EO AFRICA

Mapping and Monitoring Spatiotemporal Desertification Patterns in the Steppic Belt of Algeria

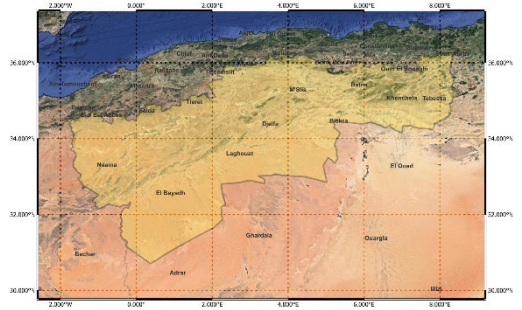
Mejdi Kaddour*, ***Amel Faiza Tandjaoui, Hachem Guerid***
University of Oran 1, Algeria
Mahdi Khodadadzadeh, Lucas De Oto
ITC, University of Twente, The Netherlands

EO FOR AFRICA SYMPOSIUM 2024
23 - 26 SEPTEMBER 2024
ESA-ESRIN

AARSE
EUMETSAT
esa

Background and Motivations

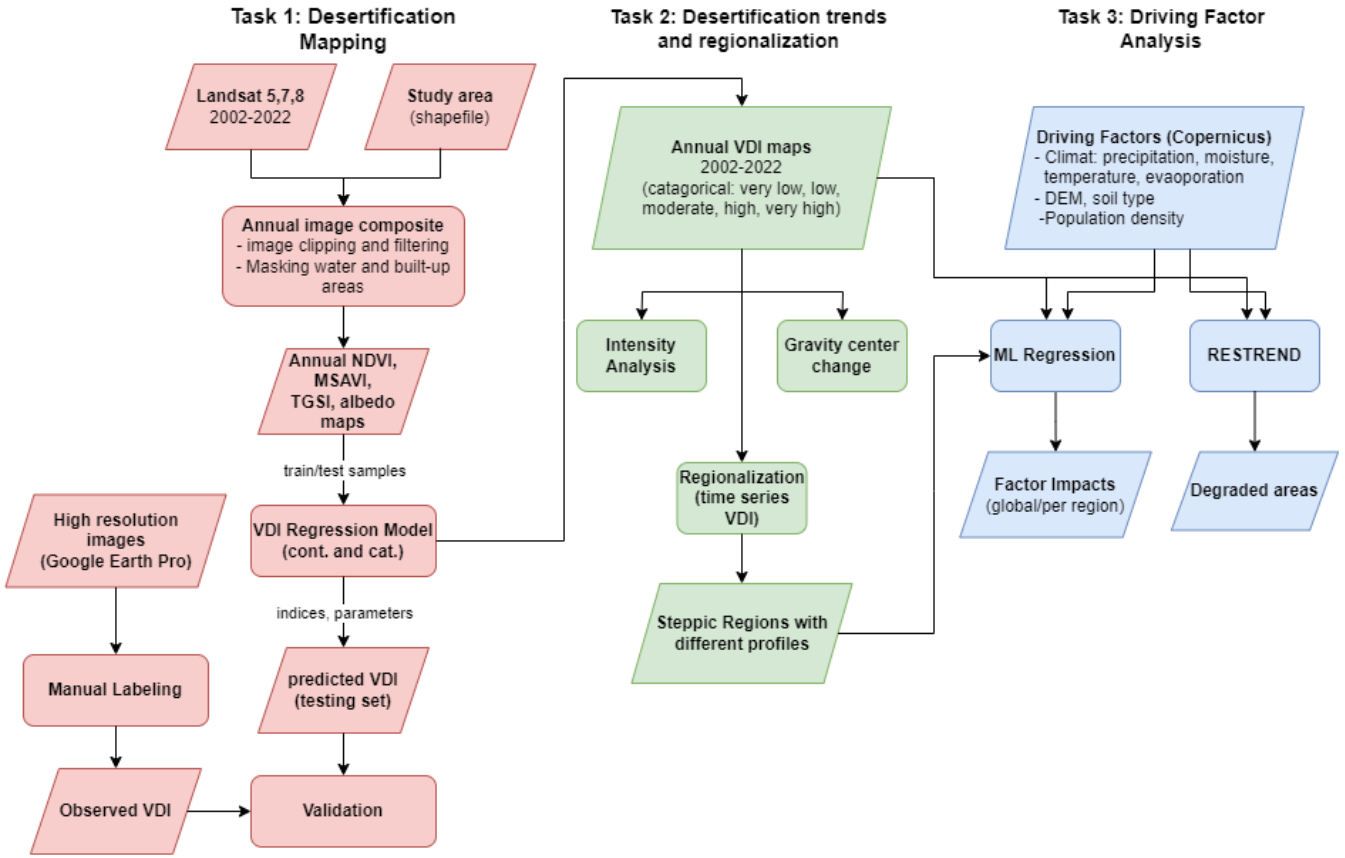
- Desertification is a major environmental issue that threatens many parts of the globe. Between the 1980s and 2000s, deserts expanded to over 9% of drylands, impacting the lives of over 500 million people [1].
- Algeria is one of the countries most affected by desertification, as evidenced by a high loss of indigenous plant biodiversity between 1975 and 2006 [2].
- Desert already occupies nearly 2 million km² (80% of the total land area) and nearly 8 out of 20 million hectares that constitute the steppe are classified as vulnerable to desertification [3].
- This region, which stretches over 1200 km, is of great strategic importance and a key area for research on desertification.
- There is no existing work that has studied this phenomenon in the whole of this region over a long period of time.



