Volcanic eruption and wildfires as interacting drivers of first-year seedling establishment in Canary pine

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Background

On the island of La Palma, Canary Islands, Spain, the Canary pine forest is largely unmanaged and depends on natural regeneration for sustainable population dynamics. Canary pine (*Pinus canariensis* C.Sm. ex DC.) has been continuously exposed to volcanic eruptions over evolutionary time scales. The species exhibits many adaptations to wildfires, but the current fire regime is likely not natural.

Occasional successful regeneration events, driven by first-year seedling establishment after a disturbance, could be essential to maintaining population structures. We investigated the interactions of volcanic eruption and past wildfires on first-year seedling establishment in the Canary pine forest after the 2021 Cumbre Vieja volcanic eruption.

Hypotheses

We aimed to understand the compounding effects of volcanic eruption and wildfires on first-year seedling establishment, hypothesizing that:

1. The recent volcanic eruption led to favorable conditions that stimulated a localized pulse of Canary pine seedling establishment.

2. Wildfires in 2012 and 2016, to the north and south of the crater respectively, diminished potential first-year seedling establishment after the eruption, as the reproductive capacity of the forest was likely already exhausted without sufficient recovery time.

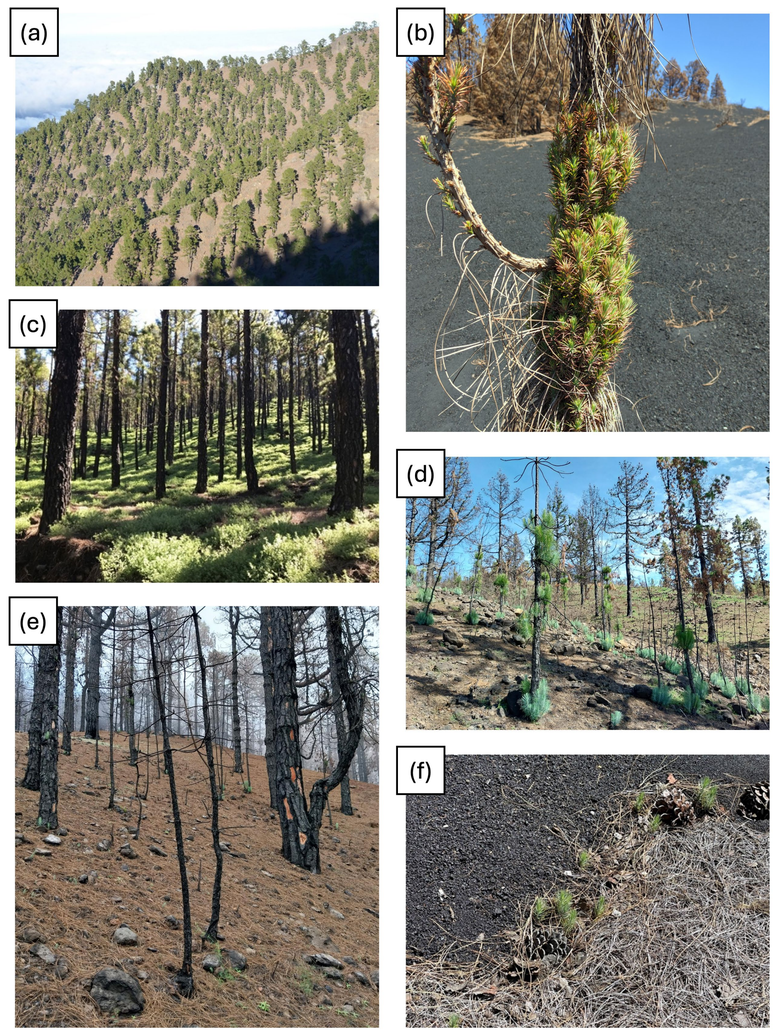

Fig. 2. **(a)** Even-aged Canary pine stand in northern La Palma at ca. 1500 m a.s.l (March 2013). Neither extensive understory vegetation nor natural regeneration is developed. **(b)** Epicormic resprouting of the trunk and branches on a Canary pine tree near the Tajogaite Volcano in April 2022. **(c)** Herbaceous vegetation develops after fires open the canopy and precipitation increases nutrient availability. Legumes, such as *Lotus campylocladus* subsp. *hillebrandii,* dominate until a period of drought or mineralized nutrients from the ashes have been leached. **(d)** Epicormic resprouting of pine trees and juveniles eight months after the 2023 wildfire. **(e)** Charred Canary pine juveniles with no visible epicormic resprouting eight months after the 2023 wildfire. **(f)** A group of Canary pine seedlings on the fresh tephra layer next to opened serotinous cones and needle litter.

Materials and Methods

Study area: Canary pine forest on the island of La Palma, Canary Islands, Spain

Target species & ecosystem: Endemic *Pinus canariensis* C.Sm. Ex DC. forms monospecific canopies and governs the Canary pine forest ecosystem.

