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Degradation or recovery of argan woodlands in South Morocco? Tree count from satellite imagery between 1967–2019 may underestimate pressures on dryland forests status

Irene Marzolff[1], Mario Kirchhoff[2], Robin Stephan[1], Manuel Seeger[2], Ali Aït Hssaïne[3], and Johannes B. Ries[2]
[1]Department of Physical Geography, Goethe University Frankfurt am Main, Frankfurt am Main, Germany (marzolff@em.uni-frankfurt.de)
[2]Department of Physical Geography, Trier University, Trier, Germany
[3]Department of Geography, Université Ibn Zohr, Agadir, Morocco

In semi-arid to arid South-west Morocco, the once ubiquitous endemic argan tree (*Argania spinosa*) forms the basis of a traditional silvo-pastoral agroforestry system with complex usage rights involving pasturing and tree-browsing by goats, sheep and camels, smallholder agriculture and oil production. Widespread clearing of the open-canopy argan forests has been undertaken in the 12th–17th century for sugarcane production, and again in the 20th century for fuelwood extraction and conversion to commercial agriculture. The remaining argan woodlands have continued to decline due to firewood extraction, charcoal-making, overgrazing and overbrowsing. Soil and vegetation are increasingly being degraded; natural rejuvenation is hindered, and soil-erosion rates rise due to reduced infiltration and increased runoff. Numerous studies indicate that tree density and canopy cover have been generally decreasing for the last 200 years. However, there is little quantitative and spatially explicit information about these forest-cover dynamics.

In our study, the tree-cover change between 1967 and 2019 was analysed for 30 test sites of 1 ha each in argan woodlands of different degradation stages in the provinces of Taroudant, Agadir Ida-Outanane and Chtouka-Aït Baha. We used historical black-and-white satellite photography from the American reconnaissance programme CORONA, recent high-resolution multispectral imagery from the commercial WorldView satellites and ultrahigh resolution small-format aerial photography taken with an unmanned aerial system (UAS) to map the presence, absence and comparative crown-size class of 2610 trees in 1967 and 2019. We supplemented the remotely-sensed data with field observations on tree structure and architecture.

Results show that plant densities reach up to 300 argan trees and shrubs per hectare, and the mean tree density has increased from 58 trees/ha in 1967 to 86 trees/ha in 2019. While 7% of the 1967 trees have vanished today, more than one third of today's trees could not be observed in 1967. This positive change has a high uncertainty, however, as most of the increase concerns small trees (< 3 m diameter) which might have been missed on the lower-resolution CORONA images.

When combined with our field data on tree architecture, tree count – albeit a parameter easily

attained by remote sensing – is revealed as too simple an indicator for argan-forest dynamics, and the first impression of a positive development needs to be revised: The new small trees as well as trees with decreased crown sizes clearly show much stronger degradation characteristics than others, indicating increased pressures on the argan ecosystem during recent decades. Structural traits of the smaller trees also suggest that the apparent increase of tree count is not a result of natural rejuvenation, but mostly of stump re-sprouting, often into multi-stemmed trees, after felling of a tree. The density of the argan forest in the 1960s, prior to the general availability of cooking gas in the region and before the stronger enforcement of the argan logging ban following the declaration of the UNESCO biosphere reserve, may have marked a historic low in our study area, making the baseline of our change analysis far removed from the potential natural state of the argan ecosystem.