[1] Mirzabaev, A., J. Wu, J. Evans, F. García-Oliva, I.A.G. Hussein, M.H. Iqbal, J. Kimutai, T. Knowles, F. Meza, D. Nedjraoui, F. Tena, M. Türkeş, R.J. Vázquez, M. Weltz, 2019: Desertification. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems
[2] Fahima Belala, Azziz Hirche, Serge D Muller, Mahmoud Tourki, Mostefa Salamani, Mohamed Grandi, Tahar Ait Hamouda, and Madjid Boughani, “Rainfall patterns of algerian steppes and the impacts on natural vegetation in the 20th century,” Journal of Arid Land, vol. 10, pp. 561–573, 2018.
[3] Abdelkader Khaldi, “La gestion non durable de la steppe algérienne,” VertigO - la revue électronique en sciences de l’environnement [Online], Regards / Terrain, September 2014.

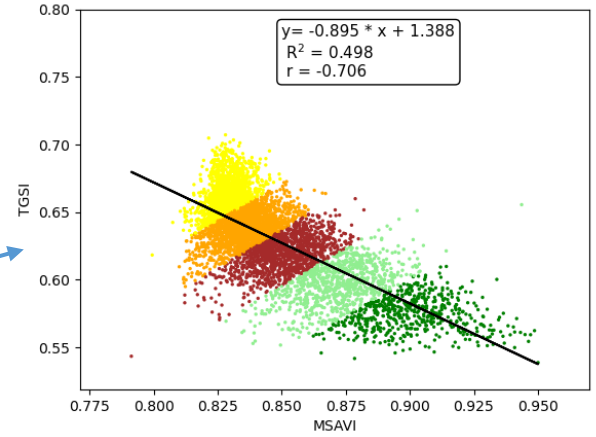
Objectives and Methods

- Harness the availability of long time series of EO and climatic data: Landsat, ESA Worldcover, Google Earth Pro, ECMWF ERA5.
- Map the spatiotemporal evolution of desertification from 2002 to 2022 in the steppic region of Algeria.
- Derive patterns that capture the main trends of desertification in the steppic region over the last two decades.
- Divide the study area into contiguous regions with homogeneous and explainable characteristics and trajectories.
- Investigate the impact of environmental and human factors.

