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Chapter

Deviation from Grazing Optimum in the Grassland Habitats of Romania Within and Outside the Natura 2000 Network

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Abstract

Grassland habitat degradation intensified in the last century worldwide and in Europe. In Romania, substantial areas of biodiverse grassland habitats that persisted due to small-scale farming are now threatened by recent land-use intensification. However, data regarding the deviation from grazing optimum, essential for management plans encompassing both socioeconomic sustainability and environment conservation, are not yet available. To fill this gap, detailed statistics of the stocking rate and its deviation from optimum were generated by spatial modeling techniques. A toolbox was developed to assess such deviations inside or outside the Natura 2000 Network of protected areas. The analysis covered an area of 33529.42 km^2, corresponding to all the Romanian permanent grasslands within the land parcel identification system. The results indicate that over half of this area is degraded, mostly from overgrazing. Less than 10% is not impacted by inadequate livestock density. Of the national grassland area, 17.34% is included within the Natura 2000 protected sites, indicating the substantial overlapping of agricultural and protection activities. For this category, the degraded area is slightly lower than at the national level (50.34% vs. 52.45%). These results can be applied for environmental conflict anticipation and optimal management of grassland habitats to achieve both socioeconomic and conservation objectives.

Keywords: vegetation, carrying capacity, grazing livestock density, grassland degradation, Natura 2000 Network, spatial modeling

1. Introduction

Grasslands are defined as herbaceous vegetation habitats with a low cover of woody vegetation, dominated mostly by grass species (family: *Poaceae*) [1, 2]. They play an important role in livestock farming but also in environmental and biodiversity conservation [3–7]. Therefore, agricultural production and nature conservation

compete for the many different services that grassland habitats provide [8–10]. Although the value of grasslands, from a socioeconomic perspective and for the environmental services provided, is widely recognized, their degradation process is continuous and global [1, 11–13]. Grassland degradation generally implies a negative reduction in biodiversity, vegetation coverage, plant height, and biomass production [14–16]. Also, the deterioration of ecosystem services and functions was also included in this definition [1, 17]. The degradation process generates a series of ecological problems—loss of biodiversity, carbon sink, and water storage capacity—as well as the intensification of soil degradation and dust storms [3, 6, 18].

Worldwide, up to 50% of grasslands are affected by degradation, mainly due to human activities and climate change [12, 13, 19]. Several studies reveal that land-use changes are responsible for up to 66% of the grassland degradation, whereas the climate dynamics account for approximately 20% [13, 14, 19, 20]. At a European level, climate is the primary degradation agent in some areas of Northern and Northwestern Europe and the southern part of European Russia, but in most areas, including Eastern Europe, degradation is mainly caused by land-use issues [13, 21]. Sudden changes in land-use intensity such as overgrazing or abandonment of traditional farming practices are among the main factors identified to cause the degradation of grassland habitats [13, 22–25]. The alteration of agricultural practices (intensification or abandonment), along with the area of degraded grasslands and the associated environmental problems, shows an upward trend [26–28].

The most important policies aiming to manage and mitigate these issues that have been developed within the European Union (EU) are the Common Agricultural Policy (CAP) framework and the Environmental Directives (especially Habitats Directive 1992/43/ECC-HD and Birds Directive 2009/147/EC-BD). For grassland habitats, these policies mainly focus on agricultural production (livestock density) and, respectively, on biodiversity conservation. The CAP directives include livestock density determination according to the grassland carrying capacity, while the Habitats Directive (1992/43/ECC) implements the conservation of the habitats of community importance which were selected according to their structure (floristic diversity) and environmental ecological functions. The favorable conservation status of these habitats must be reached or maintained within all the sites which are included in the European Natura 2000 Network (N2000). The network includes a large number of protected areas (27863 sites), being acknowledged as one of the world's most effective legal instruments for biodiversity and nature conservation, with an important function in conserving Europe's natural capital. It is estimated that approximately 16% of the habitats in N2000 areas depend on a perpetuation of extensive farming practices and especially on maintaining the extensive management of grasslands [29]. In the EU-27, approximately 18% of the permanent grasslands are within the protected N2000 Network [30]. However, the effects of grazing livestock density (stocking rate) on the grassland habitats protected within N2000 sites have rarely been considered so far, particularly the context of their actual spatial overlap. Moreover, for some countries hosting very large areas of permanent grasslands in the EU (e.g., Romania), spatially detailed data at the landscape level are not yet available, although the agricultural statistics are reported at the national level by each member state. For instance, the spatial distribution of livestock in Europe was modeled using statistical downscaling of province-level livestock statistics [31], but the possible deviations from the grassland habitats' optimal livestock density (carrying capacity) are not yet assessed.

This paper aims to evaluate the degradation status of grassland habitats by modeling and mapping the grazing livestock density and the subsequent deviations from the optimal grassland carrying capacity within and outside the N2000 sites from Romania. The permanent grassland habitats from Romania are among the

most extensive and diverse from the EU [23, 32]. They cover more than 45,000 km^2, which represents 8% of EU-27 permanent grassland habitats. Only the UK (17%), France (15%), Spain (15%), and Germany (9%) have a larger grassland area [32]. Also, the legally protected Sites of Community Importance (SCI) from N2000 Network which are designed for the conservation of all the habitats enlisted in the HD now cover 16.7% of the EU land surface and 19.5% of Romania's total territory. Detailed knowledge regarding the spatial patterns of grazing intensity within and outside the N2000 sites is therefore needed in order to identify the areas where the intensity of agricultural practices is divergent from optimum and particularly where these and nature conservation efforts overlap. Also, the identification of such areas may serve as a basis for land managers and agriculturists but also for the organizations involved in biodiversity conservation to better design the grazing patterns and protection measures in order to avoid grassland degradation either by intensification or abandonment. In the context of the high value of grassland habitats, both from socioeconomic and ecological reasons, this approach provides a meaningful perspective on the relationship between agricultural land values and nature conservation for all relevant stakeholders. This insight could further support policies aiming at a future conflict-free combination of agricultural production and nature conservation. Detailed statistics regarding the deviation from the optimal livestock density were generated by spatial modeling techniques in a geographic information system (GIS) environment. A GIS toolbox was developed for the spatial modeling of these deviations inside or outside of the protected areas. This can be used for the environmental conflict anticipation and subsequent management of the grassland habitats so that both socioeconomic and conservation targets are achieved.

