

Rural-urban transformation determines cropping patterns in an oasis of Morocco's High Atlas Mountains

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Introduction & Methods

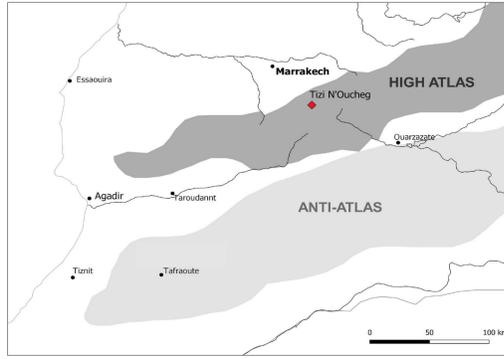


Figure 1. Oasis of Tizi N'Oucheg in the High-Atlas Mountains of Morocco

Oasis systems in the Atlas Mountains of Morocco are facing effects of rural-urban transformation processes and climate change. An interdisciplinary study was conducted to quantify changes of cropping patterns in a typical High-Atlas mountain oasis (Fig. 1) and to assess factors contributing to the transformation of these ancient social-ecological systems. Phenology metrics retrieved from NDVI time series of Sentinel satellite imagery from 2015 to 2022 were combined with ground truthing and survey data collected in the oasis of Tizi N'Oucheg in 2021 and 2022.

Results & Discussion

1. How do cropping patterns change over time?

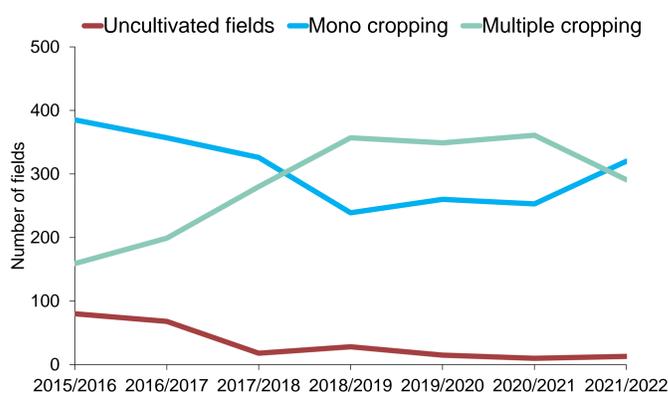


Figure 2. Changes in cropping patterns in every growing season from 2015 to 2022 in Tizi N'Oucheg, Morocco

- Mono and multiple cropping is primarily practiced (49% and 45 %) in the oasis, while uncultivated fields are rare (5%)
- The number of fields with mono- or multiple-cropping patterns is constantly oscillating over time, while the number of uncultivated fields dropped from 13% to 2% over the past 7 years (Figs. 2 and 3)
- During the last 4 years, continuous cultivation was practiced in more than half of all fields in the oasis

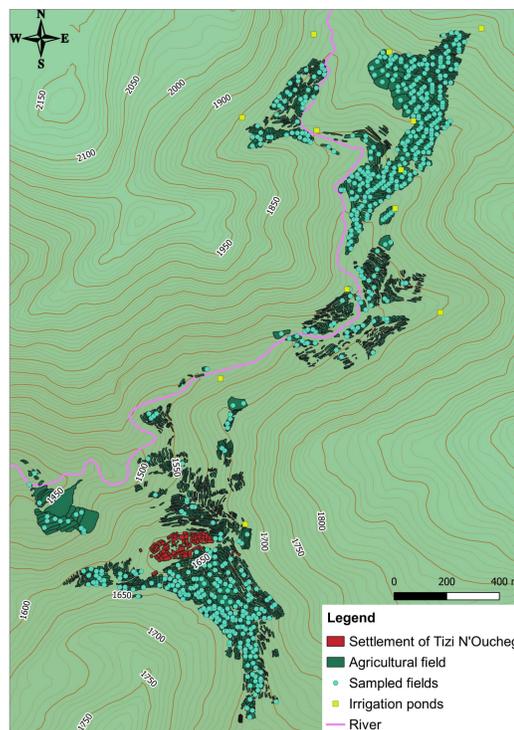


Figure 3. Map with sampled agricultural fields in Tizi N'Oucheg, Morocco

2. How do temporal factors influence cropping patterns?

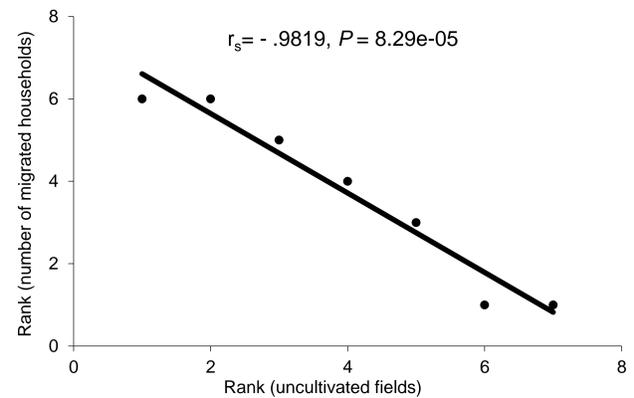


Figure 4. Spearman's rank correlation between the number of migrated households and the number of uncultivated fields in Tizi N'Oucheg, Morocco