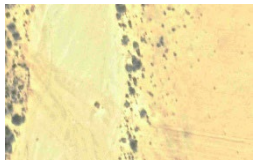


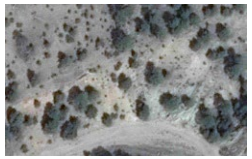
Vegetation Model

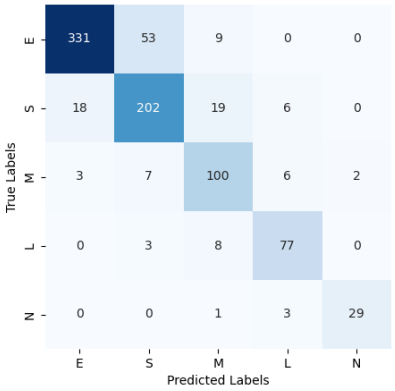
- Composition of annual vegetation maps of the best observed vegetation condition during the autumnal period (to focus on perennial vegetation).
- Synthesis of a **Vegetation Density Index (VDI)** at the pixel level by partitioning the feature space of pairwise spectral index combinations of NDVI, **MSAVI, TGSI**, and Albedo.
- Continuous VDI values are mapped to five vegetation classes using the Jenks break algorithm: ***extreme, severe, moderate, light, no.***



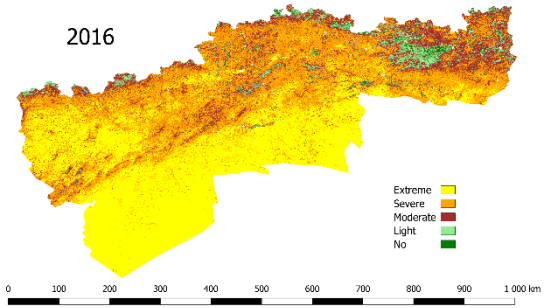
Method Validation
Visual interpretation of 877 matching Google Earth images (accuracy: 84%)

