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Quantifying woody cover dynamics in heterogeneous dryland ecosystems: a 36-year Landsat assessment (1989-2025)

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Open woody formations provide critical dryland ecosystem services—fuelwood, charcoal, construction materials, and livestock fodder—yet remain systematically underestimated by global monitoring systems prioritizing dense forests. Conventional binary forest/non-forest classifications fail to effectively detect these formations, creating a disconnect between forest cover assessments and ground reality. This limitation highlights fundamental challenges in detecting sparse woody vegetation where deciduous phenology, spectral confusion with herbaceous vegetation, and shadows compromise traditional remote sensing.

We mapped continuous woody cover (0-100%) across 36 years (1989-2025) using Landsat imagery and Random Forest regression calibrated on 505 photo-interpreted plots and validated on 41 field plots. Images acquired during rainy season/early dry season maximized detection when deciduous species retain foliage. We analyzed fire regimes (2000-2024) and human pressure via distance gradients from habitations (1-10 km) to identify degradation drivers.

Intact woody thickets declined dramatically from 60% (1989) to 35% (2025), with accelerating loss after 2010. Fire is the primary degradation driver: burned areas lose four times more woody cover than unburned zones. Crucially, fire frequency—not single events—determines degradation severity. Natural recovery is very limited even after 10 years, insufficient to offset immediate post-fire losses. Human proximity also shows significant impacts: woody cover is approximately 20% lower near habitations than in remote areas.

Continuous woody cover mapping successfully quantifies sparse woody vegetation dynamics in heterogeneous dryland environments. This approach is transferable to similar dryland ecosystems globally facing comparable detection challenges. Results reveal that fire frequency exceeds natural recovery capacity, providing scientific evidence to inform conservation and restoration strategies in drylands under increasing anthropogenic pressure.