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Monitoring carotenoid content transitions by using RGB digital images as a transversal tool: from forest vulnerability to nutritional content

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Abstract *(Between 300 and 400 words)*

The work addresses the intertwined challenges of climate change-induced forest vulnerability and declining crop nutritional quality. Although seemingly disparate, these threats are interconnected through the biochemical composition of chloroplasts within leaves. The enhancement of carotenoid content triggered by stress is widely employed as an early stress marker to evaluate and predict plant physiological status and as an early warning signal. At the same time, the higher carotenoid content translates into more nutritious food. Therefore, quantifying these compounds serves as a critical early detection tool not only for assessing tree health, essential for forest monitoring but also for plant nutritional quality. The nutritional quality of food is vital for human health by combating the many chronic diseases and disorders that are impacted by dietary carotenoids and other plant-based micronutrients. Approaches to scaling up leaf responses and assessing carotenoids from the leaf/tree level into pixels remain challenging. Using red-green-blue (RGB) channels of images assessed via digital cameras, and an additive colour model, we predict carotenoid content in two plant species and scenarios: (i) *Lemna minor* (L.) Griff. (water lens or duckweed) colonies as a future food crop with an exceptional high content of high-quality protein and essential human micronutrient contents as desirable features for cultivation on Earth and in spaceflight environments, and (ii) *Quercus faginea* Lam. trees subjected to a drought experiment in the Basque Country (Spain) and monitored during spring and summer of 2023 for their physiological, including carotenoid composition and functioning of the leaves' photosynthetic apparatus via concomitant imaging and functional/biochemical analysis. Use of repeated digital imaging

allows for scalable, cost-effective, and non-destructive monitoring of foliar phytochemicals (such as carotenoids), enabling informed decision-making in both forest and agricultural systems. Overall, this work demonstrates the utility of integrating advanced imaging techniques into ecological and agricultural research as a multifaceted tool for monitoring plant health and nutritional quality. The findings underscore the importance of interdisciplinary approaches in addressing complex environmental and public health issues. This research is part of the strategic initiatives of the BEZ-EKOFISKO consolidated group, which has received the highest grade from the Basque Government classification for Scientific Groups (IT1648-22) and is funded by the national ATLANTIS project (PID2020-113244GA-C22; funded by MCIN/AEI/10.13039/501100011033).

Keywords (Between 3 and 5): carotenoids, real-time monitoring, repeated imagery