Is Douglas-fir carbon uptake influenced more by increased temperature and vapor pressure deficit or reduced rainfall?

Carbon uptake by Douglas-fir is more sensitive to increased temperature and vapor pressure deficit than reduced rainfall in the western Cascade Mountains, Oregon, USA

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Do different kinds of drought have different impacts on western forests?

How do different aspects of drought affect Douglas-fir trees in the Oregon Cascade Range? The authors examined how transpiration, gross primary productivity, and soil water availability were affected by a) atmospheric drought, increased summer temperature and vapor pressure deficit (VPD) with unchanged rainfall, and b) soil drought, decreased spring and summer rainfall with unchanged temperature and VPD. The authors also investigated the interactive effects of increased VPD and decreased rainfall on primary productivity and transpiration.

What are the impacts of increased temperature and VPD?

- Forest productivity will likely be more strongly affected by increased temperature and VPD than by decreased rainfall. Soil saturation was 100% at the end of winter for all rainfall scenarios. The impact of decreased rainfall on cumulative transpiration and soil water content in the top 1 meter were mitigated by deep (>1 m) water availability in late summer.
- Shallow soil water content may be negatively impacted by elevated VPD. Increased VPD may cause greater dependence on soil water, resulting in decreased soil saturation and increased water stress for trees even when soil moisture alone would not have been limiting.

What are the impacts of decreased spring and summer rainfall?

- Soil water content was influenced to a greater degree by decreased rainfall in early summer than by increased VPD in late summer. Additionally, predicted changes in soil water content were smaller for deeper layers.
- Soil water saturation was affected by transpiration rates and rainfall. Reduced rainfall caused lower leaf and soil water potentials, which resulted in decreased productivity and transpiration.
- Transpiration was affected to a greater extent by reduced rainfall than by increased VPD. The negative impact of reduced rainfall was greater magnitude than the positive impact of increased VPD.

What might this mean for forest management?

- Primary productivity was more sensitive to changes in VPD while cumulative transpiration was more sensitive to changes in rainfall. There were interactive effects of VPD and rainfall on both productivity and transpiration, but these impacts were small relative to the single variable impacts.

- The amount of soil water available throughout the dry season will depend, in part, on the composition of the underlying soil and the depth of the rooting zone above the bedrock.

How do these findings help us predict impacts of climate change on Douglas-fir forests?

- Based on predicted climate-driven temperature increases, the model scenarios predict a decrease of primary productivity of 3-11% in forests of the west slope of the Cascade Mountains.
- For the most-likely climate scenario of rainfall reduced by 30%, the model predicts a 2% decrease in primary productivity.

Are there forest management strategies that may work better under warmer and dryer conditions?

- Mixed stands may respond differently to increased VPD and reduced rainfall because rooting depths, shade-tolerance, and hydraulic use strategies vary across species.
- Species with rooting depths >1 m may have higher transpiration and productivity because they can access water stored in deeper soil. Water use strategies, including stomatal regulation in response to temperature also affect transpiration rates.
- In managed, plantation stands, specific tree species may become more desirable because they are better suited to warmer, drier summers.

Research Approach/Methods

- The researchers used a soil-plant-atmosphere model to disentangle the relative effects of atmospheric variables and rainfall on carbon and water fluxes in 50-yr old Douglas-fir trees.
- They parameterized the model with data from long-term samplers in the HJ Andrews Research Forest and, when necessary, elsewhere in Oregon.
- Using changes in soil water availability, gross primary productivity, and transpiration, the researchers evaluated the impact of two scenarios: increased temperature and vapor pressure deficit in summer with stable rainfall and decreased rainfall in spring and summer with no change in temperature and vapor pressure deficit.
- They also evaluated the interactive effects of decreased rainfall and increased vapor pressure deficit on primary production and transpiration.

