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- ***PhD Thesis Abstract*** -

ASSESSING THE IMPACT OF CLIMATIC AND ANTHROPOGENIC FACTORS ON PASTURE DEGRADATION IN THE MOLDAVIAN PLATEAU

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In the Anthropocene era, grassland ecosystems face constant stress from ongoing degradation driven by climate change and anthropogenic interventions. Globally, grasslands have never been seen as a priority, whether we refer to competent authorities who can make sustainable decisions or to isolated and individualized communities.

Grassland degradation is one of the most significant challenges facing the world today regarding the natural environment and society. Globally, 25% of terrestrial ecosystems are degraded, affecting 41% of the world's population. Without explicit action, it is predicted that by 2050, 95% of the Earth's surface could be degraded, threatening ecosystem functionality, food supply, and water quality.

Grasslands are some of the most widespread terrestrial ecosystems on the planet, occupying 25% of the land area and 59% of all agricultural land. Of these, nearly 50% are exposed to various degradation processes due to climate change and anthropogenic impacts, with 5% facing an extremely high state of degradation. Grassland ecosystems are the habitat of more than 800 million people and the primary food resource for herbivorous animals, maintaining soil quality by regulating the carbon cycle and controlling erosion. They help conserve biodiversity, maintain climate stability, conserve soil and water resources, and play a vital role in supplying food needs. Grassland ecosystems are variable in terms of species composition, biodiversity, productivity, and utilization management.

In Europe, (permanent) grasslands occupy 34% of all agricultural land, representing the most sensitive ecosystem, exposed for centuries to intensive grazing and periodic mowing. Europe is facing a decline in natural ecosystems and a significant reduction in biodiversity. Grasslands are considered the most threatened ecosystems due to land use changes, land abandonment, overgrazing, and reforestation.

In Eastern Europe, grasslands account for 14.6% (282 000 km2) of the total area of the component countries, representing the western limit of the Eurasian steppe and forest-steppe.

In Romania, grasslands are the second largest ecosystem in terms of area. Out of a total of 32,357.14 km2 of grassland, 7080.05 km2 (21.88%) are represented by natural (undegraded) grasslands, 12,790.72 km2 (39.53%) are semi-degraded grasslands, and 12,486.37 km2 (38.59%) correspond to degraded grasslands. Spatially, the semi-degraded areas correspond to semi-natural grasslands, also known as pastures. As regards the Moldavian Plateau, pastures have been a vital resource of rural communities for centuries. They present a regional pattern, distributed along

floodplains and on the slopes (from gently to steep) due to extensive agriculture during the inter-war period and the intensive agriculture registered during the communist era.

According to the literature, pasture degradation is mainly caused by global climate change and anthropogenic activities. These two factors are responsible for the degradation of more than 50% of all grasslands globally. Although very difficult to quantify and separate, the two factors (global climate change and anthropogenic impacts) continue to act simultaneously on the quality of terrestrial ecosystems.

In global climate change, vegetation dynamics are conditioned by agricultural droughts, heat waves, wildfires, floods, and landslides.

Regarding anthropogenic impacts, pasture degradation is considered to have increased simultaneously with rapid economic development and population growth. Intensive grazing (overgrazing) is the leading anthropogenic cause of pasture degradation, a most prevalent phenomenon in developing countries.

Studies conducted to assess pasture quality at global and regional scales have predominantly demonstrated that pasture ecosystems have undergone several changes in biomass, productivity, and phenological stages.

Monitoring pastures for evaluation has been a topic of great interest, initially carried out at local and regional scales, often based on field observation (visual). This method is still used by farmers, who infer the phenological stage of plants by observing leaf vitality and specific colours. For specialized studies, the visual method has proved to be relatively inefficient, in some cases destructive, and costly due to the spatial distribution of pastures.