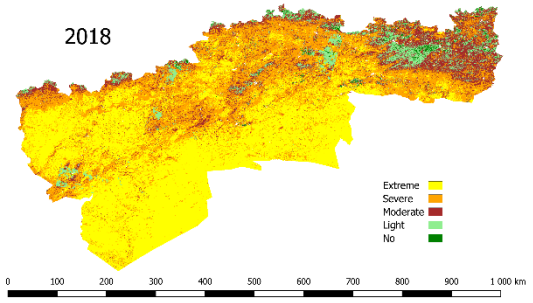






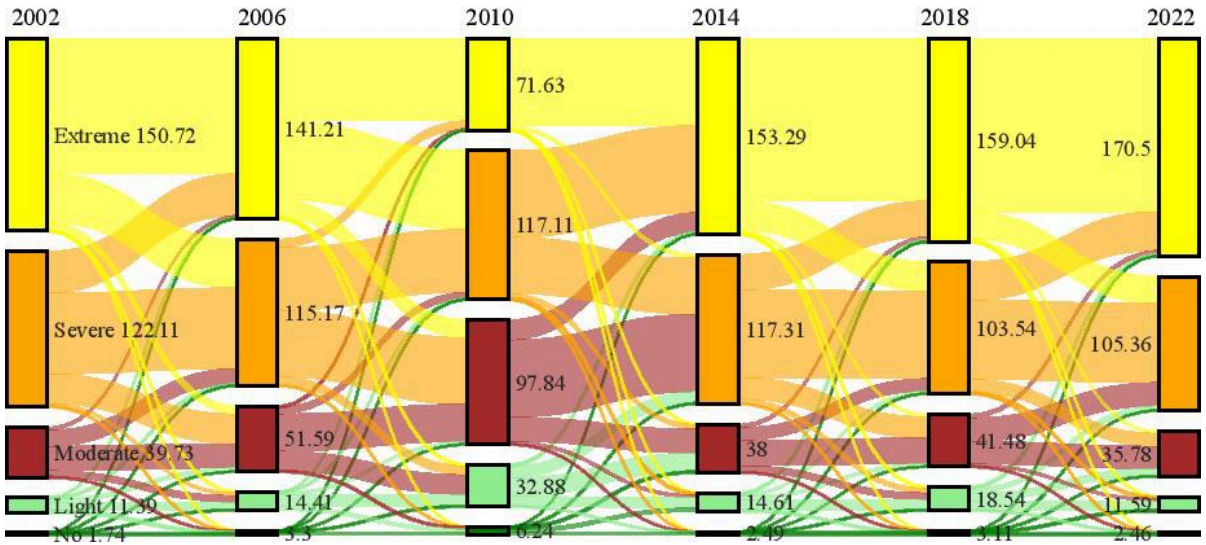
Confusion matrix



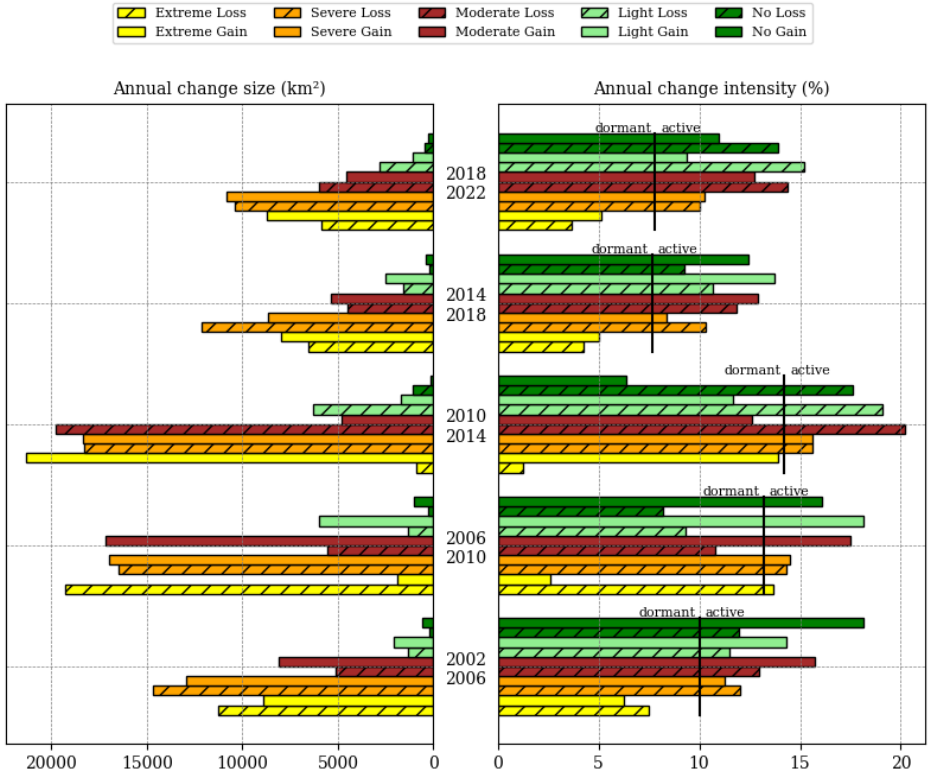


Desertification patterns (1)