Keywords gross primary productivity, transpiration, vapor pressure deficit, Douglas-fir, soil-plant-atmosphere model, climate change response

Images

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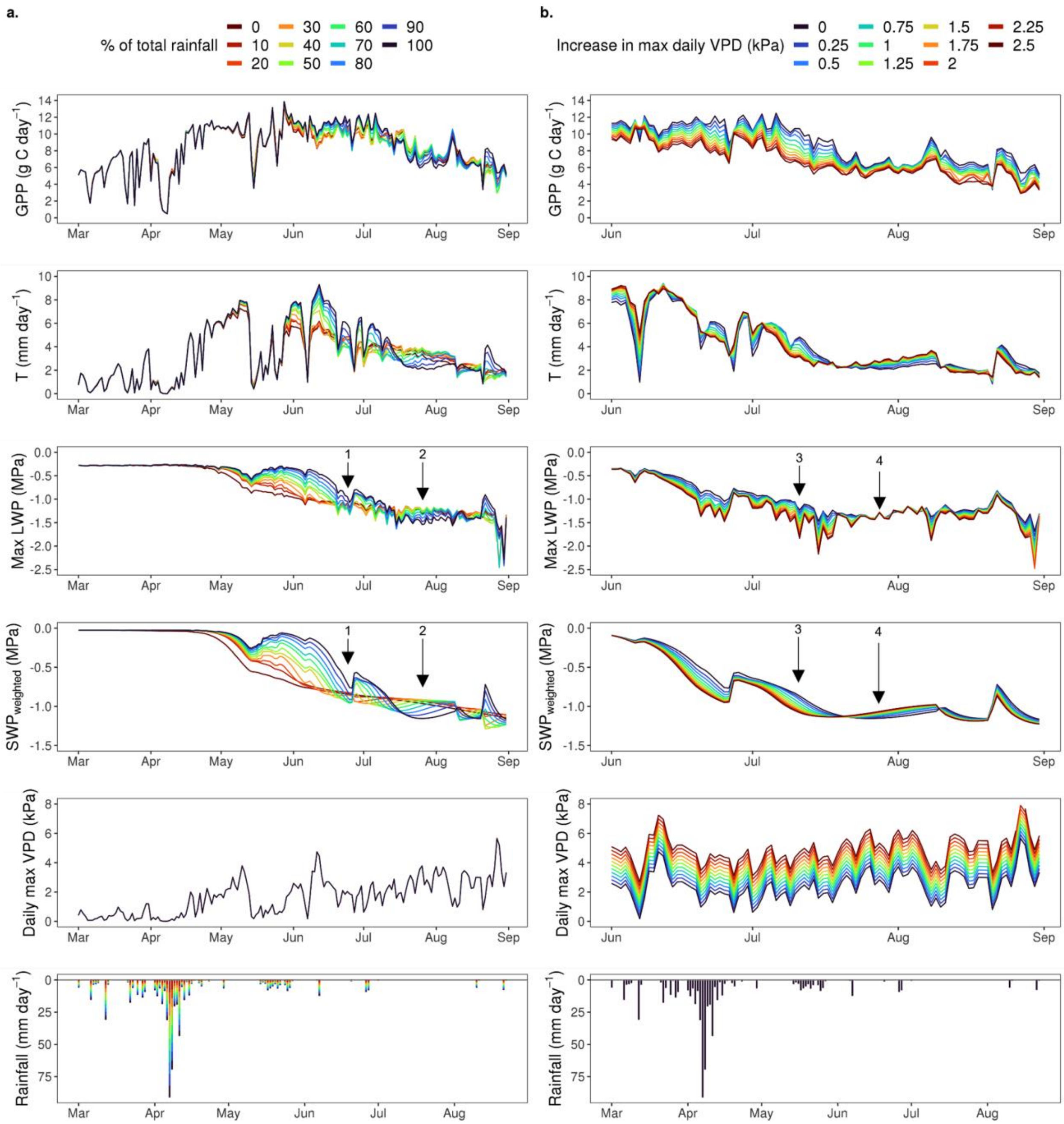

Fig. 6 in Jarecke et al. 2023. Model results for daily total transpiration (T), daily total gross primary production (GPP), daily max leaf water potential (LWP), and weighted soil water potential (SWPweighted) under various scenario for rainfall (a) and daily max vapor pressure deficit (VPD, b). The baseline model conditions for daily max VPD and rainfall in 2019 are shown. Experimental changes to rainfall occurred from March 1–August 31 and experimental changes to VPD and air temperature occurred during the climatological summer, June 1–August 31.

