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APPLICATION OF GIS TECHNOLOGY TO ASSESS THE ENVIRONMENTAL SUITABILITY FOR *RUPICAPRA RUPICAPRA* IN ROMANIAN CARPATHIANS

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ABSTRACT:

The chamois (*Rupicapra rupicapra*) is one of the primary mammals on the territory of Romania that still exists nowadays, but one which has restricted its suitable living habitat to alpine and subalpine areas due to global warming and the influence of anthropic factors (poaching, excessive grazing). The main aim of the present study consists of the ecological diagnosis of the fields in the Romanian Carpathians suitable for the chamois by using tools for mapping, as well as the statistical and mathematical analysis of the GIS technology. In order to determine field favorability modelling for the chamois, we used both knowledge expert-type data and official assessments of real actual numbers of specimens, but also, a complete database regarding the main biotic factors (topographic characteristics, hydrographic network, climate characteristics); abiotic factors (the existence of pastures, shrubby and forest vegetation, as well as the presence of feeding areas during winter), and anthropic factors (grazing, mountain tourism). All the hunting grounds at the level of the mountainous area in Romania was analysed in a qualitative and quantitative manner while taking into account the favorability and restriction character of these factors. To validate the modelling results that were obtained, the data from 97 hunting grounds where the chamois is present were used. The main results highlighted the territories situated in the massifs: Rodnei, Retezat, Făgăraș, Pietrosul Maramureșului as being territories that provide the best conditions for *Rupicapra rupicapra*. With these studies at our disposal, researchers may indirectly evaluate the genetic diversity of the species that are already present as well as the repopulation of the Romanian Carpathians' most advantageous areas.

Key-words: *Rupicapra rupicapra, Favourability, GIS, Environmental modelling.*

1. INTRODUCTION

The chamois (*Rupicapra rupicapra*) was a forest animal at its origins. It used to live at the superior limit of the forest (Anderwald et al., 2020) but due to its sensitivity to noises, once human activity started to intensify, the chamois left the forest and inhabited the rocky sides of the mountainous ridges that are hardly accessible. The chamois belongs to the Animalia kingdom, Vertebrata subkingdom, Mammalia class, Ruminantia subordinate, Bovidae family, Caprinae subfamily, evolving from *Pachygazella* sp. The species originates from Central Asia (where it lived approximately 10 million years ago). The first chamois fossils identified in Europe were found about the Mid-Pleistocene (Lovari & Scala, 1980), until the end of the ‘80s, 10 subspecies of one species called *Rupicapra rupicapra* were described. Later, as a result of thorough studies, two Chamois species were described: *Rupicapra pyrenaica* with other three subspecies, and *Rupicapra rupicapra* – this representing other seven subspecies *R. r. asiatica, balcanica, carpatica, cartusiana, caucasica, rupicapra* and *tatrica* (Shackleton, 1997, Pedrotti & Lovari, 1999, Anderwald et al., 2020).

At the present moment, the chamois population is under 500000 specimens (Corlatti et al., 2011). However, a part of the subspecies requires conserving measures, as their number is anticipated to decrease to 20% of the total, due to the extension of the network communication channels, hydroelectric stations situated in mountainous areas that increase the pressures on this species, together with poaching activities (Anderwald et al., 2020).

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In Europe, large numbers of both species exist in France (approx. 16500 specimens) (Roucher, 1987), a migration of the species towards lower areas from the Low Tatra Mountains can be identified (Corti, 2012; Barboiron et al., 2018), in the Cantabrian Mountains (approx. 19000 specimens) (Alados, 1985), in the Abruzzo National Park, in Italy (approx. 650 specimens) (Pellicioli, 2019), in the Tatra Mountains (640 specimens), in the Carpathians (9000 specimens) (Shackleton, 1997), as well as a hybridization of the subspecies *Rupicapra tatrica* in *Rupicapra rupicapra* (Zemanová, 2015). There are major differences between populations from different countries. In some, an increase in the number of specimens was registered (Vogt et al., 2019; Willisch et al., 2013, Reimoser & Reimoser, 2019), whereas in others, there is a decreasing tendency (in Switzerland, from 96000 specimens existing in 2008, the number decreased to 91000 in 2018) (Anderwald et al., 2020), However, a decrease in the number of counted or hunted specimens does not directly reflect a decline of the species (Vogt et al., 2019). At the same time, the differences may also be influenced by the frequency of inventories, economic resources or the number of people that are involved (Forsyth, 2000; Loison et al., 2006; Chantreau et al., 2019). The chamois is an important game species as trophies are highly valued by passionate hunters. Hunting them offers hunters increased satisfaction due to the remarkable landscape provided by the areas situated above the forest limits, but the adventure itself is also satisfying, as the chamois has an excellent sense of sight and it can notice a person in motion from large distances. In order to maintain equilibrium in the mountainous areas with numerous specimens, as in the case of the Alps, approx. 20% of the spring population is harvested (Shackleton, 1997). However, in the Romanian Carpathians, taking into consideration the number of species in the field and their living conditions, the harvesting rates are established depending on the actual numbers of specimens, optimal numbers of specimens at the level of each hunting ground, their natural population growth, but also the necessity of achieving selection for maintaining the best specimens from the genotypic and phenotypic points of view.

At the present moment, in order to determine the ecological diagnosis of the ares where the chamois is present, the rating method is used. With this, we determine a specific score for one area that comprises the surface of the alpine terrain and one surface that is the same with it from the bordering forest for biotic factors (the presence of pastures and shrubby vegetation in the alpine area, the composition of the bordering forest vegetation present in the alpine area, the existence of feeding areas during winter), abiotic factors (the percentage of the area occupied by rocks and heavily rugged terrains, the average temperature between April 25th – June 10th, the quantity of precipitations between April 25th – June 10th, the density of the hydrographic network, the average thickness of the snow cover) and cynegetic factors (the density of the sources of salt, the numerical control of specific predators, the density of dogs and the load on the pastures). To these, we may add negative anthropic factors that consist in poaching (number of cases/year), the density of stray dogs/1000 hectares, as well as the intensity of tourist activities in the area (Law 393/2000).

