Techniques for identification, mapping and analysis of grasslands. Case study: Arad county

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Abstract: The development, in recent decades, of specific GIS and remote sensing techniques, facilitates the spatial analysis of the pastoral space and provides access to a huge volume of geospatial data. In this context, the purpose of the research is the mapping of the grasslands of Arad county and their analysis in correlation with the altitude and slope of the terrain. For Arad county, the grassland areas were identified and mapped, as follows: the Corine Land Cover database, 2018 edition, on a medium scale, was completed on the basis of orthophotoplans and cadastral plans at a scale of 1:10000, a process that obtained representation of grasslands on a large scale. The calculations show that 12% of the area of Arad county belongs to grasslands. The overlay analysis allowed the study of grasslands in correlation with other environmental factors, which can influence the floristic composition or their spatio-temporal dynamics. Thus, 89% of the grassland areas are located between 80.8 and 300 m altitude and 96% are located on slopes with an inclination below 15º. The application of GIS techniques in the research of grasslands in a given territory, offers the possibility of a holistic approach or for particular cases.

1. Introduction

The modern methods and means of analysis of the geographical environment, based on Geographic Information Systems (GIS) and remote sensing, allow obtaining, with ease and precision, all the information related to grassland ecosystems, from cartographic representation, to complex analyses, under different aspects, quantitative and qualitative (Akeroyd and Page, 2011; Gu et al., 2013; Stewart and Janssen, 2014; Tarantino et al., 2016; Copacean et al., 2019; Boori et al., 2020; Khoshnood et al., 2021). Geographical mapping provides a systematic overview of grasslands and sets the starting point for more detailed classification and mapping at larger scales. On the other hand, the development, in the last decades, of these techniques, facilitates spatial analysis and access to information, creating a huge volume of data available in different formats and ways of representation.

Land use is defined as a series of activities undertaken to produce one or more products or services.

Data on land cover and land use change are necessary for the determination and implementation of environmental policies and can be used together with other types of data (climate data, relief data, soil data and so on) for complex assessments such as risk mapping (flood, drought, erosion etc.), assessments, predictions or sustainable development (Wang et al., 2003; Shalaby and Tateishi, 2007; Otukei and Blaschke, 2010; Alahacoon et al., 2018; Mehrabi et al., 2019; Nguyen et al., 2020; Gebrehiwot and Hashemi-Beni, 2021).
Starting from the idea of conserving biodiversity and especially grasslands with High Natural Value, a series of studies describe the methods and classification systems used for the global biogeographical characterization of grassland types (Dixon et al., 2014; Cojocariu et al., 2019). The development of applications and working methodology with satellite images offers multiple possibilities for their use also in terms of: analysis of the composition of grassland vegetation (Schmidtlein and Sassin, 2004; Harshit and Jeganathan, 2019), mapping (Simon et al., 2020), monitoring and management of grasslands (Goldewijk et al., 2007; Jadha et al., 2007; Schuster et al., 2015; Iftikhar et al., 2016; Copăcean et al., 2020), the study of biophysical parameters at the biome level, the analysis of productivity (Gu et al., 2013) or change analysis (Shalaby and Tateishi, 2007).

The purpose of the research is to identify and cartographically represent the areas of grasslands in Arad County (case study), both as a spatial location and as a relationship with the other components of the environment (altitude, slope and so on). Also, through the applied procedures, the aim is to outline the structure of a spatial database that can be used in future research.

2. Materials and Methods

2.1 Study area

The research included in this study is located in Arad County, in western Romania. The natural landscape of this county is characterized by the presence of a storied relief from east to west and is between 80 - 1467 m, resulting in an altitudinal difference of 1387 m (Figure 1). The largest extension, within the studied region, has the altitudinal class between 100.1 - 300 m, with an area of 7.467.598 ha, which represents 60% of the total area.

![Figure 1. The altimetric balance in Arad County (processing after EEA-DEM, 2021; Geospatial, 2022)](image)

2.2. Work methodology

**Stage 1: the identification of grassland areas** is based on Corine Land Cover (CLC) data, 2018 edition (EEA-CLC, 2020) and pre-existing cadastral data, respectively cadastral plans at a scale of 1:10.000, drawn up in the 1980s, the orthophoto plans from 2014 and the geometries of the plots registered as pastures and hayfields, up to the time of preparing this study, available at the National Agency for Cadastre and Real
Estate Advertising (ANCPI, 2022). Using the ESRI ArcGIS software (ArcGIS Documentation, 2022), from the CLC database, the class "pastures" (code 231) and natural grasslands (code 321) was extracted and additionally, pastures and hayfields included and to other categories such as complex crops, predominantly agricultural vegetation, shrubs and so on (code 242, 243, etc.) (Figure 2).

