

Valuation of the effects of grazing management on argan trees

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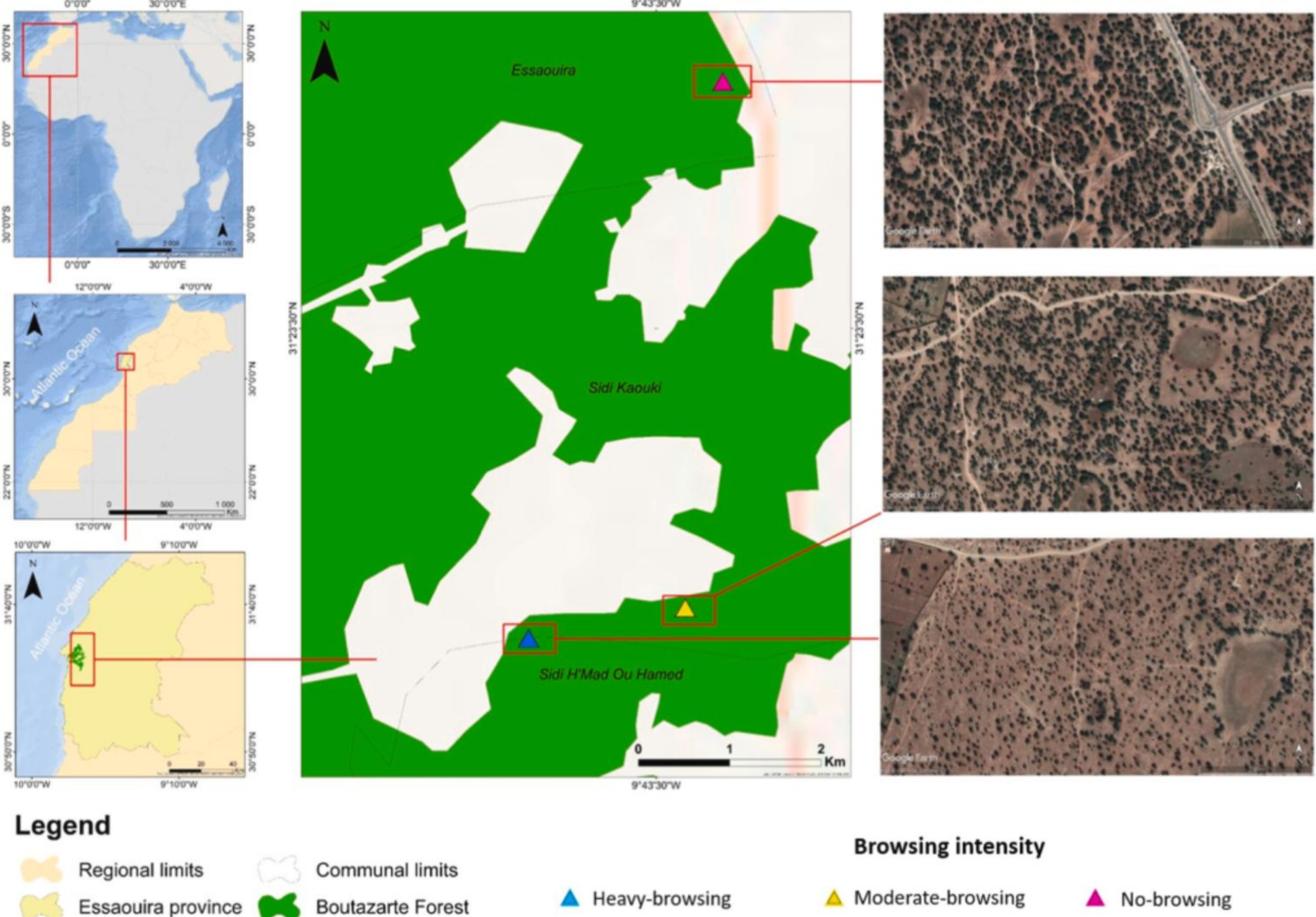
CONTEXT: *Argania spinosa* (L.) Skeels, endemic to southwestern Morocco, holds remarkable ecological and socio-economic value, with > 1.3 million rural inhabitants in southern Morocco depend directly or indirectly on the ecosystem services provided by argan woodlands. Forests experienced severe degradation since the mid-19th century.