By applying traditional methodology, all these factors receive one generalized value at the level of a hunting ground. Thus, this implies a specific level of generalization, as well as a specific level of score mediation. Considering this result, we resorted to specific modelling tools and GIS spatial and mathematical statistical analysis techniques in order to attain the objectives of the present study.

One main objective consists in favorability modelling in order to achieve the minimal conditions of existence for the chamois at the level of the Carpathian mountainous area in Romania, while using expert knowledge and official data obtained from the central public authority representatives who are responsible for forestry, like the ministry, specialists in forest administration, NMA structures (National Meteorological Administration), NAEP (National Agency for Environmental Protection), cynegetic hunting ground managers (public or private) and the custodians of the protected natural areas where this specimen is present.

In order to attain this objective, the emphasis will be put creating the databases for the determinant factors and on the analysis of all environmental factors, topographic characteristics (elevation, slope angle, fragmentation), climatic characteristics that include the quantity of precipitation and the air temperature between April 25th – June 10th, as well as the thickness of the snow cover.

At the same time, the land use classes will be analyzed. This time, the emphasis will be put on identifying the shrubby vegetation classes, the fields with pastures, the bordering forest vegetation in alpine areas that provide feeding areas also in winter. Given the high sensibility level of this species regarding noise, a database will be created that will consist of tourist tracks in the Carpathian area, but also of the transport infrastructure that has lately developed in the mountainous area through transmountain roads. This has led to an exceeding anthropic pressure, taking into account the fact that the living habitat of the species is represented by tourist mountainous areas that are highly attractive for mountain tourism.

2. STUDY AREA

The study area is represented by the Romanian Carpathians (a surface of 66286 km^2 which represents 27.8% of Romania). Due to their morphometric characteristics (elevation, slope angle, slope orientation, etc.), these determine an overlap of vegetation with the beech level (600-1200 m), Norway spruce level (1200-1800 m), mountain pine level (1600/1800-2200 m) and with the alpine grassy-vegetation level (over 2200 m) (Coldea, 19990), the last two being the ones we are mostly interested in for the present study (**Fig. 1**). In Romania, the chamois belongs to the category of protected species as it was declared "a monument of nature" even back in 1933. This moment represented an important step in the evolution of this species on a national level. In Romania, the chamois is present in the following massifs: Căpăţânii, Retezat, Făgăraş, Bucegi, Ţarcu, Piatra Craiului, Parâng, Rodnei, Suhard (Ionescu, 2002; Spiess, 2005).

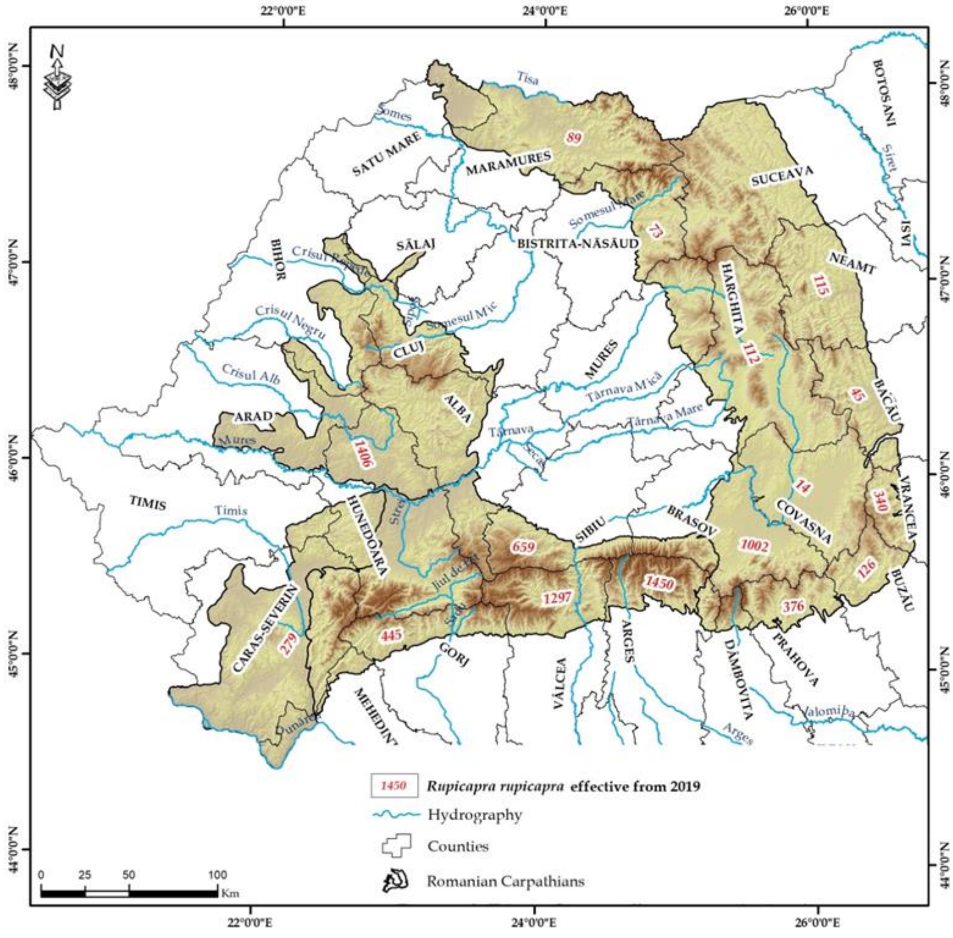

Fig. 1. The geographical position of the study area and the real number of chamois specimens in 2019.