2. Materials and methods

2.1 Study area

Romania (area 238397 km^2; capital Bucharest 44°25′57″N, 26°06′14″E) is located in Southeastern Europe, bordering on the Black Sea and the Danube, with the Southeastern Carpathian Mountains in its center (**Figure 1**). The natural landscape includes almost even proportions of mountains (31%), plains (33%), and hills (36%) that expand rather uniformly from the mountains, reaching elevations above 2500 m, to the Danube Delta, a few meters above sea level. The climate is transitional between temperate and continental. The average annual temperature goes from 11°C in the south to 8°C in the north. Annual precipitation decreases eastward and downward, averaging up to 1010 mm in some mountainous areas, 635 mm in the Transylvanian Plateau, 521 mm in Moldavia, and only 381 mm in Dobruja and close to the Black Sea.

The Corine Land Cover dataset [33] reports for Romania the following land cover classes: artificial areas (5.34%), arable land and permanent crops (39.37%), pastures mosaics (17.65%), forested land (31.68%), seminatural vegetation (2.78%), open space and barren soils (0.10%), wetlands (1.35%), and water bodies (1.69%). The General Agricultural Census in Romania, performed in 2010, indicates that the permanent grasslands cover 44940 km^2, including both grazed pastures and hay meadows, that together make up about 33% of total utilized agricultural land [32, 34]. The greatest surface covered by permanent grasslands is in the Carpathian Mountains region and in the Transylvanian Plateau, where every county has between 1000 and 3500 km^2 of grassland.

The geomorphological and climatic diversity of Romania, the geographical position at the intersection of several floristic provinces, and the extensive traditional

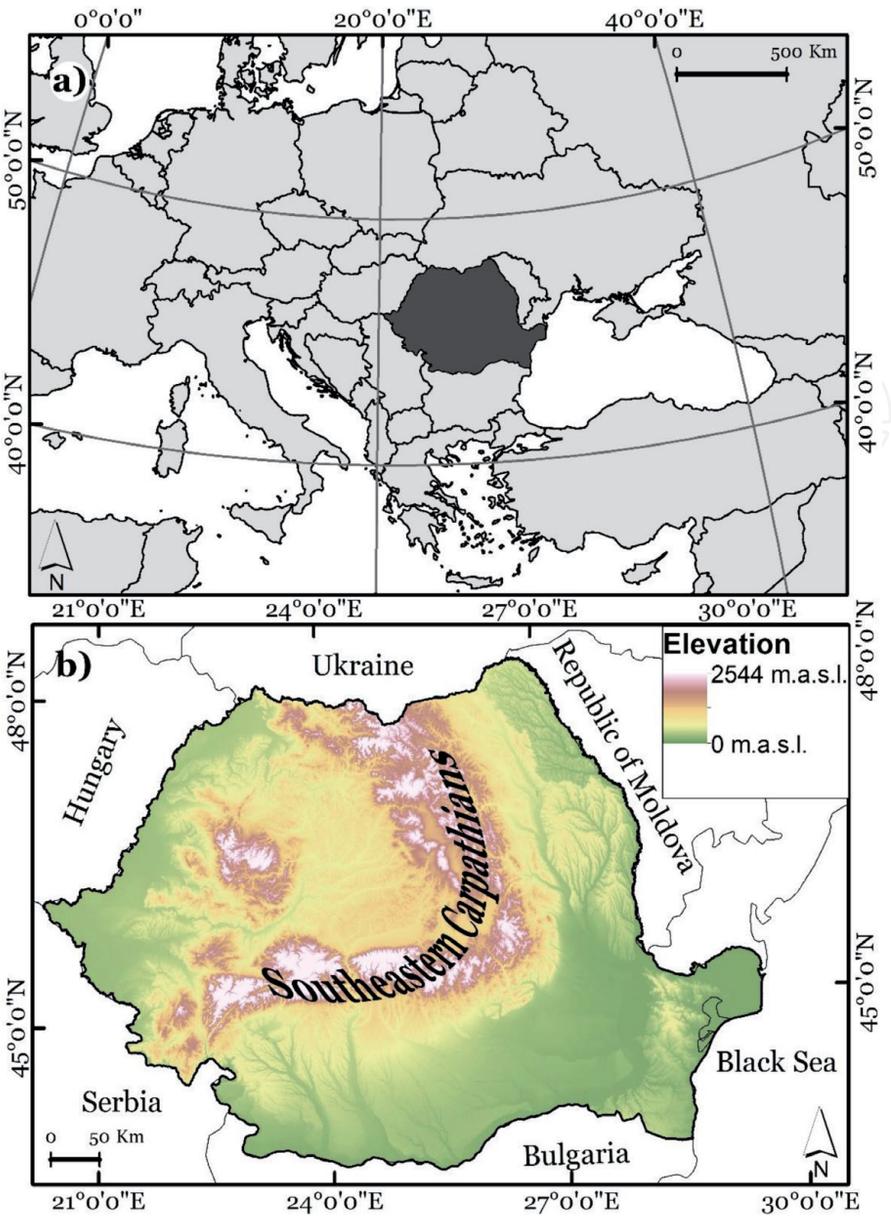


Figure 1.
The geographical position (a) and the elevation model (b) of Romania.

land use all contribute to the vegetation diversity [35, 36], reflected also in the large variety of grassland habitat types [4, 37, 38]. Most herbaceous vegetation types (except ruderal) are comprised in 15 N2000 grassland habitat types [39, 40].