Environmental stressors (i.e. aridity with more intense and recurrent droughts, soil erosion, climatic extremes) contributed to their decline. Socio-economic pressures and unsustainable land-use practices have further accelerated this process. Browsing pressure is particularly detrimental, especially in areas where goats and, more recently, camels have direct access to the trees, compromising both regeneration and canopy health.



The overuse of the ecosystem further disrupts its ecological integrity and socio-economic balance. Yet, argan trees remain ecologically and economically vital for rural Moroccan communities, particularly for women's cooperatives. National authorities have launched preservation and development initiatives, including large-scale reforestation programs, aimed at sustaining the argan ecosystem and supporting its associated economic sectors

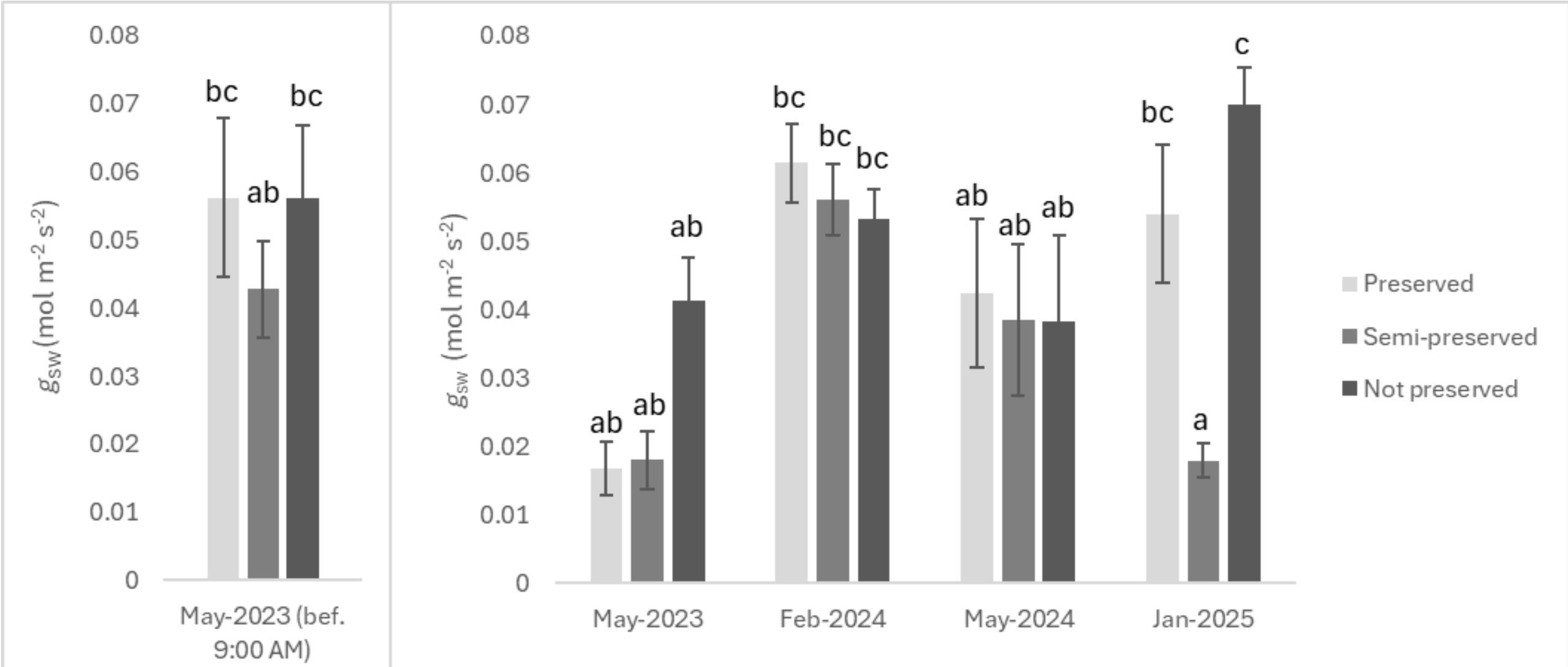
OBJECTIVE: To evaluate the impact of a regulated, argan-based agro-sylvo-pastoral system on soil fertility, soil water-holding capacity, and the health and productivity of argan plants.