A proportion of 70% of the chamois females reach sexual maturity by the third year of life, whereas the other 30% reach it in their second year. The female chamois reaches maturity quicker than the male chamois by 1-1.5 years (Rughetti & Festa-Bianchet; Anderwald, 2020). The mating period takes place from the middle of October to the middle of November. At lower elevation, the mating period could start one week earlier. At the same time, this period may vary by 1-2 weeks depending on the weather (cold weather quickens mating). The sociability of the chamois is highly pronounced as they generally live in herds. The leading of the herd is taken by a female chamois that already gave birth to one calf; it is usually a more mature female, one that has experience. In Romania, herds of chamois were observed to consist of females and calves, females without calves and males over one year of age. Males between 2-3 years old usually constitute separate herds, whereas the mature ones are generally solitary. The size of the herd increases depending on the density of its number, with the possibility of reaching 10, 20 or even more specimens. In Romania, an average size of such a herd is estimated to be made of 8 specimens.

The food of the chamois is exclusively vegetal, consisting of graminaceae, stems, buds and mainly lichens (*Festuca, Poa, Carex* and *Trifolium* species are very important for the alimentation of the chamois). and from the category of shrubs and subshrubs feeding on species such as: *Coryllus avellova, Juniperus communis, Ribes grossularia, Ribes nigrum, Crataegus monogiyna*. Salt also has an important role together with the water they consume when eating. They are active during the day – feeding before noon and afternoon – lying down at midday.

3. DATA AND METHODS

The chamois is a forest animal that is truly a glacial relict, living with predilection along the superior limit of the forest in the least accessible rocky and steep areas. The presence of the inaccessible steep rocks, intercalated by scrublands of mountain pine and grey alder with rare tree vegetation, then by alpine plains that provide water sources, are mandatory conditions for its existence. Being aware of the requirement of this species for the environmental factors represents the necessary database for the implementation, the processing and the calibration of the current model.

In order to classify the mountainous territory of Romania on favorability classes for the chamois, the creation of a GIS complex database with high resolution is necessary for such interdisciplinary studies, but this must cover the entire Carpathian mountain range. Thus, a complex database was made, consisting of both vector databases (meteorological stations, hydrographic network, cynegetic areas, county limits, land use, etc.) and raster databases (precipitation grid, temperature grid, thickness of snow cover, etc.) which influence individually and cumulatively the favorable and restrictive conditions for the analyzed species (**Table 1**).

It is also necessary to analyze the thickness of the snow cover for the entire Carpathian mountainous range. In this sense, the database consisting of the thickness of snow cover is used for the period 1960-2010, available online for the entire Carpathian Mountain range (Szalai et al.,2013).

The analysis of climatic data is extremely important. Both the precipitation grid and the average annual temperature grid at the level of the Carpathian mountainous range will be used. These databases resulted from generating the specific grids for each parameter while using GIS spatial interpolation techniques and correlation equations between the point values of these parameters and the elevation of the meteorological stations that monitor the Carpathian mountain area, as well as those situated in its proximity, in order to guarantee the continuity of the databases. These climatic data are included in the analysis, as they cause the mortality of some young specimens, predominantly male (because when winter comes, they are already weak as a result of the mating period).

The density of the elementary hydrographic network and its equal distribution in the mountainous area represents an element of favorability, as it provides places with water supply for the chamois. Considering these aspects, the hydrographic network was digitized by using topographic maps for the entire Carpathian area, as the density of the hydrographic network is one of the parameters that was included in the final model of favorability.

Table 1.

Used database.

No.	Database	Type of database	Format	Result
1	Meteorological stations	primary	Vector (point)	Vectorization
2	Precipitation grid in the period April 25th – June 10th (mm)	modelled	Raster (GRID)	Modelled by using as data source: carpatclim
3	Air temperature grid in the period April 25th – June 10th (degrees Celsius)	modelled	Raster (GRID)	Modelled by using as data source: carpatclim
4	The thickness of the snow cover	modelled	Raster (GRID)	Modelled by using as data source :carpatclim
5	Hydrographic network	primary	Vector (line)	Vectorization
6	Land use	primary	Vector (polygon)	Corine Land Cover 2018 Database, v.20, European Environment Agency (EEA) - Copernicus Land Monitoring Service
7	Digital Elevation Model (m)	modelled	Raster (GRID)	Derived from DEM
8	Geodeclivity (slope angle of the terrain)	derived	Raster (GRID)	Interpolation of point values from the terrain
9	Mountain tourist tracks	primary	Vector (line)	Open Street map database
10	Hunting grounds with chamois specimens	primary	Vector (polygon)	Digitization
11	Real number of chamois specimens	primary	attributes	Attribute tables
12	Bordering forest vegetation in alpine area	derived	Vector (polygon)	Corine Land Cover 2018 Database, v.20, European Environment Agency (EEA) - Copernicus Land Monitoring Service
13	Pastures	derived	Vector (polygon)	Corine Land Cover 2018 Database, v.20, European Environment Agency (EEA) - Copernicus Land Monitoring Service
14	Shrubby vegetation in the alpine area	derived	Vector (polygon)	Corine Land Cover 2018 Database, v.20, European Environment Agency (EEA) - Copernicus Land Monitoring Service
15	Rocky landform unit (% from the occupied area)	derived	Vector (polygon)	Corine Land Cover 2018 Database, v.20, European Environment Agency (EEA) - Copernicus Land Monitoring Service
16	The limits of landform units	primary	Vector (polygon)	Geo-spatial.org

At the same time, from the category of limitative factors of anthropic nature, we can notice the degradation of habitats preferred by the chamois, as the touristic activities can determine the fragmentation of living habitats, the change of diet or even the disappearance of sheltering places for the chamois. In this sense, we will use the shapefile of tourist tracks in the Romanian Carpathians by using Open Street Map national database. In order to identify biotic parameters that influence the living habitat for the chamois, we will use Corine Land Cover 2018 database, v.20, European Environment Agency (EEA) - Copernicus Land Monitoring Service. Thus, the polygons will represent the shrubby vegetation, the rocky areas with exposed rock, but at the same time, we will extract the territories with forest vegetation from nearby alpine grasslands from this database, and this will be used in the final modelling of favorability.