Figure 2. Hierarchization of the CLC database and extraction of grassland areas (processing after EEA-CLC, 2020)

**Stage 2: detailed study** - correcting and validating the geometries of the grassland plots. It consisted in importing the .shp file into the AutoCAD software, a file that was superimposed on the orthophotoplans of Arad County in order to visualize the spatial dataset and "adjust", through vectorization, some inconsistencies between the orthophotoplan and the CLC database (Figure 3). Thus, a much more precise spatial database was obtained than in its initial form.

Figure 3. Processing of the CLC 2018 database in the CAD environment (processing after EEA-CLC, 2020; ANCPI, 2022)

The analysis is based on the CLC data, where the category boundaries were drawn at the minimum unit of 25 ha, but this minimum value was increased by using high precision data.

In order to increase the accuracy of the data, the geometries of the grassland plots were also corrected according to the cadastral plans at a scale of 1:10000, available at the administrative-territorial unit level (Figure 4).
In the specific GIS vector format (.shp), automatically, the surfaces of each spatial entity and implicitly the total surface were calculated.

**Stage 3: multicriteria analysis of grasslands.** On the basis of the Digital Elevation Model (EEA-DEM, 2021) with a spatial resolution of 25 m, altitudinal floors with a gap of 200 m were established. By overlaying and processing the data, the altimetric distribution of the grasslands and their weight in each floor was obtained altitudinally. On the same principle, the grasslands were analyzed by slope groups and vegetation zones, with the specialized bibliography as cartographic support.

**Stage 3 – analysis of grasslands according to altitude, slope and vegetation formations.** Based on the Digital Elevation Model (DEM) with a spatial resolution of 25 m (EEA-DEM, 2021), altitudinal levels were established with a gap of 200 m. By overlaying and processing the data in the GIS environment (Tabulate Area, Zonal Statistics as Table) the altimetric distribution of meadows and their weight in each altitudinal level was obtained. The slope map (in degrees) was generated from the DEM, which was later reclassified into nine slope classes; thus, based on the same technical protocol described previously, the analysis of grasslands by slope groups was carried out. For grouping the grasslands according to the vegetation zones, cartographic support from the specialized bibliography was used, namely the Map of grassland formations (Puşcaru – Soroceanu et al., 1963), on which, after scanning, the vectorization and completion of the database was done.

### 3. Results and Discussion

The graphic database in which the grassland areas of Arad County are included consists of a number of 1335 entities, with a total area of 101372 ha, which means that 12% of the county's area is covered with pastures and hayfields. The cartographic representation of grasslands is exemplified in Figure 5. A simple visual analysis shows that the share of grassland areas is lower in the western part of the county because arable land predominates in that area.

In the spatial distribution and typology of grasslands, one of the most important factors is the relief, which, through its characteristics (altitude, slope and exposure of the slopes), exerts both a direct and indirect influence. For example, the orientation of the slopes influences the amount of radiation, temperature and humidity of the soil, elements that influence the growth and development of plants (Lieffering et al., 2019). Also, the exposure and slope influence the distribution of species (Bennie, 2003; Lieffers and Larkin-Lieffers, 2011), but also productivity (Gonga et al., 2008).

In the case of the territory analyzed in this study, the share of grasslands on altitudinal steps, but also on each altitudinal floor, is represented in Figure 6. The analysis of Figure 6 highlights the predominance of grasslands in the second altitude class, the one between 100.1 - 300 m. In this altitude range, grasslands occupy an area of 56737 ha.
The first altitudinal class, between 80.1-100 m, occupies the second place as the degree of occupation with grasslands, the total area of grasslands in this level being 33554 ha.

In the altitudinal interval 300.1-600 m (third class) a considerable decrease in grassland areas is observed, reaching 8768 ha.

Figure 5. Map of grassland areas in Arad County (processing after EEA-CLC, 2020; EEA-DEM, 2021; Geospatial, 2022)

Figure 6. Areas of grasslands on altitudinal floors (processing after EEA-CLC, 2020; EEA-DEM, 2021; Geospatial, 2022)

The fourth altitudinal class, running between 600.1-800 m, occupies the fourth position with an area occupied by grasslands of 1196 ha.