The Romanian grassland habitats are diverse, including dry grasslands, mesophilous grasslands, high-mountain grasslands, and wet grasslands. The detailed description of the floristic structure specific to these vegetation types can be found in phytosociological studies [41] and the Romanian grassland inventory [42]. According to the latter source that mapped an area of 3900 km^2, the best-represented habitat types were mesophilous (39.1%, mostly *Arrhenatheretalia* vegetation order) and dry grasslands (38.2%, mostly *Festucetalia valesiacae*), followed by high-mountain grasslands (12.7%, *Nardetalia*, *Caricetalia curvulae* etc.), wet grasslands (5.35%, mostly from *Molinietalia*), and ruderal-degraded grasslands (4.2%).

2.2 Data and spatial modeling

The spatial distribution of the deviations from the optimum livestock density (DEV_{OLD}) was modeled in GIS in order to quantify and map its effect on the

grassland habitat degradation status throughout the grassland habitats from Romania. The data presented in **Table 1** were geoprocessed in ModelBuilder, and a GIS toolbox was developed for analyzing the DEV_{OLD} (grazing carrying capacity). All the GIS processing and spatial analysis were performed using ArcGIS 10.5 [43].

This study encompassed all the permanent grassland polygons (GP) (33529.42 km^2) which are included in the Land Parcel Identification System from Romania [44]. The permanent grassland area is the land used to grow grasses or other herbaceous forage that is not subject to crop rotation for at least 5 years or longer [32, 34, 44]. Also, the data regarding the area (40451.91 km^2) covered by all the 435 Romanian Sites of Community Importance (ROSCI) was included in the model. The dataset with the numbers and types of livestock from each TAU was downloaded from the National Statistics Institute of Romania [34]. The total number of the different livestock types (animal heads) was recorded during the General Agricultural Census from 2010 for 3177 TAUs from 41 counties. Only the following types of grazing livestock were included in the analysis: cattle (dairy and beef), sheep, goats, horses, donkeys, and mules. Livestock numbers were converted into livestock units (also called animal units) using specific coefficients indicated in the official Romanian guidelines [45]. The livestock unit (LU) is a reference unit which facilitates the aggregation of livestock from various species and ages. One LU is the grazing equivalent of one adult dairy cow producing 3000 kg of milk annually, without additional concentrated foodstuff. According to the transformation coefficients from the national regulations [47–49], the formula and coefficients used for the conversion of the animal numbers and types in number of LUs (for each TAU) is:

$$\text{LU number} = \text{Cattle Number} + (\text{Sheep Number} \times 0.15) + (\text{Goats Number} \times 0.15) + \text{Horses Number} + (\text{Donkeys \& Mules Number} \times 0.4) \quad (1)$$

Input data	Data source
Permanent grassland polygons (GP)	Land parcel identification system from Romania [44]
The polygons of territorial administrative units (TAU)	http://geoportal.ancpi.ro/geoportal
The polygons of N2000 Sites of Community Importance (ROSCI)	http://www.mmediu.ro/articol/date-gis/434
Digital elevation model (DEM 25 m)	Digital elevation model over Europe (EU-DEM) https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem#tab-gis-data
Livestock numbers and types from TAUs	National Statistics Institute of Romania—The General Agricultural Census 2010 [34]
Coefficients for the transformation of different animal types in livestock units (LU)	The official regulations in Romania regarding the methodology for the evaluation of the optimal livestock density per hectare [45, 46]
Optimal livestock density for socioeconomic production (OLD_E)	The official regulations in Romania regarding the grazing management plans and grassland experts [47–49]
Optimal livestock density for biodiversity conservation (OLD_B)	The upper limit/level for the optimal livestock density recommended by various studies for biodiversity conservation in Central and Southeastern European countries [21, 50–54]

Table 1.
The input data for spatial modeling of the deviations from the optimal livestock density within and outside the N2000 sites from Romania.

The total livestock density (LD) measures the stock of animals, expressed in LU, per hectare of permanent grasslands. LD was calculated considering the total number of LUs from each TAU divided by the total area of permanent grassland of the respective TAU. Since there are no available data regarding the spatial distribution of the LD within each TAU from Romania, the LD (LU/ha) was calculated for the permanent grassland area of each TAU. Also, this approach is supported by the fact that a single grazing management plan is designed for all grassland parcels at the TAU level [45].

The difference between the current LD of a grassland and the optimum livestock density for the respective area and conditions represents the deviation from OLD. The equation for generating the deviation from optimum livestock density (DEV_{OLD}) in each grassland polygon is:

$$DEV_{OLD} = \frac{LD \times 100}{OLD} - 100 \quad (2)$$

LD is the livestock density as livestock units/hectare (LU/ha); OLD is the optimum livestock density for the grassland polygon.

The areas where the deviation from the DEV_{OLD} is at most plus or minus 10% are considered not impacted. The fragments of grassland habitats where the DEV_{OLD} is between 10.1 and 50% (plus or minus) are considered partially impacted. Those where DEV_{OLD} is over 50% (plus or minus) are considered to be subject to a major impact, and degraded because of inappropriate livestock densities [48, 49]. Impact and degradation can be caused both by overgrazing and abandonment. In the first case, the grass cover decreases and allows the expansion of ruderal species that are good competitors but have a low forage value, or, worse, the soil is stripped of vegetation, favoring erosion. In the second case, the abandonment of grassland usage (as pasture or hayfield) is also harmful, resulting in shrub invasion which decreases grassland biodiversity and finally in the establishment of forest habitats.