The influence of the snow coverage, low temperatures and unavailability of food in the cold season are the main factors that induce morbidity around the mountain ungulates in the Alps where losses of over 6500 chamois specimens were identified within a period of 13 years due to the snow layer and the avalanches (Jonas et al., 2008), The most favorable territories that were identified are those exposed to the sun where accumulations of snow are more reduced (Gonzales & Crampe, 2001). For this kind of studies, the spatial and temporal analysis of the pursued causality are highlighted (Johnson et all., 2008; Boyce et all., 2003, Hysa et all., 2021, Bilașco et all., 2022, Hyka et all., 2022).

The temperature intervenes in the quantity of consumed food, fecundity, growing speed, the arrival to the stage of reproduction, thus influencing the vital processes. Low temperatures, especially when they are correlated with the increase of humidity, may cause losses among the offspring of some game species. Values higher than 4 degrees Celsius for the analyzed period are classified using the best rating notes in the classical methodology as well. This is because the available food resource is extremely important in this period for the female specimens found in their gestation period, while the direct influence of the climatic factors (minimal temperature especially corroborated with high values of mixed precipitation at the beginning of the period) and the environmental conditions are very important for the calf. At lower elevations, where extreme temperatures have little effects and the quantity of precipitation is reduced, greater natural growth of the population can be identified than at the level of territories where these factors induce inadequate conditions, especially in the first days of the life of the calf when the incidence of illnesses is higher. To these inadequate development conditions, we can also add the accentuated parasitism or the existence of a large number of predators (Șelaru, 2000). Heavy rains, snow, floods or droughts influence the life of the game in multiple ways, either by the direct losses they produce or by restricting the access to food. The animals get the water they need to survive directly by drinking or through the food they consume. It is known that there is an interdependence between the faunistic species and the forest vegetation. Thus, the richer the variety of wooden species, the better food and sheltering conditions for the game species. The sum of climatic, edaphic, ecological and anthropic factors may have numerous influences on the health of forests and on the game species from the economic, social or structural organization points of view.

From the category of biotic factors, the factors that are linked to the available food source for the studied species were included in the model by knowing the fact that this species feeds on lichens, grasses and shrubbery, buds, stems, moss, depending on the season (Dumitrescu et all., 2019, Curovic et all., 2020). The role of vegetation in the life of the game is to provide shelter and food. In this sense, the forest vegetation provides the herbaceous plants, shrubs and young species of trees as food source.

The noise produced as a result of traffic is a stress factor for various animal species, such as the bear, the stag, the boars or the chamois (Shackleton, 1997; Switalski & Nelson, 2011). This is the reason why major investments are made in order to carry out the creation of passages for wild animals (Mata et all., 2008) some studies also highlighting the possibility of using drainage culverts (Brunen et all., 2020). Due to disturbances caused by mountain tourism and excessive grazing, a longer movement of the chamois in search for food was signaled which altered the animals' accustomed daily and seasonal pattern of home range use (Hamr, 1988), as the magnitude of avoiding areas with a dense road network increased together with the increase of pressure caused by hunting (Laurance et all., 2006). The attention was drawn to the negative effects induced by the dense system of roads that also infiltrates in the natural protected areas. The reason why this is brought up is the negative potential of reducing the biodiversity that is directly proportional with the extension of the road network that serves rural areas continuously expanding. In this sense, the roads participate at the over-fragmentation of terrains and at a reduction in the quality of landscapes. The level of stress during the season was identified through the concentration of fecal cortisol metabolites (FCM) which in the studies carried out in the Tatra Mountains highlighted higher values in the territories with greater frequency of tourism compared to the protected areas situated at higher distances from the tourist tracks and the road network (Szijacz-Kosica et all., 2013). Thus, the level of stress may reduce immunocompetence and the reproductive output (Apanius, 1998; Mullner et all., 2004). To all these factors, the influence of human beings on the existence of the game is added, as this is felt under multiple aspects, such as the intense hunting, which could lead to the decrease or the disappearance of some game species. The intervention of the human being is reflected through selective harvesting of trophies. Eliminating the mature specimens leads to the structure alteration of a population. Massive deforestation, agricultural practice, intense mechanization and chemicalization have important effects on living habitats, causing imbalance among the game species. All these factors are important to be included in the analysis, but, due to nonuniformity and variable availability at the level of the entire Carpathian mountainous range, these were not included in the assessment in order to avoid local overestimations (Cota et all., 2001).

By applying the GIS geospatial modelling techniques, this GIS database will allow the implementation of a quantitative model of classification on classes of favorability for the chamois, both at the level of mountainous massifs and at the level of detail. Thus, the statistical analysis and the interrogation of the database and of the final result are possible at any moment. The first methodological stage consists in acquiring the previously mentioned databases directly, through vectorization from different data sources, and indirectly, by modelling and spatial analysis, while using specific techniques of conversion and rating. The second aspect consists in the actual analysis of the obtained submodels and the applying of techniques of rating scores for favorability and restriction for every class of each factor included in the model, as well as the result of favorability classes cumulated for the entire analyzed area. Building a complex, interdisciplinary database that includes ecological determinants for the species under analysis, landform characteristics, climatic characteristics, food resources, snow cover thickness is a challenge both for small study areas and for a mountain range as in this case.