Intensity analysis: quantitative analysis of land use and land cover change

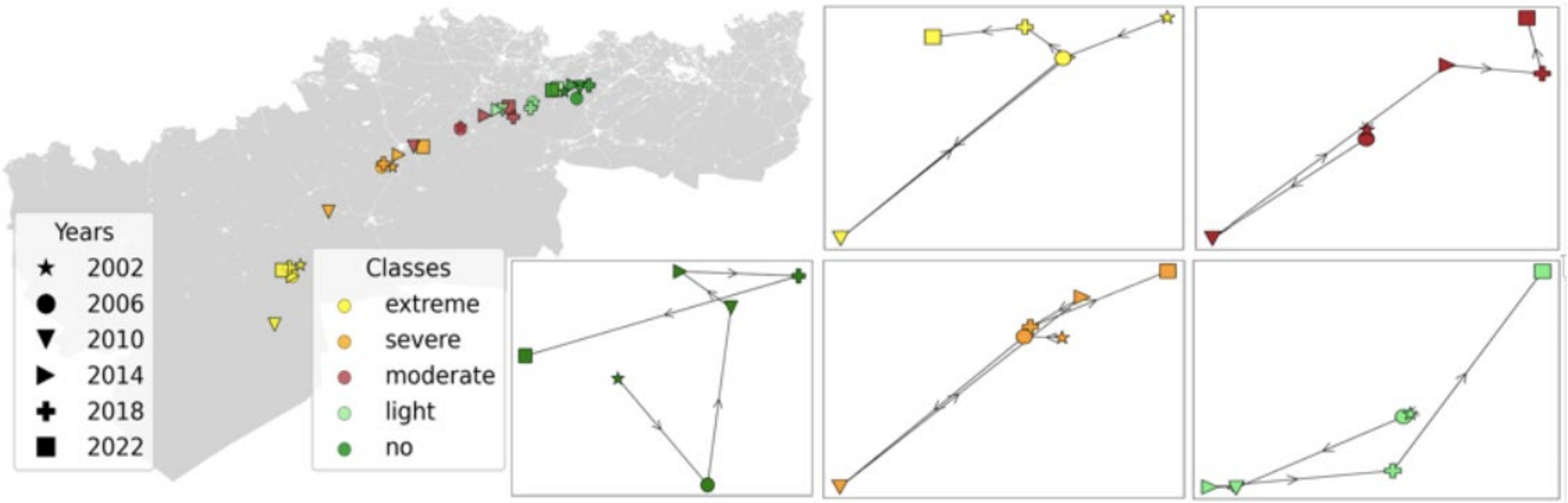


Category-level size



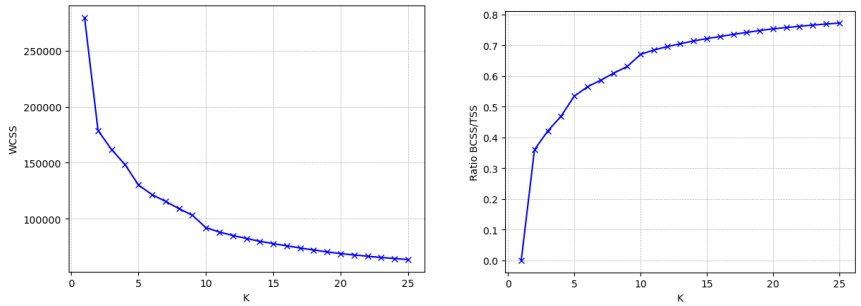
Desertification patterns (2)

Gravity Center Change: characterize the spatial location of centers of gravity of some phenomenon and its changes over time.

