Monitoring climate and land-use change impacts on Alpine vegetation dynamics and carbon sinks

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I. Introduction

Vegetation is one of the major terrestrial carbon sinks, contributing to climate change mitigation. Protecting (and enhancing) **carbon storage** in natural and managed ecosystems requires a better understanding of **vegetation dynamics**. In this context, **Alpine** mountain ecosystems, are dealing with two significant challenges: **accelerated warming**, twice the global average, combined with more frequent droughts and heatwaves, and **socio-economic** shifts leading to land **abandonment**, **affecting the structure and function** of **plant species**. In the Aosta Valley region (**Northwest Italian Alps**), land-cover and land-use changes (LCLU) are reshaping vegetation dynamics, particularly through the abandonment of mountain pastures below the forest line (~1500 m asl).

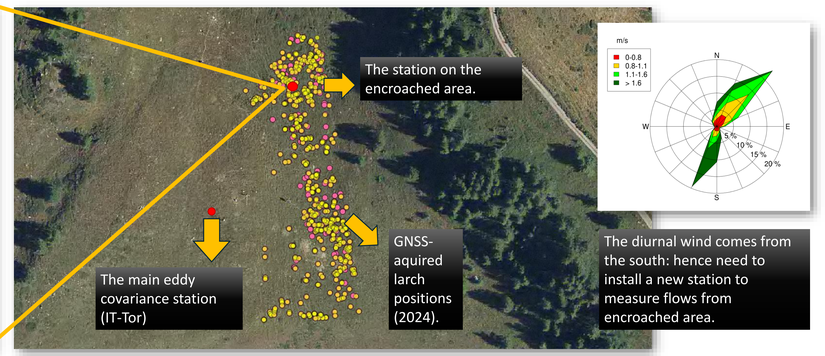
LAND USE CHANGE: abandonment of grazed pasture leads to natural vegetation succession, from shrub encroachment to forest expansion, altering ecosystem structure, biodiversity, and carbon dynamics.

II. Methods

Our research explores how climatic and socio-economic factors drive woody species encroachment into mountain grasslands, altering species composition, carbon fluxes, and ecosystem dynamics. The study was conducted at the ICOS Associated site Torgnon (IT-Tor), an abandoned subalpine pasture (total exclusion since 2010) dominated by Nardus stricta, located in the Aosta Valley region at about 2100 m asl. The encroachment process was analysed over an area of 15000 m^2.

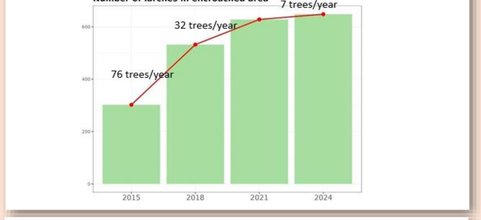
Larix decidua, Calluna vulgaris, Vaccinium myrtillus, Rhododendron ferrugineum, Juniperus communis

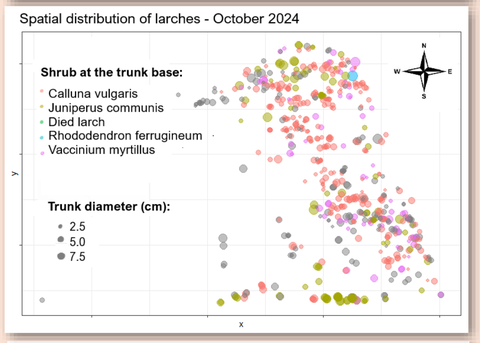
Vegetation dynamic has been monitored through periodic **field surveys** (2015, 2018, 2021, 2024) using line transects and GNSS mapping (5 cm accuracy) to track each larch growth (trunk diameter, height, and crown size) and associated shrubs. Annual UAV images complemented ground data. Continuous CO_2 flux, and meteorological variables have been recorded since 2008, and a second eddy covariance station was installed in October 2024.