4. RESULTS AND DISCUSSIONS

The results obtained from applying the GIS model were materialized in a collection of thematic maps (**Fig. 2 - 9**) which implicitly led us to the possibility of classifying on favorability categories all the hunting grounds from the Romanian Carpathians, as well as at the level of major landform subunits from the analyzed territory. From the category of anthropic factors that influence the living conditions of the analyzed species, rock distribution and slope angles were analyzed, as this species prefers territories where over 50% of the surface of the hunting grounds is represented by with rocks and cliffs with slope angles over 35 degrees. These surfaces will be classified within the present model in the very high favorability class which is found on 32.2% from the studied area (**Fig. 2**). To these, the territories that consist of surfaces occupied by rocks and cliffs up to 40-50%, and the slope angle ranges between 20-35, are added. These are territories that are classified in the high favorability class.

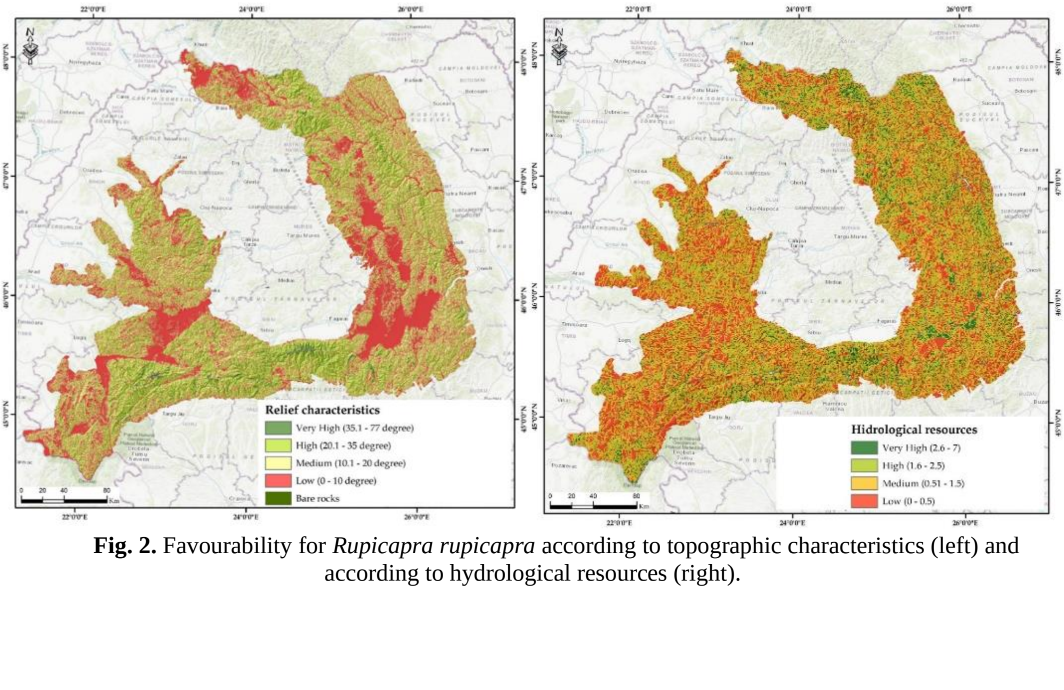

Fig. 2. Favourability for *Rupicapra rupicapra* according to topographic characteristics (left) and according to hydrological resources (right).

The areas with medium conditions are represented by territories characterized by cliffs where rocks occupy up to 30-40% of the territory, and the slope angle is between 10-20.

In order to discover the most favorable territories for *Rupicapra rupicapra*, the water supply available for this species was analyzed at the level of the entire Carpathian mountainous range. Thus, by using G.I.S. spatial analysis techniques, the density of the hydrographic network (km/km^2) determined. This consists of values between 0-4.37 km/km^2, territories with a higher density than 2.6 km/km^2 as well as territories where natural and anthropic lakes are found. These are classified as belonging to the very high favorability class. In this sense, we can notice the compensation provided in the high mountainous area on the surfaces where the hydrographic network does not cover the necessary water supply by the 642 glacial, natural and anthropic lakes.

In order to discover the influence of the snow cover on living conditions for the chamois, the CARPATCLIM database (Szalai et all., 2013) was used. This was used through a process-related snow cover model based on pre-finished CARPATCLIM grids, the application of the snow cover model was not divided among the project members according to their national domains but collectively, by the project associate member ZAMG. Pre-finished CARPATCLIM daily grids of mean air temperature [°C], precipitation sum [mm] and relative air humidity [%] were used as input (**Fig. 3**). For the territory of the Romanian Carpathians, the average of the thickness of snow cover was obtained for the period between October and March. This varies between 6-193 cm thickness, with the highest values being characteristic for the areas present at a higher elevation (**Fig. 3, left**). The territories with the snow cover thicker than 60 cm are classified in the low favorability areas for *Rupicapra rupicapra* because it makes their movement and resistance difficult in the face of their natural predators. The areas with the thickness of the snow cover between 40 and 60 centimeters are classified in the medium favorability area whereas the areas characterized by the thickness of the snow cover between 20-40 or the territories with snow less thick than 20 cm are classified in the areas with the highest favorability for the studied species. Regarding the air temperature between April 25th and June 10th, we may notice that, in the studied area of the Romanian Carpathians, the values of this indicator are classified in the range between 1.8-16 °C (**Fig. 3, middle)**. Temperature levels were classified by using Natural Breaks classification, higher temperatures corresponding to better favorability classes. From the point of view of the quantity of precipitation, we can notice the fact that the entire Romanian Carpathian Mountain range benefits from quantities of precipitation between 9.48-39.12 mm for the analyzed time period (April 25th – June 10th) (**Fig. 3, right**). This precipitation range is not restrictive according to the classic rating norms, but in our study case it was, so the territories that receive more than 30 mm of precipitation for the critical period are included in the low favorability class. Indeed, it is interesting to analyze the quantity of precipitation for the entire Carpathian Mountain range in Romania for the entire year, as this varies between 557-1620 mm/an (Rosca et all., 2019) because the quantity of precipitation will influence the development of herbaceous, shrubby and forest vegetation that constitutes the main food source for the chamois.