Two scenarios were considered for the grassland habitats included in the N2000 ROSCIs. The first one, which was applied for all the grassland habitats of Romania, employs an optimum livestock density considered suitable for the grassland habitat areas with predominant socioeconomic purpose (OLD_E). OLD_E was synthesized from the Guidelines for Elaborating the Grazing Management Plans [47] that takes into account the different ecological and production characteristics of the various grassland habitat types. As a consequence, for each of the three main altitude belts of Romania, a specific OLD (LU/ha) was assigned, as follows: 0.46 (20–200 m a.s.l.), 0.6 (201–800 m a.s.l.), and 0.9 (801–2544 m a.s.l.).

The second scenario analyzes the prospect of using a lower OLD, favoring biodiversity conservation (OLD_B), for the grasslands situated within N2000 ROSCIs, where lower intensity grazing is recommended [21, 50–54]; in the case of OLD_B, the value of 0.45 LU/ha [21] was employed, although the large range of elevations and ecological conditions from the territory of Romania might require more specific values for different grassland types and altitude belts.

3. Results and discussions

The assessment and mapping of the deviation from the grazing carrying capacity were carried out within an area of 33529.42 km^2 that corresponds to the permanent grasslands from Romania. Our results indicate that 17.34% (5814.75 km^2) of these grasslands are situated within the N2000 ROSCIs (**Figure 2**). This indicates an important overlap between domestic livestock husbandry and nature conservation

within ROSCIs, both supported by the EU within the rural, regional, and environmental development policies. The grazing livestock types (cattle, sheep, goats, horses, donkeys, and mules) from each TAU, presented in **Figure 2**, depend on these grassland habitats, which are the most important resource for livestock production systems [34]. It is estimated that permanent grasslands provide at least 60% of the forage necessary for cattle and 80% for sheep [49]. The livestock density is considered to be one of the most relevant indicators of grassland degradation status, being strictly connected to both the socioeconomic factors and the ecological carrying capacity of grassland habitats. Overstocking permanent grasslands as well as understocking them until abandonment impacts them and, at high intensities, causes their degradation.

However, the time span between successive grazing events may also be very important besides LD and grazing intensity [31, 55], but it is very difficult to quantify and map at large scale for each individual grassland polygon. Modeling the livestock data reported at the TAU level for evaluating the LD and DEV_{OLD} is the best alternative for the available data, although it has the limitation of assigning the same values and status for all the grasslands within a TAU.

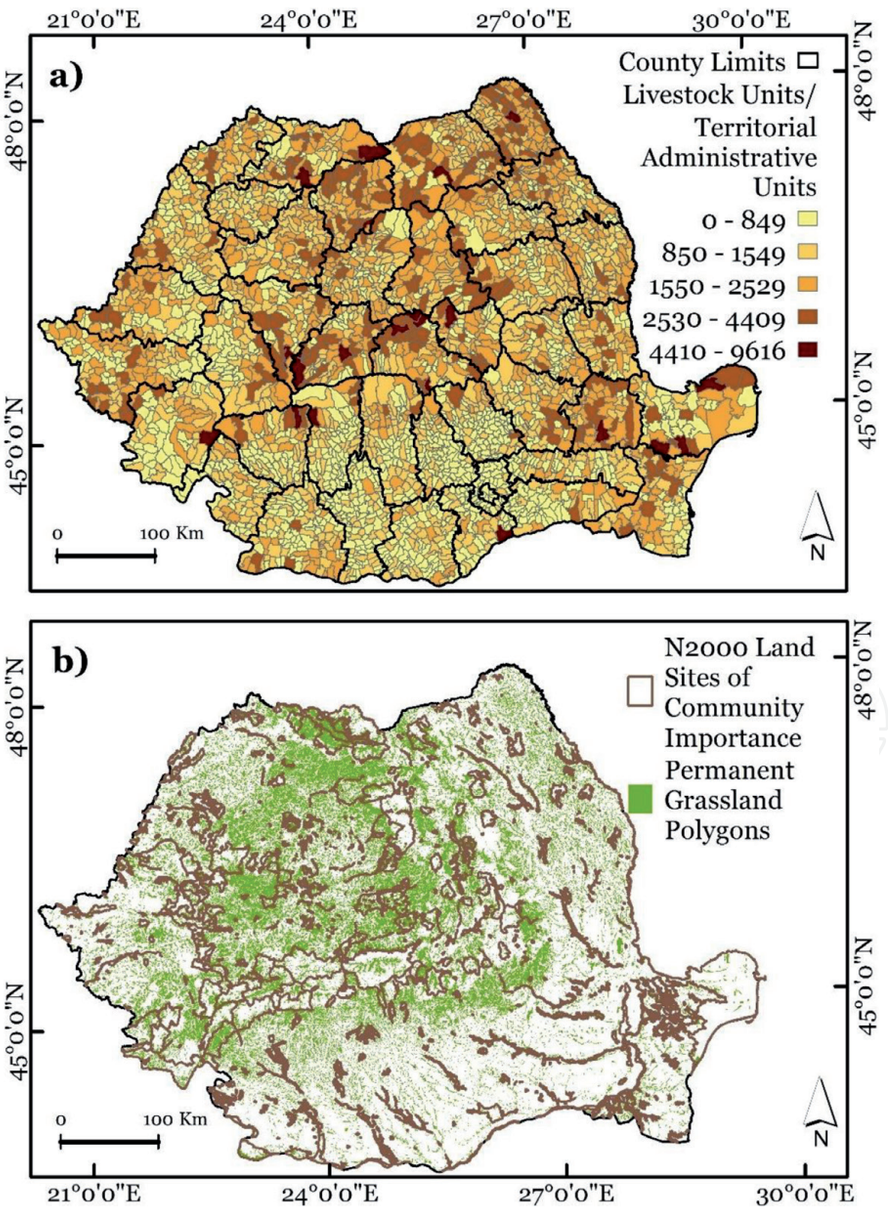


Figure 2.
Livestock distribution in the territorial administrative units from Romania (a). The permanent grassland habitats and the limits of the N2000 Sites of Community Importance from Romania (b).