Data collection: Seedling abundance data in 117 plots of 5 m radius in April 2023.

Remote sensing: NDVI change detection (Sentinel-2 and MODIS) to quantify the impact of the volcanic eruption and previous wildfires in 2012 and 2016.

Data analysis: (1) relationship between seedling abundance classes and each individual predictor and **(2)** binomial generalized additive model (GAM).

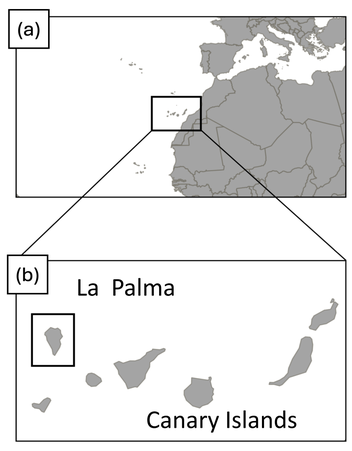

Fig. 1. Investigation Area.

Results

Large areas of the island were found to be impacted by pyroclastic ashes and by wildfires. Those impacts were found to interact regarding pine seedling establishment. This was locally enhanced by the eruption. However, this finding did not hold for forests to the north and south of the crater, which had been affected by past wildfires. Particularly, ΔNDVI2016 was a significant predictor in our model.

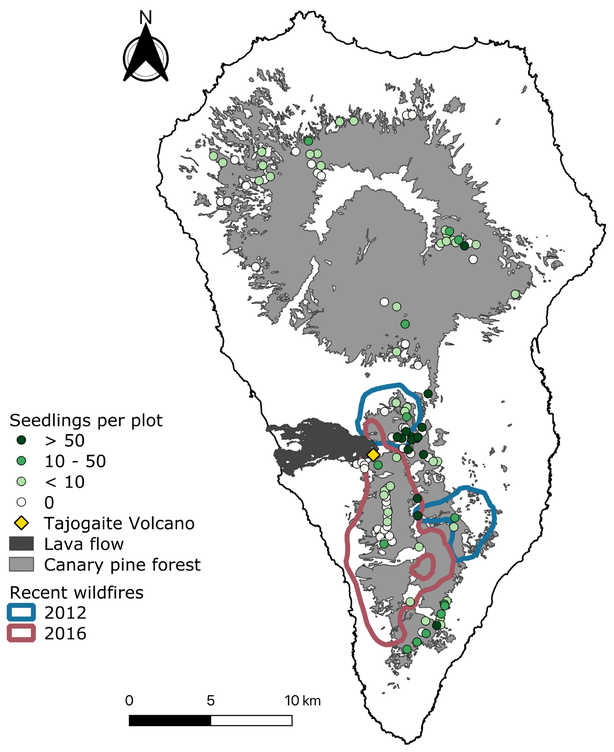

Fig. 3. Location of sampling sites and areas affected by wildfires. The surrounding of the Tajogaite Volcano crater (yellow diamond) is strongly influenced by tephra deposition.