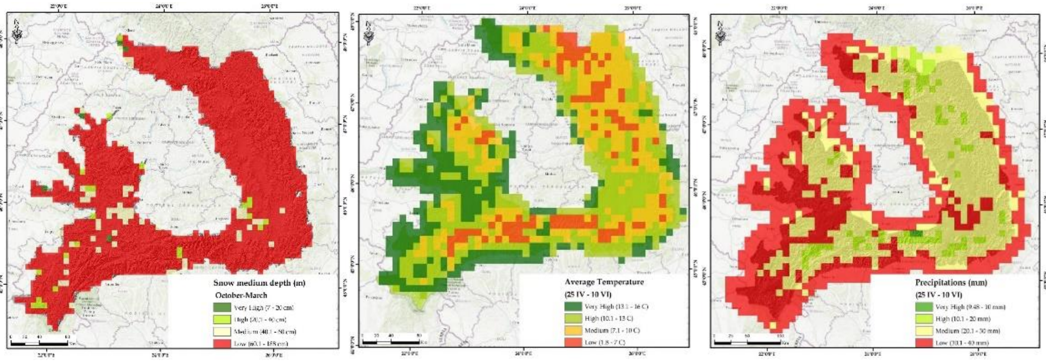

Fig. 3. Favourability for *Rupicapra rupicapra* according to average snow thickness between October and March (left), to average temperature in the period 25 IV – 10 VI (middle), to precipitation in the period 25 IV (right).

By using CorineLandCover database (CLC), we extracted the territories classified in the category of pastures; the territories classified in the category of areas occupied by shrubby vegetation (scrub and/or herbaceous vegetation associations according to CLC, 2018) – these being extended on 2108 km^2 within the analyzed area. To these, we add the areas classified in the category of subalpine vegetation (moors and heathland according to CLC, 2018) that are extended on 739 km2, 5141 km^2 represented by pastures and 5107 km^2 represented by natural grasslands (**Fig. 4**).

Various studies have highlighted the tendencies of increasing pressure on living habitats, especially in the context of future changes regarding land use (Powers & Jetz, 2019). To these factors, the analysis of the afforested areas at the level of the Romanian Carpathians was added. In this sense, the database was used in order to highlight the forests situated in the proximity of the alpine area with a greater consistency than 30%, thus with a stand of trees that presents rare consistency (31-60%), almost full consistency (71-90%) and full consistency (90-100%). Thus, the areas of alpine pastures with bordering forest are classified in the high-est favorability class, as they offer both food source and shelter; the area of alpine pastures and sub-shrubby vegetation is classified in the high favorability class, the bordering forests in the alpine area are classified in the medium favorability class, and the forests situated at elevation lower than 1800 m, together with the pastures situated at medium and low elevation are classified in the low favorability class (**Fig. 4**).

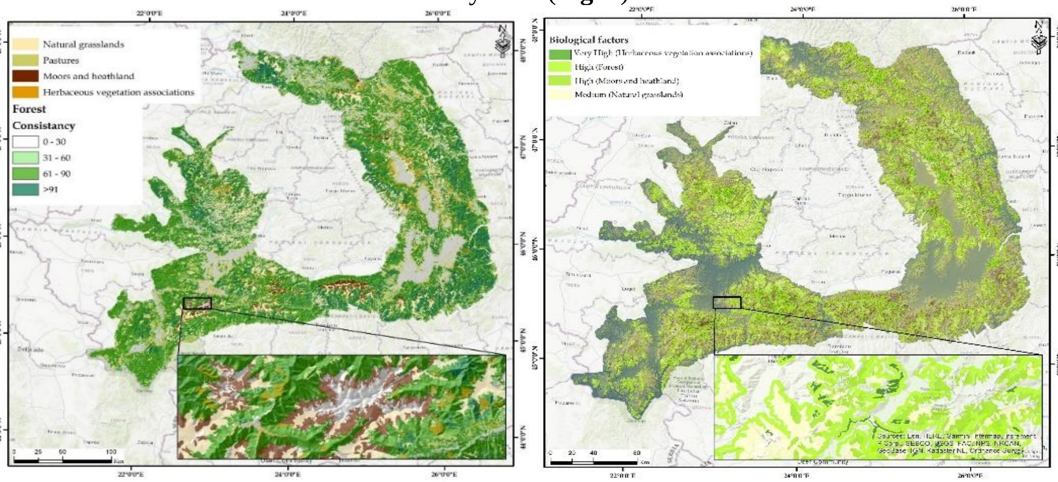

Fig. 4. Favourability for *Rupicapra rupicapra* according to biological factors.

The analyzed species is found in mountainous massifs with rugged landforms, steep slopes (the Făgăraș, Rodnei and Bucegi Mountains), but this species also looks for shelter against unfavorable meteorological conditions and natural pests. Therefore, in areas such as the Retezat Mountains, where the topography offers both morphometric and morphologic diversity, the presence of glacial valleys and lakes, as well as the abundant subalpine vegetation led to a greater number of specimens (Georgescu, 1989; Ionescu, 2002; Sapies, 2005; Dumitrescu et all., 2016). The adaptation of the species to high slopes is well-known, as their hooves are big and cloven and these allow them to move with relative lightness on the rocky areas with high slopes (Ionescu, 2002; Spiess, 2005). The analysis of the behavior of the species is extremely important within these types of analyses. Previously, tendencies of higher frequency among the male specimens on sectors with exposed high slopes were identified, unlike the female specimens with calves that avoid exposed slopes as they are rather looking for shelter (Boschi & Nieverggelt, 2003). However, the areas with high slopes and vegetation are used as escape places, meaning that the female specimens are more sensitive than the male ones (Hamr, 1988).