The geoprocessing steps that were performed and integrated into ModelBuilder in order to identify the status of each grassland polygon regarding the DEV_{OLD} are presented in **Figure 3**. In the first stage, all the input data were processed at the national level. The current LUs and subsequently the LD (LUs/ha), OLD, and DEV_{OLD} were derived for each grassland polygon based on the OLD_E values recommended for each of the three altitude belts from Romania (**Figure 3a**). In the second stage, the resulting grasslands–DEV_{OLD_E} dataset was intersected with the limits of ROSCIs in order to analyze the status of the grassland habitats included within these protected areas (**Figure 3b**). Subsequently, in the third stage, the OLD_B value was input into the model as an alternative to OLD_E for the grassland habitats included in ROSCIs (**Figure 3c**). The developed GIS toolbox with the OLD model is flexible, allowing to easily test a different OLD or to be adapted for any similar case study. As mentioned above, the results obtained from the model are an approximation that considers the LD as having a uniform distribution throughout all the grassland habitats from each TAU. Although the situation within individual grassland parcels might be different, on average it is accurate at the TAU level, particularly taking into account the spatial and temporal dynamics of grazing, the high probability

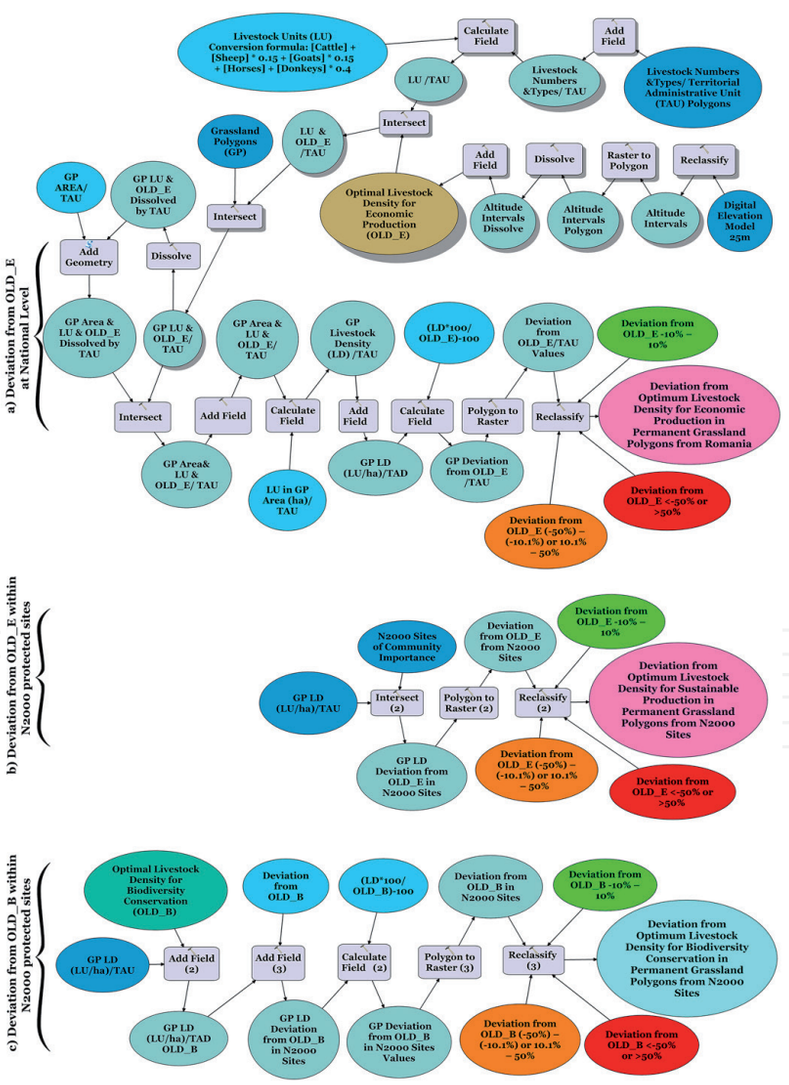


Figure 3.
The models generated for the analysis of the (a) grassland habitats at the national level, using deviations from the optimal livestock for socioeconomic production (OLD_E); (b) grassland habitats from the N2000 SCIs, using deviations from the optimal livestock for socioeconomic production (OLD_E); and (c) grassland habitats from the N2000 SCIs, using deviations from the optimal livestock for biodiversity conservation (OLD_B).

