agree with the reviewer there are several factors exacerbated by a changing climate that are influencing fire regimes in our study region. We will increase discussion of this in the introduction, and cite relevant literature such as Roebuck et al., 2025; Francis et al., 2023, Halofsky et al., 2020 and Reilly et al., 2017.

  References:

  Roebuck Jr, J. Alan, et al. "Molecular shifts in dissolved organic matter along a burn severity continuum for common land cover types in the Pacific Northwest, USA." ***Science of the Total Environment*** **958 (2025): 178040.**

  Francis, Emily J., et al. "Proportion of forest area burned at high-severity increases with increasing forest cover and connectivity in western US watersheds." ***Landscape Ecology*** **38.10 (2023): 2501-2518.**

  Halofsky, Jessica E., David L. Peterson, and Brian J. Harvey. "Changing wildfire, changing forests: the effects of climate change on fire regimes

and vegetation in the Pacific Northwest, USA." *Fire Ecology* 16.1 (2020): 1-26.

Reilly, Matthew J., et al. "Contemporary patterns of fire extent and severity in forests of the Pacific Northwest, USA (1985–2010)." *Ecosphere* 8.3 (2017): e01695.

- **Line 285 (Figure 1):** The distinction between moderate and high temperatures for Douglas fir is unclear. The figure appears to show overlapping temperature ranges - maybe you can think of a different phrasing? Additionally, the lines on the figure should be explained—do they represent the 25th and 75th percentiles? Are they median or mean values?

  Response: Thank you for bringing this point of confusion to our attention. Burn severity was assessed via visual metrics, which includes ash color, degree of charring, and degree of consumption (Parsons et al., 2010). Therefore, burn severity is not just dependent on temperature, but is also impacted by duration of heating and additional fuel loading metrics. We had originally included temperature in our figure axes to increase comparability with temperature-based studies of P chemical changes common in the literature. We will move Table S4 to the main text to better set up our burn severity definition and details of the burn table experiments studied herein. We will also point to the SI figure on burn severity (Figure S1) in the main text.

  Regarding Figure 1, this is a boxplot. We will annotate in the figure legend this detail to reduce possible confusion on interpretation, remove the temperature ranges on the axis, and remove colors from the boxplots for simplicity. We will refer to the table brought into the main text from the SI for sample numbers of each observation and the temperature ranges for each severity.

  References:

  Parson, Annette, et al. "Field guide for mapping post-fire soil burn severity." *Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p.* 243 (2010).

- **Line 334 (Figure 2):** The color scheme should be adjusted to better differentiate between organic P and inorganic P. Additionally, the use of "moderate" and "high" temperatures for Douglas-fir is unclear, as it appears inconsistent with figure 1.

Response: We will add in hashing onto the colors for organic P in both this figure and figure 3 to increase clarity and remove the temperatures from figure legend.

- **Line 453 (Figure 3):** Similar to Figure 1, further clarification is needed. What do the dots above the boxes represent? How many samples were measured? The figure suggests that Douglas-fir moderate fire has significantly higher leachable P than low-temperature burns, and that high-temperature burns are significantly higher than moderate burns. For sagebrush, in the lower right panel, the "a" and "a" labels above the boxes indicate significant differences, yet the values appear different. Please review and clarify.

  Response: We believe this comment is in reference to figure 4, not figure 3. Similar to figure 1, we will clearly state in the figure legend that this is a boxplot. We will also remove the temperature ranges on the axis and remove colors from the boxplots for simplicity. We will also clarify the lettering for significant differences in the figure caption (briefly, those with the same lettering above them are not significantly different). We will refer to the table brought into the main text from the SI for sample numbers of each observation and the temperature ranges for each severity.

- **Line 455:** The impact of pH on phosphorus solubility is mentioned, but actual pH values are not provided. I suggest including these values in the results.

  Response: In response to this comment and a similar comment from R1, we will move Figure S7 from the SI into the main text, which shows our pH data.

Line 470: The proportion of Na-P is relatively high in Douglas-fir. A brief discussion of the potential role of Na-P in post-fire phosphorus dynamics would be useful.

Response: Our current understanding of P biogeochemistry is largely around Ca-, Al-, and Fe-P given the popularity of sequential chemical fractionation schemes, which infer speciation of these compounds based on solubility (Kruse et al 2015). XANES is increasingly being used to identify P speciation within environmental samples, but many studies still focus on Ca-, Al- and Fe-P compound identification. However, other studies characterizing chars have identified Na-P (i.e., Rose et al 2019) and Li and Brett (2013) have identified sodium tripolyphosphate as having high nutrient uptake and bioavailability during bioassay experiments. We will add these emerging viewpoints into our discussion section.

References:

Kruse, Jens, et al. "Innovative methods in soil phosphorus research: A review." ***Journal of plant nutrition and soil science*** **178.1 (2015): 43-88.**

Rose, Terry J., et al. "Phosphorus speciation and bioavailability in diverse biochars." ***Plant and Soil*** **443 (2019): 233-244.**

Li, Bo, and Michael T. Brett. "The influence of dissolved phosphorus molecular form on recalcitrance and bioavailability." ***Environmental Pollution*** **182 (2013): 37-44.**