Taking into consideration the influence of the transportation network on the comfort of mammal species within the mountainous areas, the factor related to the road network, railroad system and tourist tracks was added as a mostly limitative fac-tor for the studied species (**Fig. 5**). By using the Euclidean distance analysis, the studied territory was classified on favorability and restriction classes, while taking into con-sideration the influence of the road network on the studied species.

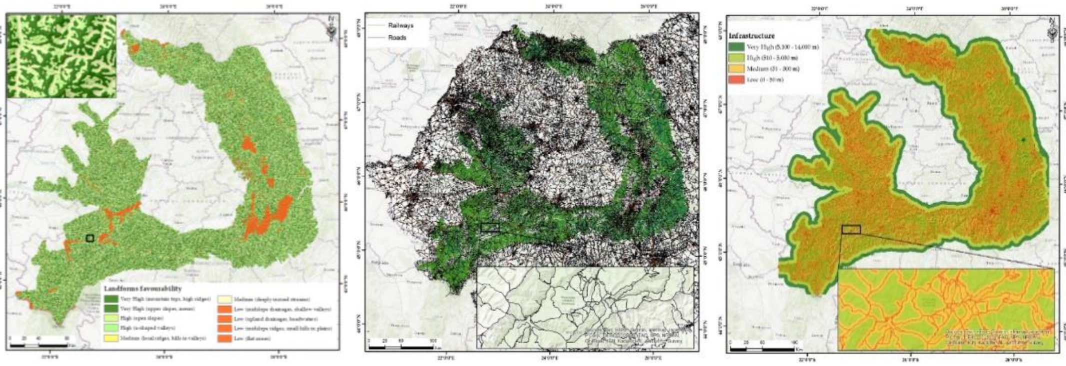

Fig. 5. Favorability for *Rupicapra rupicapra* according to landforms (left), according to the density of the roads (middle and right).

Territories situated in the immediate proximity (up to 50 m) of them, are classified in the most restrictive class, those situated between 51-500 m from it are part of the medium favorability area, those situated between 501-5000 m are part of the high favorability class, whereas the areas situated at higher distances than 5 km present the best living conditions for the chamois (**Fig.5**).

All ecological conditions found under “proper functioning” conditions – food abundance, quietness in the environment of each species, as well as human intervention restricted only to help game species in critical moments, such as epidemic diseases, water and food shortages, or the presence of pests, with no accentuated involvement in the forest ecosystem – may lead to good results in order to have specimens that are healthier and more reliable from a genetic point of view.

5. DISCUSSION

The use of the GIS technology in order to classify the Romanian sector of the Carpathians depending on the level of favorability or restriction for the chamois represents an element of novelty for the spatial modelling studies. However, due to the possibility of integration of spatial databases regarding the accumulation of biotic and abiotic factors that take part in guaranteeing living habitat conditions for the chamois, this is constituted through a modern means, innovative for the interdisciplinary analysis.

As a result of applying the G.I.S. complex spatial analysis model after taking into account the provided input based on expert knowledge-type information regarding the ecological necessities for the analyzed species, the entire Romanian Carpathian mountainous range was classified on favorability classes for the chamois (**Fig. 6**). Thus, the 7900.8 km^2 that represent 20.9% of the analyzed territory are highlighted, as these represent the territories situated in the very high (3848.5 km^2) and high (4052.3 km^2) favorability classes, which provide good living conditions from the point of view of abiotic factors (topography, climate) and biotic factors (mainly represented by an adequate food source). There is also a reduced anthropic pressure from the point of view of reduced density of transportation network, as well as reduced practice of winter sports and tourist activities.

At the opposite pole, territories with high anthropic pressure are identified at a lower elevation in marginal and intramountainous depressions where environmental characteristics rather induce limitative and restrictive conditions for the chamois, but good living conditions for their natural enemies. It is the case of 9000.2 km^2 (23.9 % of the analyzed territory) which are classified in the low (36.6 %) and very low (11.2 %) favorability classes. The advantages of the G.I.S. technology and the cumulated spatial analyses with expert knowledge-type information are successfully used in studies related to the movement of animals (Hooge & Eichenlaub, 1997). As a result of applying the proposed quantitative model, we obtained a global classification of the entire Romanian Carpathians Mountain range on favorability classes for the chamois (**Table 2**) taking into consideration the correlative influence of environ-mental factors, topographic characteristics, forest, shrubby and herbaceous vegetation, as well as anthropic influences on this species.