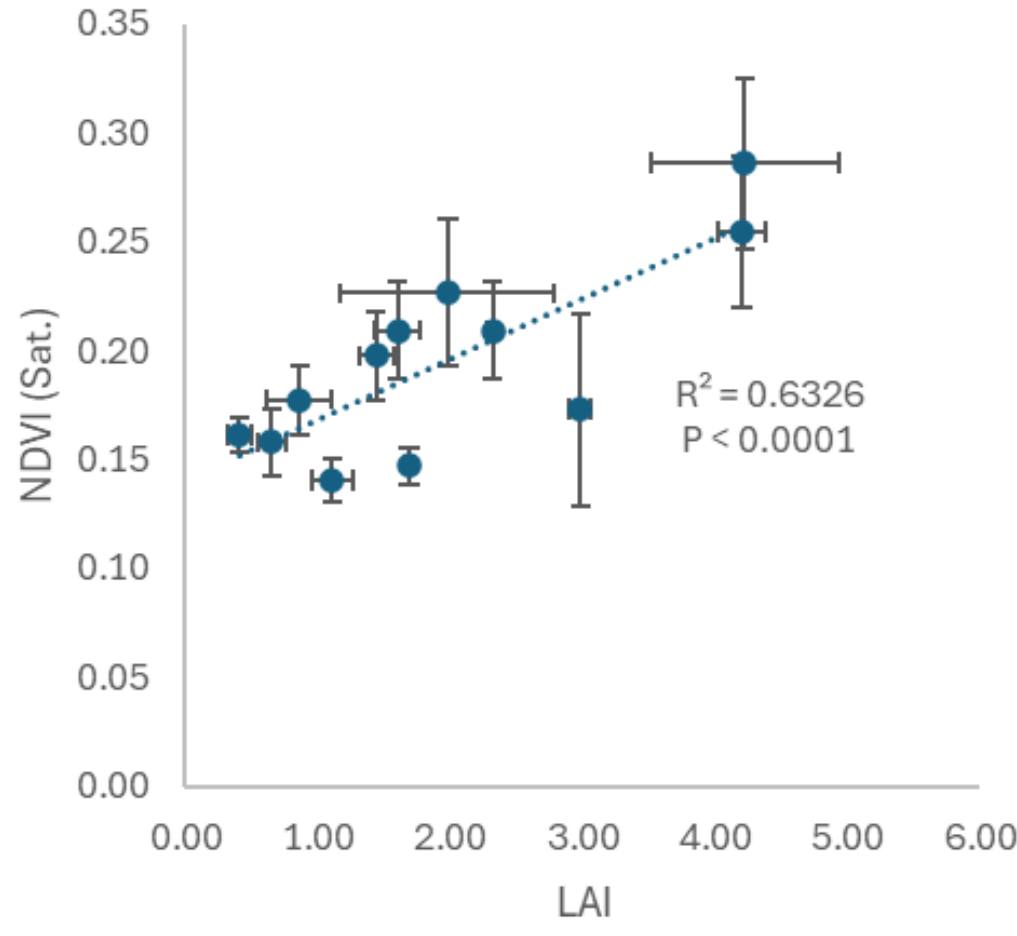
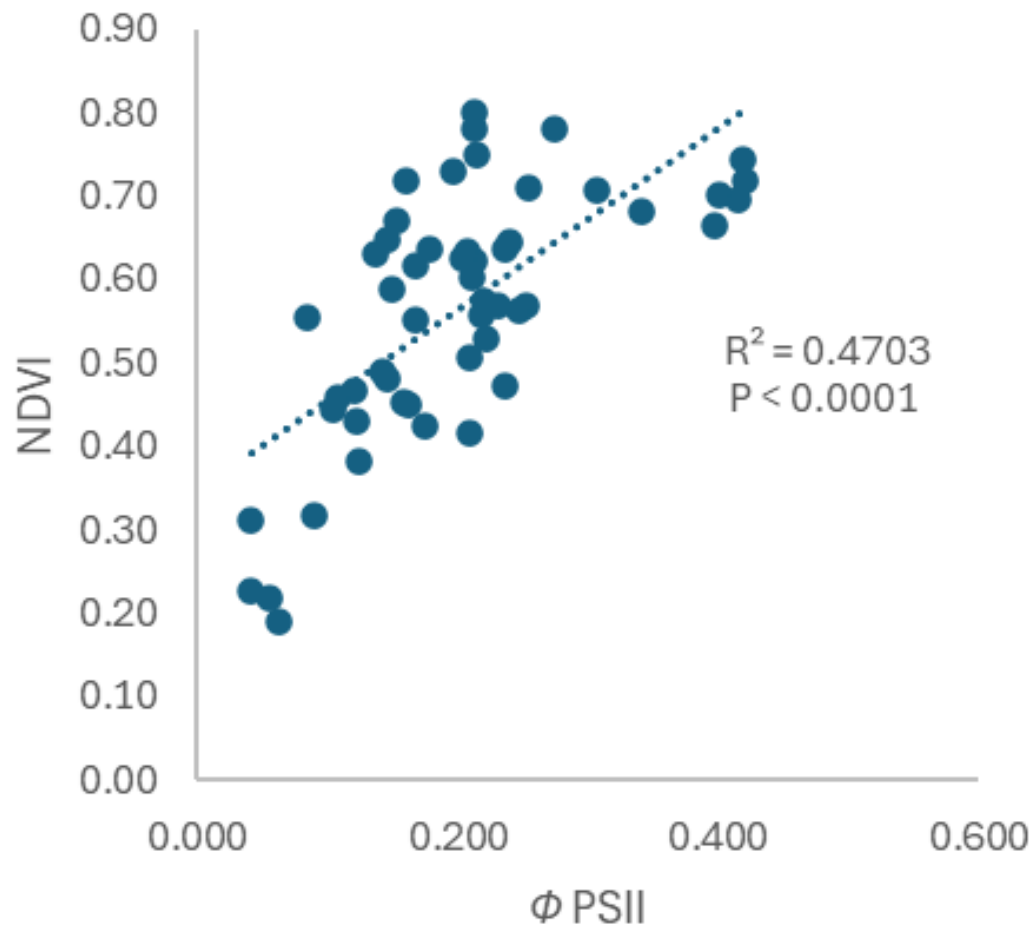
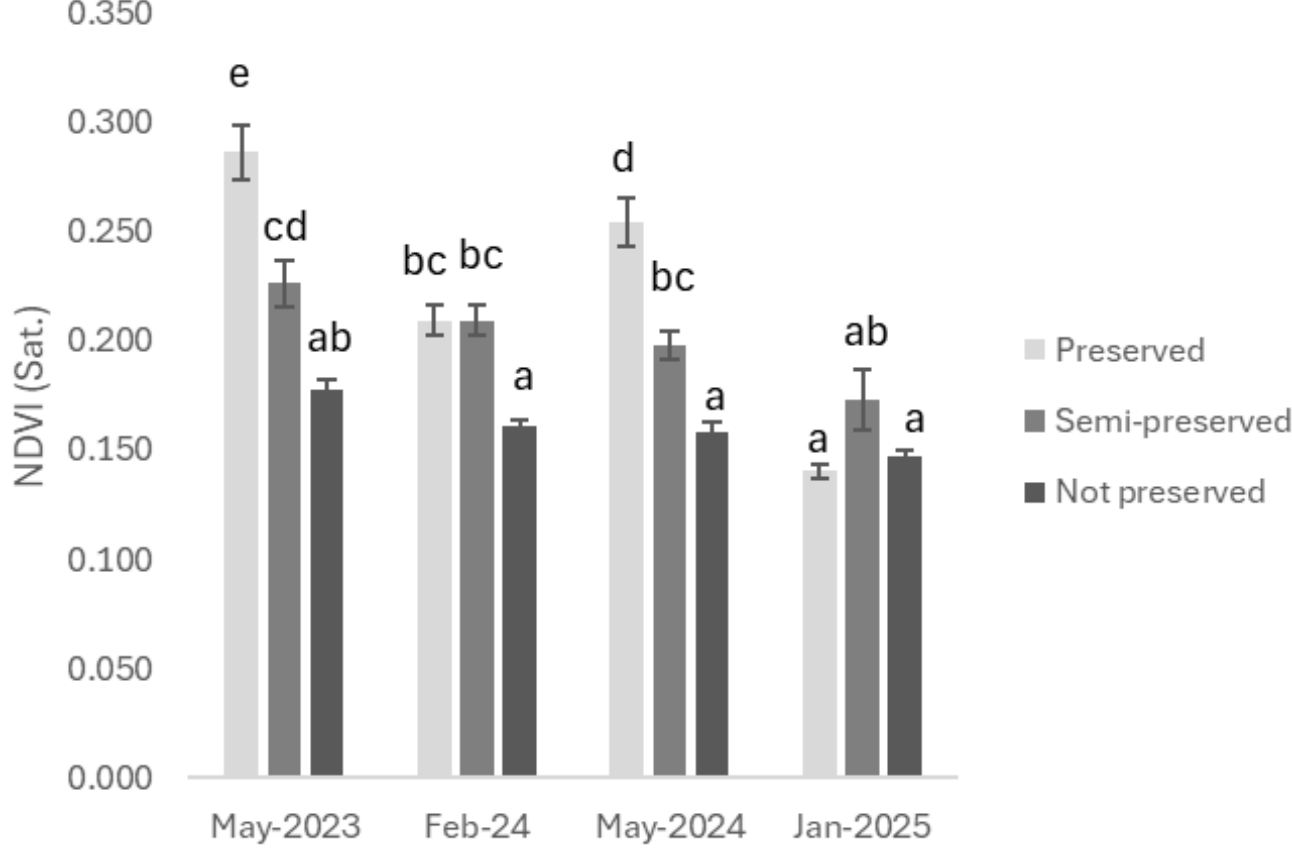
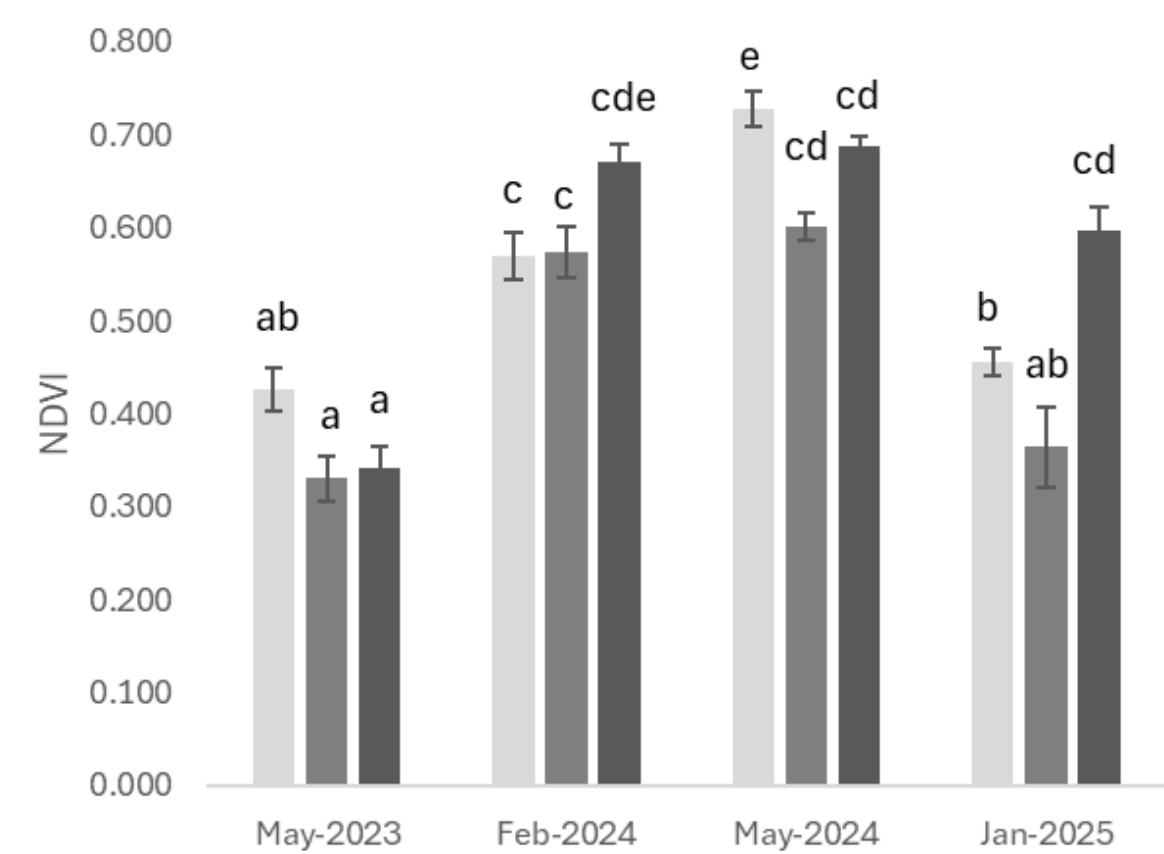
METHODOLOGIES: The research was conducted in the Boutazart argan forest (Essaouira region of Morocco) on 3 sites: preserved (no-browsing), semi-preserved (moderate-browsing), and non-preserved (heavy-browsing) to goat and camel browsing.

MEASUREMENTS: Soil moisture; Photosynthetic Photon Flux Density (PPFD) and Leaf area index (LAI); Stomatal conductance to water (g_{sw}) and fluorescence quantum yield of chlorophyll a (Φ_{PSII}); Chlorophyll fluorescence (Fv/Fm); Chlorophyll index (Chl), Flavonols (Flav) leaf content and a nitrogen balance index (NBI); Biometric and Morphological Trait; Reflectance spectra