- Time-dependent factors (maximum temperature, annual rainfall, days of rain, number of migrated households) were tested for significant correlations with the different cropping patterns
- Significant monotonic correlation between the number of uncultivated fields and the number of migrated households (Fig. 4)
- Positive monotonic but insignificant correlation between the number of fields with multiple crops and annual rainfall

3. How do spatial factors influence cropping patterns?

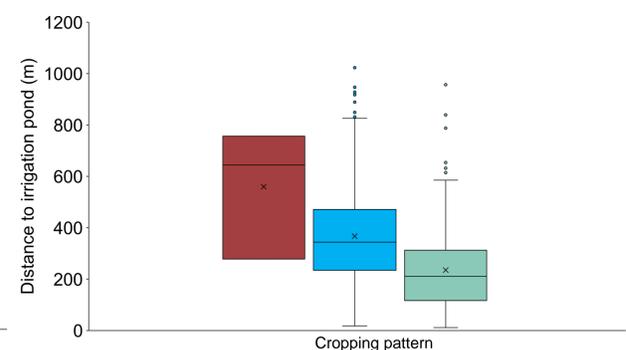
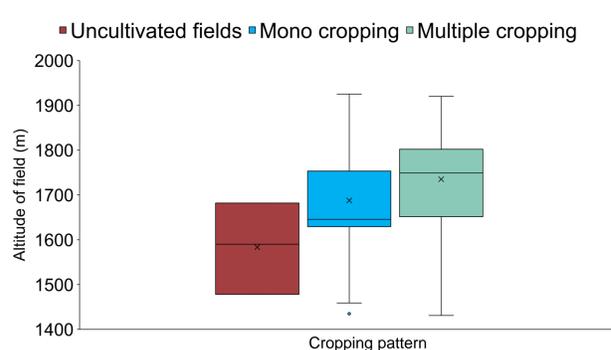
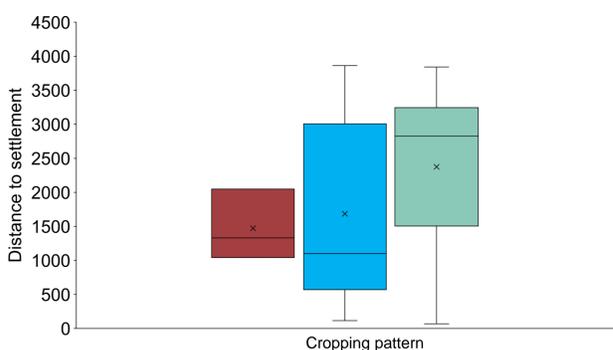


Figure 5. Differences in cropping patterns determined by spatial factors (walking distance from field to settlement, distance as the crow flies from field to irrigation pond, altitude of field, average insolation time, average irradiance) displayed in boxplots for Tizi N'Oucheg, Morocco

- Significant differences between means of the mono-cropping group and multiple-cropping group for all spatial factors ($P < 0.001$, Fig. 5)
- Cropping patterns depend on the field altitude, distance to settlement, and distance to irrigation pond ($\eta^2 = 0.07$; 0.075 ; 0.12)
- The associations between the type of cropping pattern and both its altitude and distance to the irrigation pond can be modeled by a multinomial logistic regression ($P < 0.05$)
- An increase in altitude maximises the probability of a field to have a mono cropping or multiple cropping pattern
- An increase in the distance to the irrigation ponds maximises the probability of a field to be uncultivated

Conclusion & Recommendations

Cropping patterns in the oasis of Tizi N'Oucheg, High Atlas, Morocco vary not only spatially but also temporarily. While distant fields remain often uncultivated, those that are located at higher altitudes are cultivated with multiple crops. The number of out-migrants in a household is an important determinant factor and shows that fields with multiple crops increase with rising migration. Rather than climatic factors, rural-urban transformations have a pronounced effect on the diversity of cropping patterns, which indicates the necessity to understand their multiple causes and effects on traditional agricultural systems and agrobiodiversity.