With the increase in altitude, a decrease in the areas occupied by grasslands is observed. Thus, in the range of 800.1-1000 m, grasslands occupy only 158 ha.
In the last two classes, those between 1001-1200 m and 1201-1467, the areas occupied by grasslands fell below the threshold of 100 ha.

The share of grassland areas on altitudinal levels is presented in Figure 7.

![Figure 7](image)

**Figure 7.** The proportion of grassland areas on altitudinal levels

From the analysis of the distribution of grasslands by altitudinal levels, we can see that the first two places are occupied by levels 1 and 7 with 32% and 24%, respectively.

For floor 7 this happens due to the fact that the floor has a very small area of 534 ha and a grassland area cover of 90 ha. The distribution on the other floors decreases from 18% for the 2nd floor to 3% for the 6th floor. According to Figure 7, a weight of 10% is observed for the 3rd floor, 8% for the 4th floor and 5% for the 5th floor.

The slope is one of the most used geomorphometric parameters, there are correlations between it and the intensity of some geomorphological processes (surface erosion, landslides, collapses).

Map of geodeclivity, which shows the inclination of the earth's surface to the horizontal, is shown in Figure 8.

![Figure 8](image)

**Figure 8.** Grassland surfaces superimposed on the geodeclivity map (processing after EEA-CLC, 2020; EEA-DEM, 2021; Geospatial, 2022)
Relative to our study area, the value classes of the slopes were set between the minimum value of 0° and the maximum value of 53°. Thus, we opted for a number of nine classes: 0° - 2.86°, 2.92° - 5.71° - slopes with very low inclination; 5.76° - 8.53°, 8.58° - 11.31°, 11.37° - 14.04° - slopes with low inclination; 14.09° - 19.29°, 19.34° - 26.57° - slopes with medium inclination; 26.61° - 36.87°- steep slopes; 36.9° - 53.06° - very steep slopes.

We can see that the region has surfaces with a slope especially between 0°-5°. Areas with a geodeclivity of over 30° are less representative of this area, predominating in the eastern part of the area.

In order to represent the formations of grasslands on the territory of Arad County, the "Map with the areas of the formations of pastures and hayfields in the Romania" (Puşcaru - Soroceanu et al., 1963) was superimposed, as there is currently no other unitary map with the vegetation of the grasslands in the analyzed area (Figure 9).

The extraction of spatial data was done as follows: the map was scanned (converted into digital format) and georeferenced, with the Arad County limit superimposed on it. In the next stage, the grassland formations were vectorized (digital - vector conversion) and the descriptive database was created. The grassland surfaces were superimposed on the vector map.

The vegetation formations represented in Figure 9 are at the level of territorial units (complexes of plant associations) with floristic and ecological individuality in the study area. They overlap the relief forms specific to the study area. Thus, according to the classification in Figure 9, the arrangement of the zonal vegetation falls into the following types of grasslands: Grasslands of low plains and low plateaus (0-200-350 m), Grasslands of hills and high plateaus (200-600-800 m, Mountain grasslands (800-2500 m) and Azonal-intrazonal grasslands. In the analyzed area, 32% belongs to the grasslands of low plains and low plateaus, with *Festuca vallesiaca – F. pseudovina – F. sulcata – Andropogon – Stipa sp*

![Figure 9. Map of grassland formations](image_url)
each other in space depending on the mosaic of seasonal conditions in the study area (Anghel et al., 1971; Doniţă et al., 1992; Kovács-Láng et al., 2000; Moisuc et al., 2010; Sărăţeanu et al., 2010; Nicu et al., 2018).

4. Conclusions

Through the use of GIS techniques, it was possible to identify and map the areas of grasslands in the study area, according to a work procedure that involved the correction of the pre-existing medium-scale CLC database with aerial images of high spatial resolution and cadastral plans at scale 1:10000. In this way, the representation of grasslands was obtained on a large scale, with high precision and accuracy.

The use of the Digital Elevation Model allowed the analysis of grassland surfaces on a vertical altitudinal gradient, thus making it possible to differentiate grasslands in terms of their typology.

The overlay analysis involved, in addition to the grassland areas, the map of slopes or the map of grassland formations, which means that the identified grassland areas can be analyzed in correlation with other factors, which can influence the floristic composition or the spatio-temporal dynamics of those grasslands.

The application of GIS techniques in the research of grasslands in a given territory, offers the possibility of a holistic approach or for particular cases, depending on the requirements imposed.

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