and reflectance indices measured from close distance to the tree canopies (proximal sensing), compared with satellite-based surveys (remote sensing).

RESULTS: In response to environmental conditions, stomatal conductance (g_{sw}) regulates and balances water transpiration from leaves and carbon assimilation. In argan trees, g_{sw} was strongly influenced by both browsing treatment and time of day: g_{sw} under water-limited conditions remained higher during early morning hours and declined later in the day. In the non-preserved site g_{sw} remained consistently higher than in the other two treatments, likely because of lower Leaf Area.



Comparing proximal and remote sensing techniques to assess argan trees conditions, satellite-derived Normalized Difference Vegetation Index (NDVI) integrates the greenness signal of the entire forest canopy per unit of land surface and is strongly influenced by tree cover and stand architecture. As a consequence, areas with higher total leaf area per unit of surface tend to show higher NDVI values, as shown by the positive correlation between satellite NDVI and LAI. In contrast, NDVI measured on single trees reflects the physiological status and canopy functionality of individual plants, as confirmed by the significant relationship found with Φ_{PSII} . Thus, while satellite NDVI provides information on vegetation cover and forest canopy structure at landscape level, tree-level NDVI is more sensitive to plant functional responses.



SOCIAL AND POLITICAL IMPACTS: This study integrates physiological, biochemical, and remote sensing data to assess the impact of browsing intensity on Morocco's argan forest ecosystem. Results highlight the pivotal role of soil moisture retention in sustaining ecosystem functionality under increasing aridity, climatic variability, and high evaporative demand. The traditional *Agdal* silvopastoral system, combining argan cultivation with controlled browsing, appears to promote resilience by limiting excessive canopy growth, reducing transpiration demand, and improving WUE. Effective management requires the engagement of local communities and regulation of browsing practices. Argan trees remain vital for rural livelihoods, with women's cooperatives leading the argan oil value chain and contributing to social empowerment and cultural preservation.