Point of No Return: Identifying Critical Thresholds for Plant Functioning and Recovery from Drought

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Abstract. The efficient transport of water to the sites of photosynthesis and other plant tissues is essential for the processes of carbon assimilation, growth, and maintenance of turgor. Water transport in plants occurs through xylem conduits which operate under negative pressure. As a consequence of water stress, the tension within the xylem can exceed critical thresholds which can result in embolism, the loss of function by the replacement of liquid with gas. Embolism formation represents a physiological weakness in plants, leading to permanent damage, particularly following drought. Due to the complexity of observing xylem functioning in crop species, artifacts from invasive methods likely skew our interpretations of when hydraulic systems fail. Our study focuses on pinpointing the stages of embolism occurrence and exploring the potential for refilling and repair in intact plants by utilizing non-invasive methods of optical vulnerability. We quantify leaf embolism and leaf shrinkage in the canopy leaves of maize during a near-fatal dry-down in a controlled environment. Continuous monitoring of gas exchange, chlorophyll fluorescence, and whole plant transpiration allows us to present the sequence of physiological failures leading to leaf mortality and senescence. Additionally, we find that recovery from extreme water stress is highly dependent on the accumulation of embolism within the xylem. By understanding the relationships between embolism occurrence, plant physiology, and agricultural practices, we aim to enhance crop productivity and resilience in the face of evolving environmental challenges.