Subsequently, with the rapid development of remote sensing, it became possible to monitor grassland areas at a larger scale, which is considered a non-destructive type of analysis with an advanced level of detail. Nowadays, many studies aiming to analyze vegetation over large areas (regional, national, or even continental scales) rely primarily on satellite technology. Satellite data provided by space-based sensors (Landsat, Sentinel, MODIS, AVHRR) or proximity sensors (multispectral cameras attached to UAV/UAS devices) are used to monitor pastures. The potential of satellite remote sensing-based methods for determining vegetation quality has been demonstrated in many studies. Green vegetation can be constantly monitored using spectral reflectance properties measured by optical sensors. Some of the most qualitative and commonly applied methods are based on the Normalized Difference Vegetation Difference Index (NDVI),

which is considered the best predictor of vegetation conditions, especially grassland. It represents the normalized difference between the near-infrared (NIR: 0.7 - 1.1 μm) and red (RED: 0.6 - 0.7 μm) spectral wavelengths, divided by the sum of the two.

The central hypothesis is to attribute the primary disturbances in pastures to climatic and anthropogenic factors. Based on the geomorphologic characteristics of the Moldavian Plateau, the geomorphologic factor is also considered an agent of pasture degradation.

Thus, to determine the current status of pasture degradation in the Moldavian Plateau and to validate the established hypothesis, this PhD thesis proposes a method for analyzing vegetation dynamics using NDVI Landsat 8 OLI (2013 - 2020) with a spatial resolution of 30m, downloaded from the Google Earth Engine (GEE) platform; MODIS data - MOD13Q1 (2000 - 2023), with 250m spatial resolution, made available by NASA in partnership with the USGS; and AVHRR data merged with MODIS (9.5 km), materialized through the PKU GIMMS NDVI dataset (1982 - 2022), made available by Li et al., (2023). The varied spectrum of satellite data collections used was a cornerstone of this study, as it aims to accurately identify the behaviour of grasslands in the face of external, destructive factors at different spatial scales. Thus, it is possible to detect the impact of climatic factors by referring to the PKU GIMMS NDVI data series, which is associated with a spatial resolution of 9.5 kilometres with the ERA-5-Land climate data series. MODIS data with a spatial resolution of 250 meters have been used to validate the impact of climatic and hydrological factors on pastures. In contrast, Landsat data provided a much more precise view at the local level, which is considered suitable for identifying the impact of anthropogenic, geomorphological, and, from particular perspectives, geological factors.

The processing of the NDVI data series was possible with the help of the Rstat Core Collection and the R Greenbrown package. Through R Greenbrown, two methods of detecting the interannual variability of NDVI (Annual Aggregate Trend Method - AAT) and the seasonal variability (Seasonal Trend Model - STM) were applied. The R Greenbrown package, as well as the AAT and STM methods, are specialized in detecting trends of phenological variations corresponding to pasture vegetation, as well as breakpoints, which are considered leading and reliable indicators in the context of irreversible disturbances manifested at a given moment in time during the analyzed multi-temporal series. These breakpoints divide the time series into several segments, characterized by abrupt or gradual trends, with statistical significance or no significance. Analysis of the trend itself and the typology of trend changes can indicate the causal factor of

degradation: i) climatic, ii) anthropogenic, iii) hydrological, iv) geomorphological, or v) geological.

The precise association of the trend perturbation with a possible driver is unfounded without a comprehensive validation procedure. Thus, the trend deviations associated with the climatic factor have been validated by analyzing the ERA5-Land data series. In contrast, those associated with the other factor typologies have been validated by setting up case studies or referring to available cartographic materials or field analyses.

Thus, this PhD thesis comes to the aid of local communities by identifying the main pasture areas affected by degradation, establishing the related causes, and proposing sustainable solutions based on rigorous scientific investigations. Pasture degradation addressed as an imminent risk to human communities in international studies, is often ignored or almost non-existent in Romania. Although not an immediate danger, pasture degradation can have irreversible consequences.