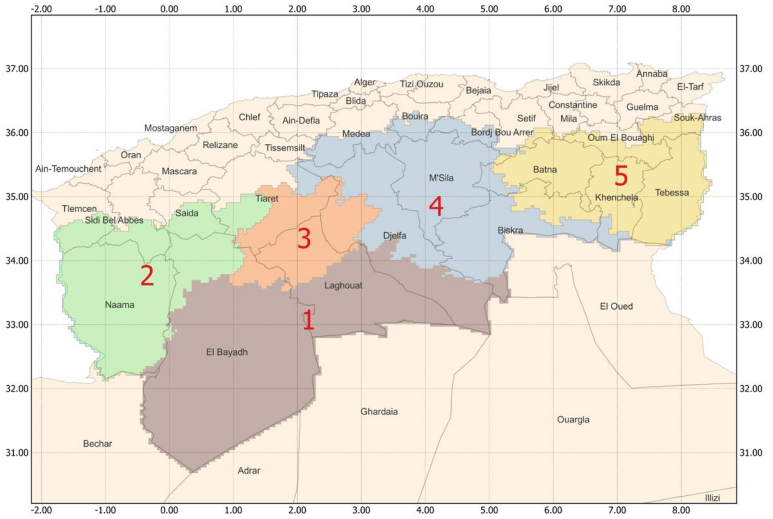


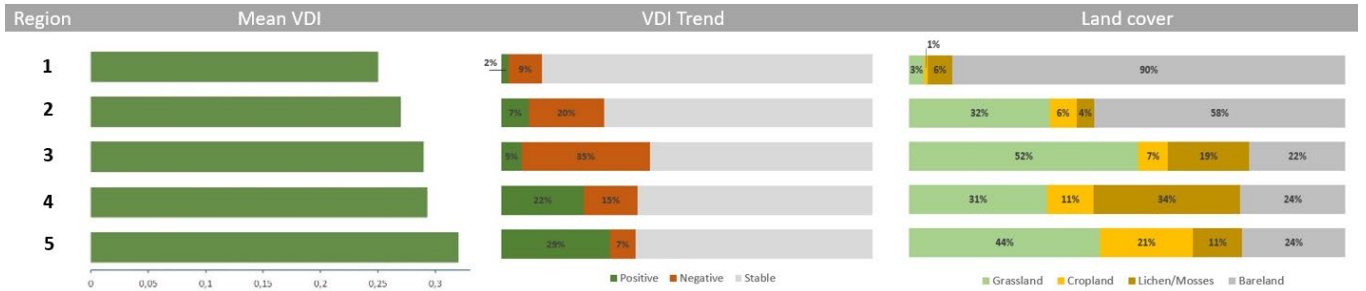
Regionalization

Process of partitioning geographical space into contiguous areas that show a high degree of similarity regarding a set of features and are, at the same time, distinct from neighboring areas.



Elbow graphs of regionalization: WCCS (left side) and BCSS/TSS ratio (right side) vs. number of clusters (regions) K.





Driving Factors (1)

Class of factors

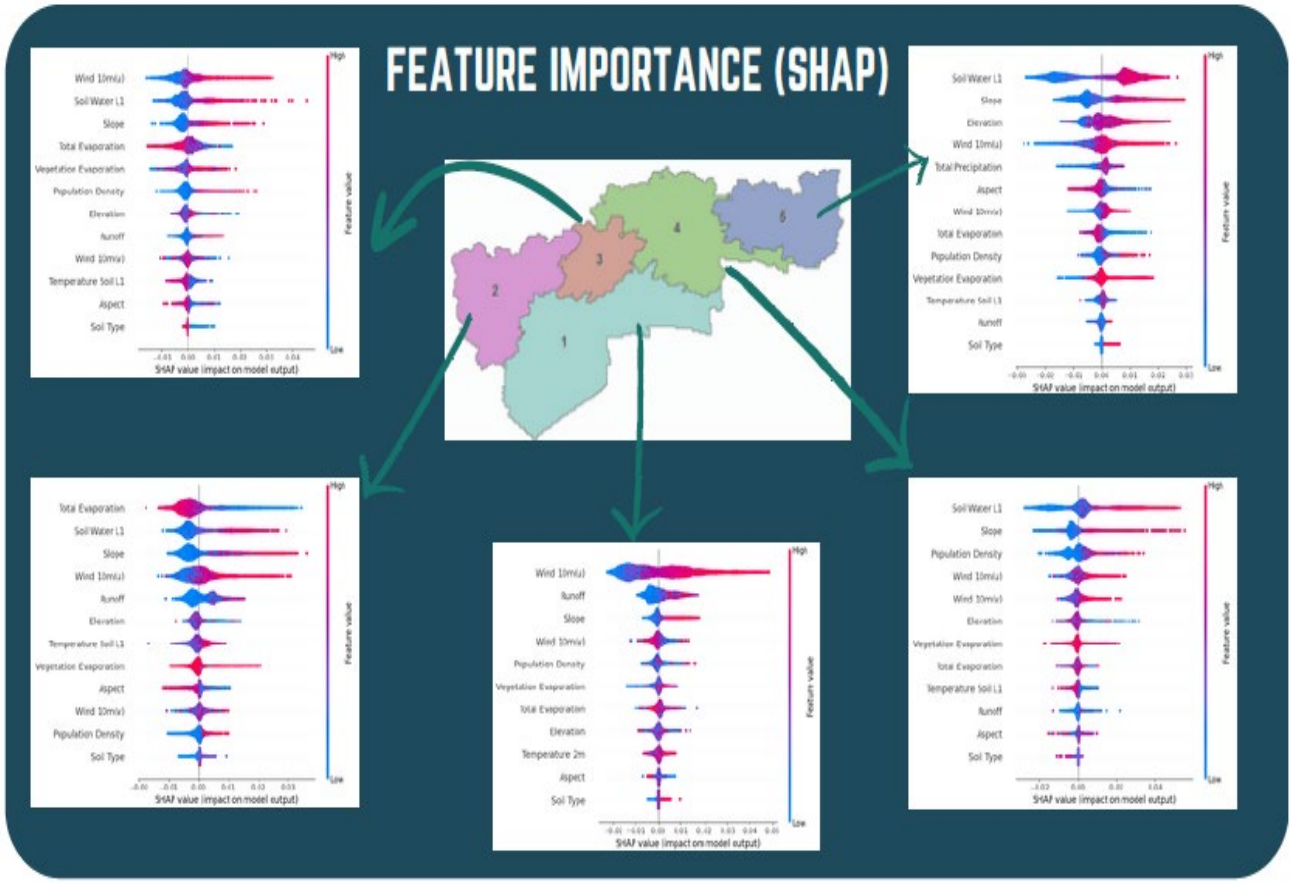
- **Climate:** total precipitation in each year; volumetric soil water layer 1 (0-7 cm) per year; total evaporation (accumulated amount of water that has evaporated from the Earth's surface); temperature of the soil in layer 1; air temperature at 2m above land surface; 10m u-component of wind (eastward), 10m v-component of wind (northward); evaporation from vegetation transpiration.
- **Topography and soil:** elevation; slope; aspect; soil type (ranging from 1 to 4 in our study area).
- **Human:** population density per square km.