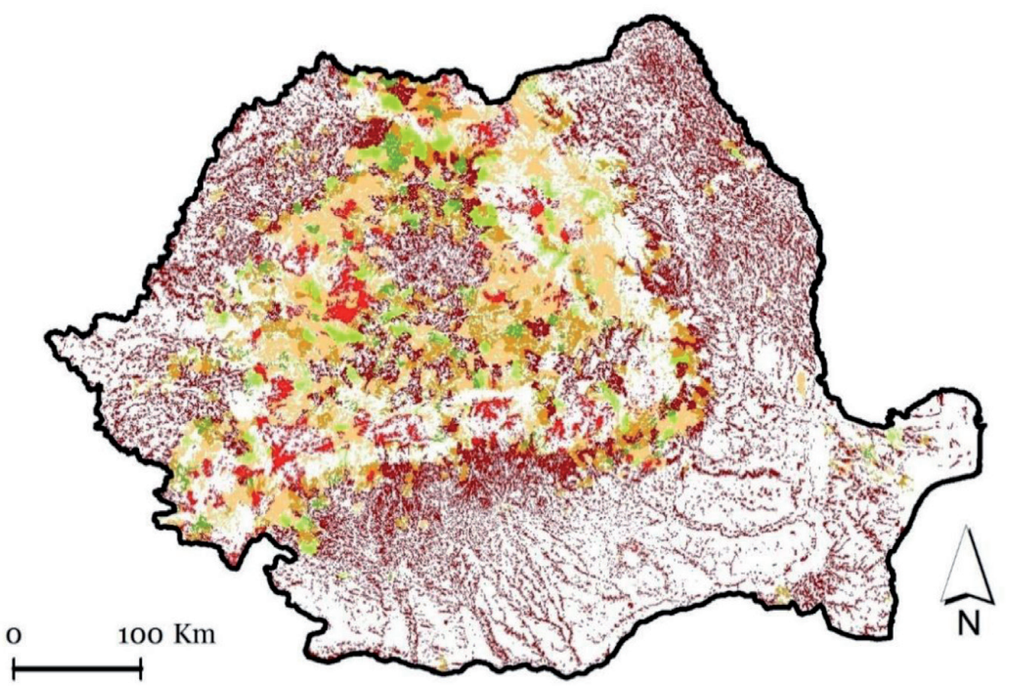
of livestock grazing within the TAU of their owners, and the grazing management plans which are designed at the TAU level.

The assembly of the input data within the OLD model and the used spatial analysis tools are presented below for the grassland habitats situated within and outside protected areas (**Figure 3**).

3.1 Case scenario 1: status of the grassland habitats with the optimal livestock density for sustainable economic production (OLD_E)

This scenario considers the values of the optimal livestock density (carrying capacity) recommended by the Romanian grassland experts for sustainable economic production of biomass [47–49]. Most grazing management studies and textbooks recommend different optimal LDs (stocking rates), but they generally tend to increase with altitude following the available plant biomass.

For the analyzed grassland polygons of Romania (33529.42 km^2), the deviation of the existing livestock density from the OLD_E (**Figure 4**) results in 52.45% of the grassland area being degraded (major impact, current LD with more than 50% over or under OLD_E). The LD was much higher than the carrying capacity (overgrazing impact) for 44.05% of the area, with 8.40% of the area being impacted by abandonment, the LD being far under the OLD. Of the 39.25% grassland habitat area that is partially impacted (10.1–50% over or under the CC), 23.94% has an LD under the optimal value, while 15.31% is moderately overgrazed. At the national level, only 8.28%

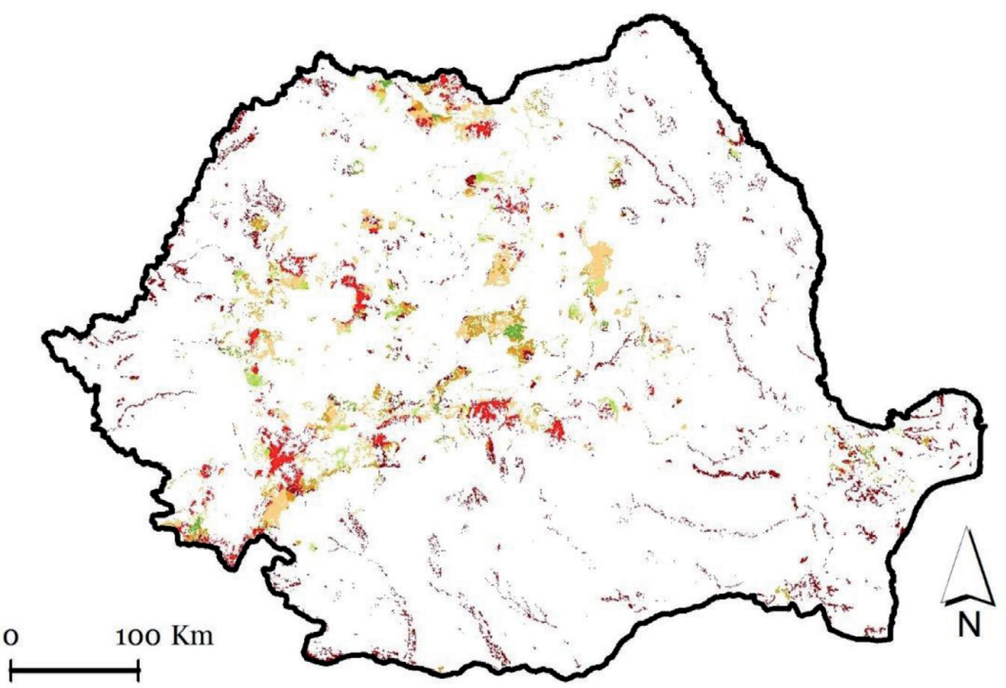


Deviation from Optimal Livestock Density for Economic Production	Grassland Habitat Status in Romania	Percent (%)	Area (km²)
-10% – 0%	No impact - Slight Abandonment	4.91	1645.93
0% – 10%	No impact - Minor Overgrazing	3.37	1131.27
-50% – -10.1%	Partial impact - Moderate Abandonment	23.94	8026.25
10.1% – 50%	Partial - Moderate Overgrazing	15.31	5132.02
<-50%	Major impact (Degraded)- Abandonment	8.40	2817.70
>50%	Major impact (Degraded) - Overgrazing	44.05	14770.09
No Data	No Data	0.02	6.17

Figure 4.
The spatial distribution of impact and degradation at the national level caused by the deviations from grazing optimum for the socioeconomic production scenario; the deviation classes, status, their percentage, and area at the national level.

of the permanent grassland area is not impacted with regard to the carrying capacity, the LD being within the interval of 10% over to 10% under the optimal value, 3.37% being partly overgrazed, while 4.91% of this area being used slightly below the optimal intensity. Although the obtained results concerning the LD distribution and deviation from OLD are consistent with other studies that evaluate the grassland status from Romania [31, 32, 48, 56], they are only supported by the livestock statistical reports, field data regarding the habitat status not being available yet. Validation by grassland experts in the field was only performed for one TAU (Zăvoi) [48] for a model that used the same dataset (livestock units within the permanent grassland polygons of a TAU) to extract the livestock density classes and evaluate the grassland status.