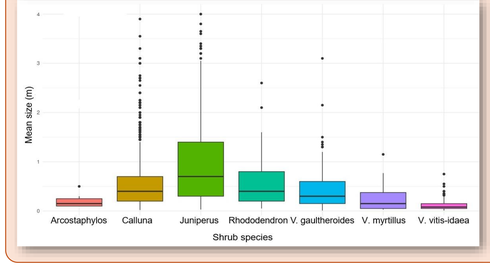


III. Results

	2015	2018	2021	2024
Total number of larches	301	531	627	649
Average trunk diameter	1.45 cm	1.37 cm	1.72 cm	1.78 cm
Average height	35.12 cm	36.94 cm	57.72 cm	59.23 cm
Average canopy diameter	33.84 cm	42.69 cm	45.49 cm	46.70 cm

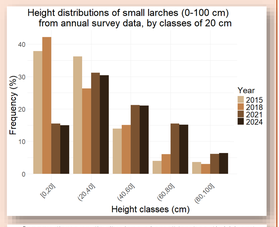


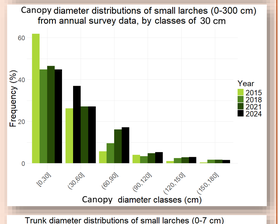


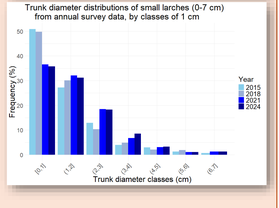


Results show a significant increase in the number of larches between 2015-2018, when the number of larches almost doubled. After 2018, growth rates declined, suggesting a saturation point. From here on, larches tend to increase in dimension rather than in number.

A consistent association between larch trees and shrubs was observed, especially for Calluna vulgaris and Juniperus Communis. Tree size measurements indicate a growing proportion of larger individuals, supporting the hypothesis that the system is transitioning toward a more mature stage.

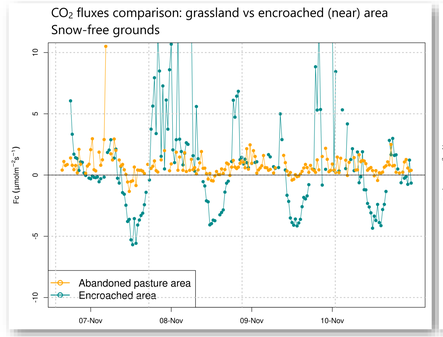


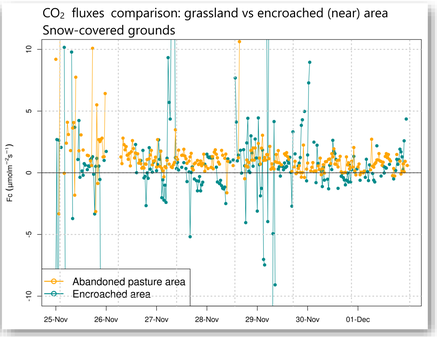


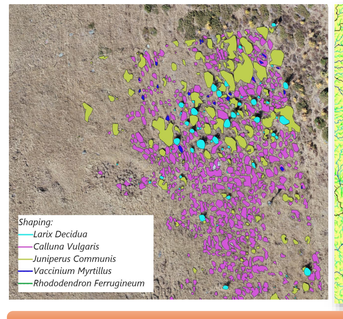


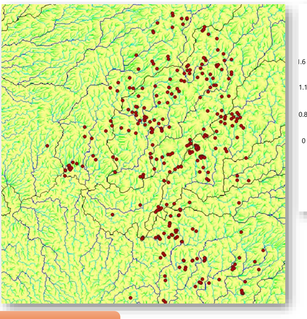
IV. Ongoing Work

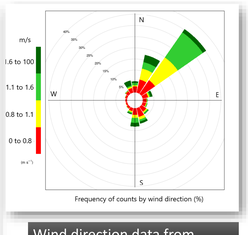
Next steps include a comparison of CO_2 fluxes of the two areas (abandoned pasture vs. encroached areas), the quantification of larch and shrubs cover changes through photointerpretation [1] of UAV images, the evaluation of possible relationships between vegetation dynamics and meteorological variables, and the impact of extreme events (e.g. heatwaves).











Wind direction data from the eddy covariance measurements on the encroached area.

References and acknowledgements

[1] Oddi, L., Cremonese, E., Ascari, L., Filippa, G., Galvagno, M., Serafino, D., Morra di Cella, U. (2021). Using UAV imagery to detect and map woody species encroachment in a subalpine grassland: advantages and limits. *Remote sensing*, *13*(7), 1239.

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