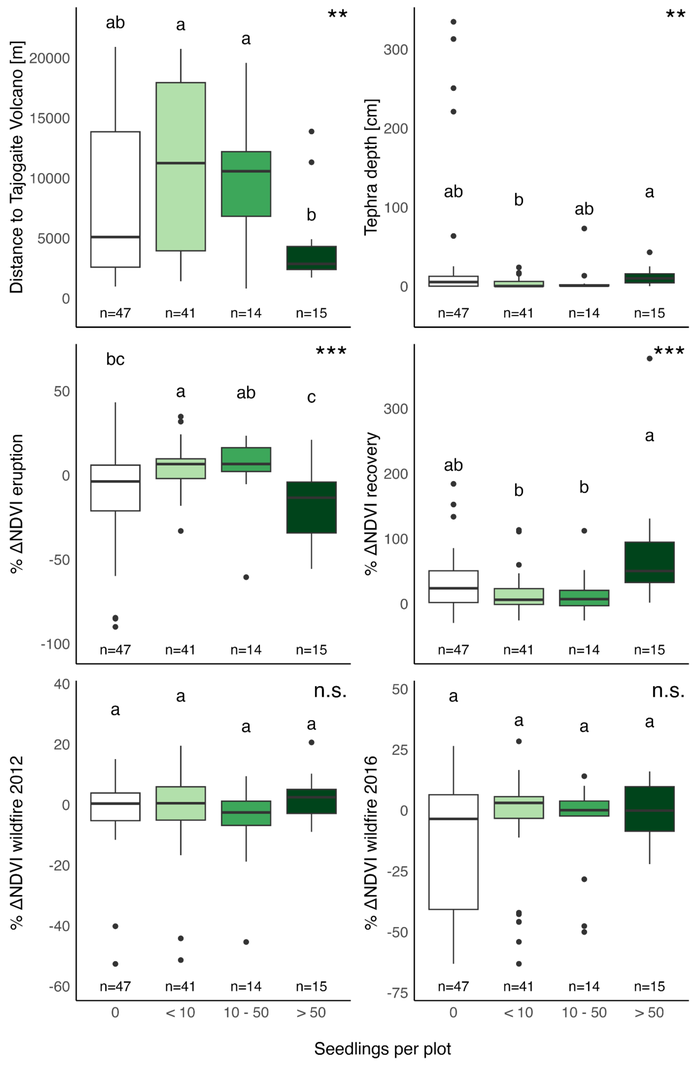

Fig. 4. Distance to the volcano and tephra deposition as well as NDVI changes are corelated with seedling establishment. The most recent wildfire from 2016 has an additional negative influence on seedling establishment

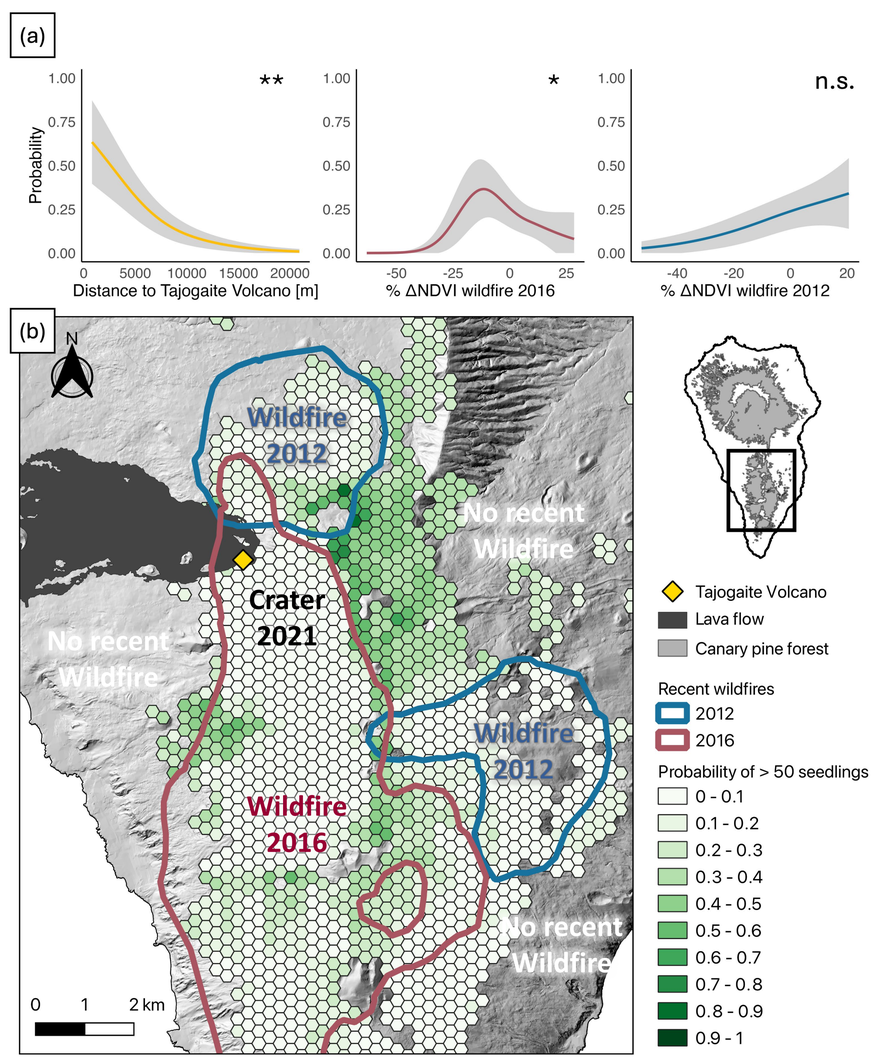

Fig. 5. In general, the probability of seedling establishment decreases with the distance to the volcano, indicating that pine forest recovery can be stimulated by ash deposition. However, the most recent wildfire from 2016 had a significant additional negative effect on the probability of seedling establishment.

There is evidence that to the south of the volcano, first-year seedling establishment of Canary pine was likely constrained due to an insufficient recovery time since the previous disturbance (wildfire 2016), impacting flowering and cone maturation.

Conclusions

- Decreasing distance to the eruption crater was significantly associated with high seedling abundance (> 50 per plot).
- The 2016 wildfire was a significant predictor for patterns of seedling establishment negatively modified by fire history.
- Serotiny increases the resilience of Canary pine to volcanic eruptions at the stand-level.
- Compounding disturbances with short return intervals threaten long-term population dynamics of Canary pine forests.

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