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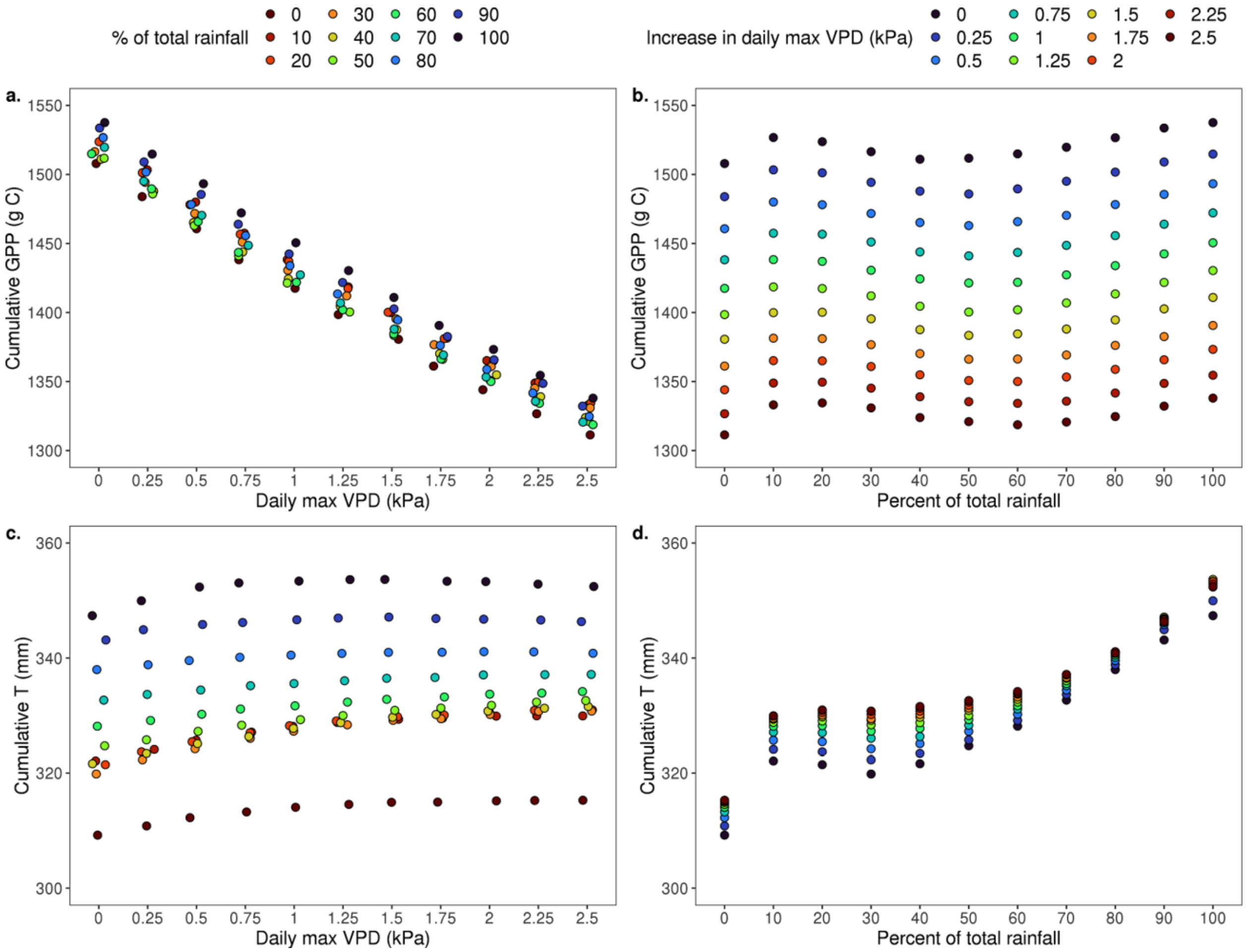

Fig. 8 in Jarecke et al. 2023. The interactive effect of decreased rainfall and increased vapor pressure deficit (VPD) on cumulative gross primary production (GPP) and cumulative transpiration (T) from March–August with colors representing percent of total rainfall (a, c) and increase in daily max VPD (b, d).