Approach

- Build a region-wide random forest model to predict the observed VDI
- Use SHAP method to measure the impact of each factor on the predicted VDI - local (sample level) and global explanations, as well as the direction of features' impact on predictions (i.e., negative and positive contributions).

Driving Factors (2)

- **Region 1 (southernmost):** stable area with a predominance of bare land. Due to the lack of rainfall, the main factors positively correlated with vegetation density are eastward wind, surface runoff and slope.
- **Region 2 (west):** It is a hybrid transitional zone. The main factors are total evaporation, soil water, slope and eastward wind.
- **Region 3 (west central):** transitional zone but concentrates the highest percentages of negative VDI trends. Main driving factors: eastward wind, soil water and slope.
- **Region 4 (east central):** transitional zone but contains most of the residual negative trends that were observed. The main factors: soil water, slope and population density.
- **Region 5 (east):** It presents the highest mean VDI values and positive VDI trends. The main factors: soil water, slope and elevation.



Conclusions and future work

- The analysis of desertification trends showed a northward expansion of bare land in the western and central parts of the steppe from 2010.
- Regionalisation clustering combined with driving factor analysis identified 5 regions with different trends and profiles.
- Significant land degradation has also been observed in the central part since 2008, which could have serious consequences for the local economy and environment.
- In addition to water, eastward winds and slope have been identified as factors positively correlated with vegetation preservation.
- As future work, we intend to deepen our understanding of drivers and establish causality at a narrower scale by integrating other global and local data sources, such as land cover and livestock (consider land use and vegetation types).

Ressources

- Kaddour, Mejdi, et al. "Analysis of Desertification Trends in the Algerian Steppe Using Multitemporal Satellite Imagery for the Period 2002-2022." *IGARSS 2024-2024 IEEE International Geoscience and Remote Sensing Symposium*. IEEE, 2024.

- Jupyter notebooks: https://github.com/mejdik/mapspades

- Kaddour et al, 2024, "HR Images Algerian steppic zone", https://doi.org/10.17026/PT/POJGN2, DANS Data Station Physical and Technical Sciences, DRAFT VERSION.

- Kaddour et al, 2024, "RS based driving factors of desertification in the Algerian steppic zone", https://doi.org/10.17026/PT/0DNFS0 , DANS Data Station Physical and Technical Sciences, DRAFT VERSION.