When analyzing the situation of the grassland polygons that are within N2000 ROSCIs, the percentage of the degraded area is 50.33%, slightly lower than at the national level (**Figure 5**). Of this, 30.52% represents areas prone to degradation from intense overgrazing (the current LD being far over the OLD), while in 19.81% of the area degradation is caused by abandonment. The proportion of partially impacted grasslands is slightly larger within the N2000 sites than at the national level, reaching 42.99% of the total area. Most of these grasslands are undergoing moderate abandonment (28.86%), while moderate overgrazing affects an area only half as large (14.13%). A smaller proportion of the ROSCI grasslands—6.68%—are not impacted with regard to this criterion than at the national level. Of these grasslands, those experiencing minor overgrazing and the ones with slight abandonment have similar percentages, 3.22% and 3.46%, respectively.



Deviation from Optimal Livestock Density for Economic Production	Grassland Habitat Status in Natura 2000 sites (SCI) from Romania	Percent (%)	Area (km²)
-10% – 0%	No impact - Slight Abandonment	3.46	200.77
0% – 10%	No impact - Minor Overgrazing	3.22	187.12
-50% – -10.1%	Partial impact - Moderate Abandonment	28.86	1675.35
10.1% – 50%	Partial - Moderate Overgrazing	14.13	820.14
<-50%	Major impact (Degraded)- Abandonment	19.81	1149.76
>50%	Major impact (Degraded) - Overgrazing	30.52	1771.86
No Data	No Data	0.01	0.32

Figure 5.
The spatial distribution of impact and degradation within the N2000 ROSCIs caused by the deviations from grazing optimum for the socioeconomic production scenario; the deviation classes, status, their percentage, and area at the national level.

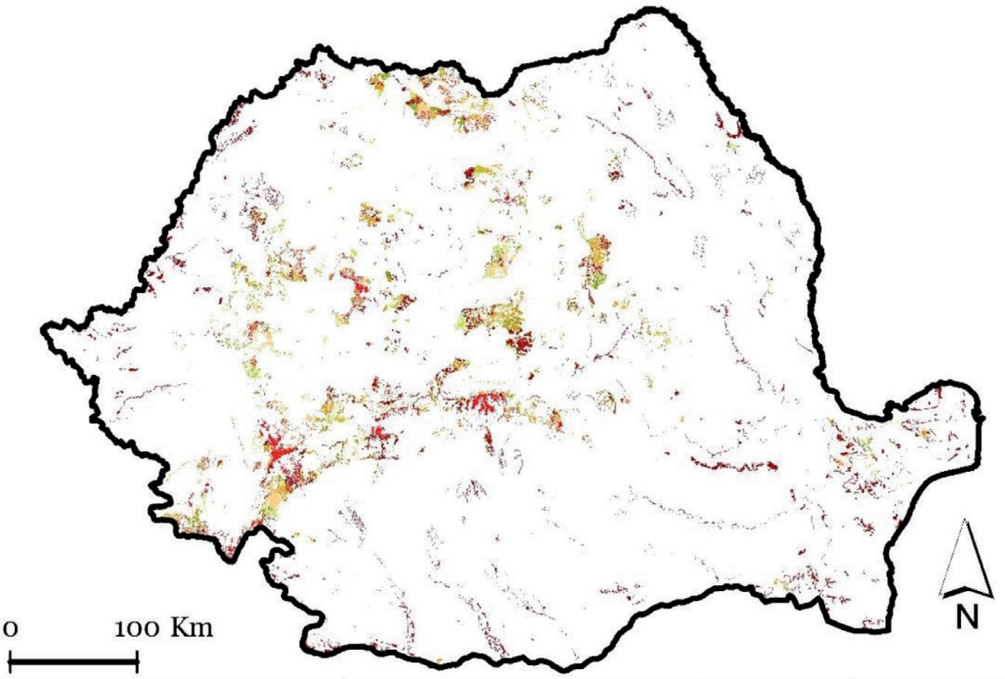
3.2 Case scenario 2: status of the grassland habitats with the optimal livestock density for biodiversity conservation (OLD_B)

For the grasslands included in N2000 ROSCIs, a lower livestock density might be recommendable that has been shown to maintain and enhance biodiversity in similar contexts from Central and Southeastern Europe [21, 50–54]. For the analysis, the value of 0.45 LU/ha was tested, the recommended LD for biodiversity conservation being under 0.5 [21, 50–54]. However, the large range of elevations and ecological conditions from Romania might require more specific values for different grassland types and altitude belts if a more accurate evaluation is desired. In the perspective of this lower optimum LD (**Table 2**), an 8% increase in the proportion of degraded N2000 grasslands appears (to 58.49%), the major impact source being overgrazing, 50.46%, while abandonment contributes with only 8.03% to degradation. The percentage of partially impacted grassland areas is lower than in the previous scenario by 33.35%, while overgrazing and abandonment have almost equal importance in this case (17.91% and 15.44%, respectively). In this scenario, the percentage of the area not impacted is 8.15%, very similar to the nationwide figure for all the grasslands. Of this area, 4.41% is lightly overgrazed, while 3.74% is used slightly below the optimal intensity.