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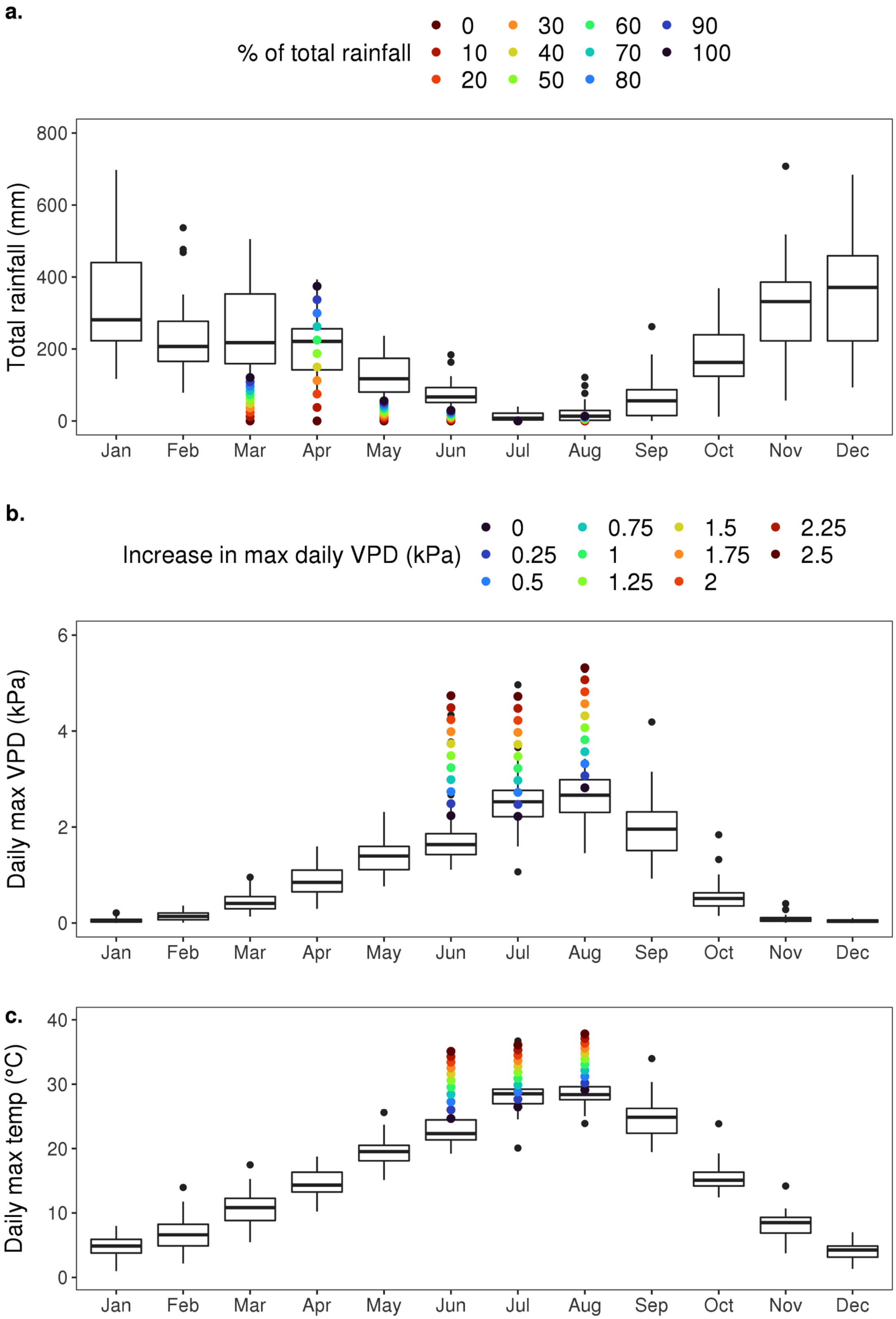

a.
% of total rainfall
0
10
20
30
40
50
60
70
80
90
100
Total rainfall (mm)
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
b.
Increase in max daily VPD (kPa)
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Daily max VPD (kPa)
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
c.
Daily max temp (°C)
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fig. 4 in Jarecke et al. 2023. Distribution of monthly total rainfall (a), monthly mean daily maximum vapor pressure deficit (VPD, b), and monthly mean daily maximum air temperature (c) from 1989 to 2019 and monthly means for experimental climate scenarios that increase daily max VPD during June, July, and August and decrease rainfall from March to August. The boxplot shows the interquartile range which included the median, 25th, and 75th percentiles with whiskers representing the smallest and largest values no further than 1.5 times the interquartile range. Extreme outliers beyond the whiskers were omitted from the graphic to improve visualization of data.