It appears that in the case of the grasslands from N2000 sites, which are important for biodiversity conservation, under the existing LD conditions, a lower optimal LD can be proposed without generating widespread conflicts between the socioeconomical activities and nature conservation. Since the major impacts include both overexploitation and abandonment, in some neighboring TAUs that experience opposite tendencies, sharing the grassland resources and a better distribution of the livestock may be a first, easier step to improve grassland degradation status (**Figure 6**). Our results regarding the areas free from overgrazing are consistent with other studies which revealed that the spatial (geographical) distribution of grazing may be as important as the LD [24, 57, 58]. This means that, beyond good local management of grazing, an optimized, larger scale of grazing management is needed as well. When viewed at a regional scale such as TAUs, where we graze may be as important as how we graze.

DEV_{OLD}	Grassland habitat status	DEV_{OLD_E} in ROSCIs (%)	DEV_{OLD_B} in ROSCIs (%)	Difference
−10 to 0%	No impact—slight abandonment	3.46	3.74	0.28
0 to 10%	No impact—minor overgrazing	3.22	4.41	1.19
−50 to −10.1%	Partial impact—moderate abandonment	28.86	15.44	−13.42
10.1 to 50%	Partial—moderate overgrazing	14.13	17.91	3.78
≤50%	Major impact (degraded)—abandonment	19.81	8.03	−11.77
>50%	Major impact (degraded)—overgrazing	30.52	50.46	19.93
No data	No data	0.01	0.01	0.00

Table 2.
Comparison of DEV_{OLD} percentages between the socioeconomic and biodiversity-focused scenarios in ROSCIs.



Deviation from Optimal Livestock Density for Biodiversity Conservation	Grassland Habitat Status in Natura 2000 sites (SCI) from Romania	Percent (%)	Area (km²)
-10% – 0%	No impact - Slight Abandonment	3.74	216.92
0% – 10%	No impact - Minor Overgrazing	4.41	256.24
-50% – -10.1%	Partial impact - Moderate Abandonment	15.44	896.47
10.1% – 50%	Partial - Moderate Overgrazing	17.91	1039.88
<-50%	Major impact (Degraded)- Abandonment	8.03	466.45
>50%	Major impact (Degraded) - Overgrazing	50.46	2929.12
No Data	No Data	0.01	0.32

Figure 6.
The spatial distribution of impact and degradation within the N2000 ROSCIs caused by the deviations from grazing optimum for the biodiversity conservation scenario; the deviation classes, status, their percentage, and area at the national level.

However, most grasslands in the Eastern European socioeconomic region, similarly to other regions of Europe, within or outside the protected areas, were created and are maintained (along with their biodiversity) by an extensive form of management [4, 21, 59].

4. Conclusions

Since grassland habitats are very important for both socioeconomical and biodiversity reasons, their continuous degradation is a significant and urgent matter. Of the degradation factors, their use for forage/fodder and particularly the livestock density within the grasslands are highly relevant. This is also true for Romania, which hosts grassland habitats that are among the most extensive and diverse from the EU and where data regarding the impact of livestock density that deviates from the optimal value are not available. By combining environmental conservation data and agricultural statistics within a GIS, this paper assessed the grazing livestock density and the subsequent deviations from the optimal grassland carrying capacity within and outside the N2000 sites in order to highlight the areas with higher risk of impact and degradation and help monitor them. The extensive area analyzed, 33529.42 km^2, corresponds to all the permanent grasslands from Romania. The results indicate that more than half of this area is subject to a major impact and degraded, most of it from overgrazing. Only less than 10% of the permanent grassland area is not impacted by grazing livestock. Of the total

national grassland area, 5815.75 km^2 (17.34%) of grasslands were determined to be situated within N2000 Sites of Community Importance, indicating the substantial presence within these protected areas of agricultural activities that are supported within the rural and regional European development policies. The major impact—degraded area—is slightly lower than at the national level by 50.34%, and within the N2000 grasslands abandonment is more important as an impact factor than at the national level. Given the high percentage of N2000 grassland habitats that are prone to major impact and degradation, the use of the lower, conservation-oriented optimal LD (of 0.45 LU/ha) is recommendable in their case. In this scenario, although the proportion of the strongly impacted-degraded N2000 is very similar (49.82%), the cause of degradation shifts toward a predominance of overgrazing, implying a need to reduce the livestock density in these areas. The simplest and most straightforward solution therein is to optimize the spatial distribution of the LD, particularly where neighboring TAUs experience opposite tendencies, abandonment vs overgrazing.

As a further approach, the spatial patterns of grazing intensity presented in the study allow to identify the areas where the intensity of agricultural practices is divergent from optimum and particularly where these and nature conservation efforts overlap. The detailed statistics obtained may serve as a basis for the design of optimized grazing and protection measures to prevent grassland degradation. This insight could further support policies aiming at a future conflict-free combination of agricultural production and nature conservation. The developed GIS toolbox can be used for environmental conflict anticipation and subsequent management of the grassland habitats so that both socioeconomic and conservation targets are achieved, being particularly useful in the case of protected areas. Although the analysis is focused on the Romanian grasslands, the model can be easily adapted to be used for similar situations abroad.

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Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

Anamaria Roman, Tudor-Mihai Ursu, Irina Onțel, and József Pál Frink substantially contributed to the conception and design of this work. Teodor Maruşca, Oliviu Grigore Pop, Sretco Milanovici, Alexandru Sin-Schneider, Carmen Gheorghe, Sorin Avram, and Sorina Fărcaș contributed to the data acquisition and interpretation. Anamaria Roman, Tudor-Mihai Ursu, and Irina Onțel performed the analysis and prepared the first draft of the manuscript. All authors participated in the final drafting of the work. All authors approve the final version of the work to be published.

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