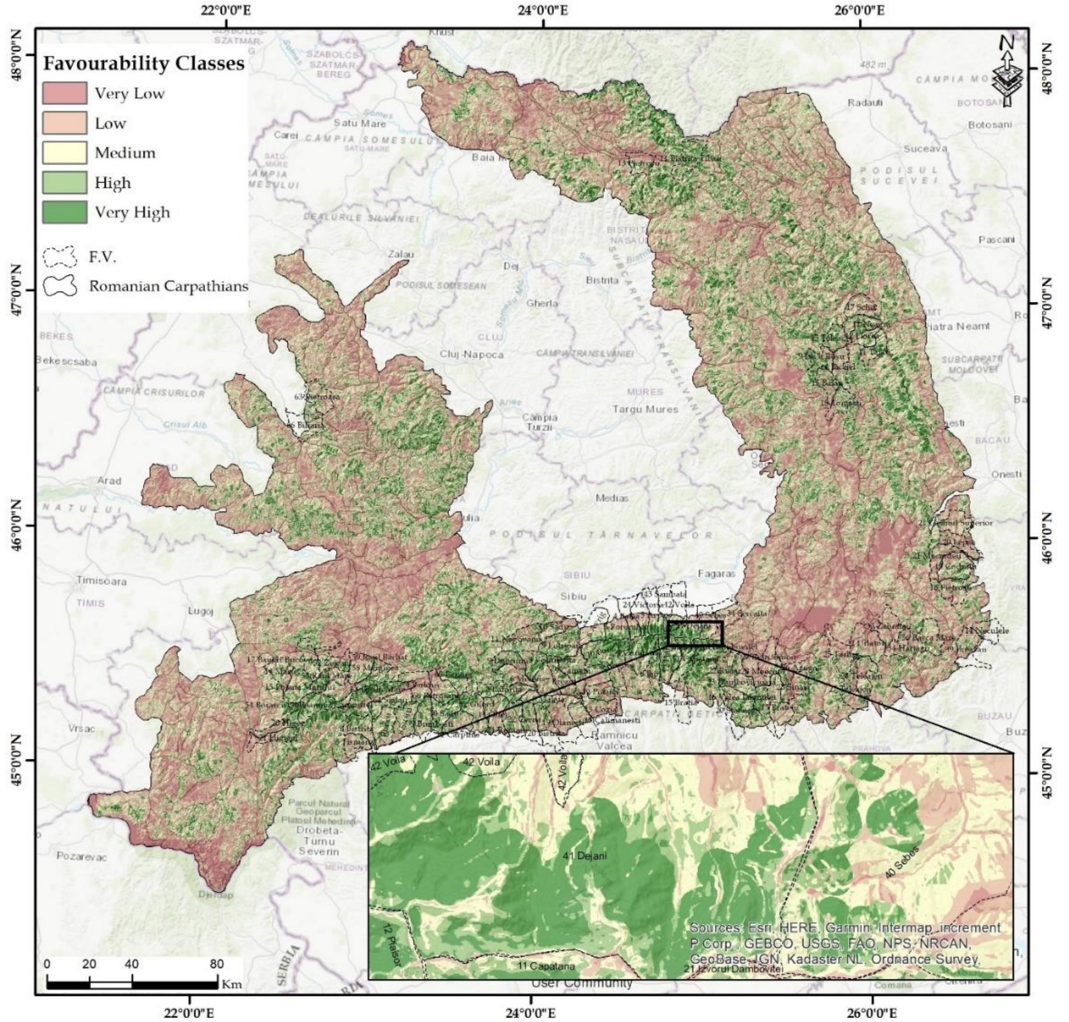

Fig. 6. Favorability map for *Rupicapra rupicapra* in the Romanian Carpathians.

The advantages of using these models, in the detriment of the classic method based on the diagnosis keys for the chamois, mainly consist in maintaining the variability of factors at the level of each hunting ground, for every analyzed factor, as well as for the territorial surfaces found at different levels. At the same time, there is the possibility of carrying out comparative analyses between different massifs which could help us within the regional and national projects and politics, but also within the exchange of information between institutions for an efficient implementation of conservation strategies for the chamois in Romania.

As a result of carrying out this analysis, the hunting grounds were identified as hotspots providing the best developing conditions of the studied species (**Fig. 7**). Thus, hunting grounds are situated in the Retezat Mountains where previous studies have analysed the food resources (raw protein, etheric extract and raw fiber) and high-lighted areas like Gorganu, Negru and Secări (Dumitrescu et all., 2019) or other territories belonging to the Rodnei National Park (Iușan & Filipoiu, 2010). We may notice the fact that, as a result of modeling, extended areas within the well-known hunting grounds in Romania were classified in the very high and high favorability classes due to the high number of chamois specimens. For instance, at the level of the hunting ground 12 Plăișor in Argeș county, 394 chamois specimens were registered in the inventory; the hunting ground in Dejeani presented 231 specimens and 170 chamois specimens were registered in the inventory at the level of the hunting ground 54 Borascu Godeanu in the Retezat Mountains.

Table 2.

Classification on high favourability classes of mountainous massifs with the most extended surfaces that provide favourable conditions for the chamois.

Massif	Favorability classes					
	Very High		High	Medium		
	Km^2	%	Km^2	%	Km^2	%
The Țarcaului Mountains	215.7	10.2	135.1	10.7	331.1	31.3
Rodna Massif	183.1	25.3	155.2	15.9	321.8	38.9
The Călimani Mountains	172.2	19.3	207.9	16.4	616.8	34.0
The Goșmanu Mountains	90.9	10.4	88.7	12.5	252.9	37.1
Fâncel Mountain	87.8	13.3	83.8	13.0	262.8	37.1
Pietrosul Maramureșului Peak	86.8	12.6	44.3	12.0	99.3	37.7
The Țibles Mountains	78.0	25.0	68.7	12.8	169.8	28.6
The Neamțului Mountains	74.7	19.4	83.4	16.4	211.9	39.0
Cearcanu Peak	70.6	12.2	45.5	13.6	68.5	34.5
Mount Cucu	65.0	29.6	83.9	19.0	205.1	28.7
Toroioaga Peak	64.7	10.8	44.3	14.0	102.5	34.2
Hășmaș Massif	63.6	21.4	62.7	14.6	120.7	33.8
The Corbului Mountains	59.8	17.8	43.2	17.6	73.1	33.8
The Suhard Mountains	58.6	26.7	50.4	19.3	95.3	32.7
Mount Saca	58.4	19.2	82.0	16.5	173.4	31.2
The Șumuleu Mountains	56.1	11.1	74.4	15.6	146.2	33.0
Grintiesul Mare Massif	55.4	12.2	44.9	16.2	125.3	31.7
The Bodoc Mountains	54.3	18.9	49.7	15.3	139.8	42.8
The Farcău Mountains	49.3	24.8	34.6	15.3	73.7	35.3
Mount Mădăraș	46.2	16.9	87.8	15.8	203.1	39.7
The Bârgăului Mountains	43.0	6.5	75.9	12.3	342.7	28.5
Nemira Peak	42.4	4.9	36.0	8.7	97.1	39.2
Budacu Massif	39.7	13.8	29.3	12.9	92.4	34.5
Viscolului Peak	36.1	19.1	36.7	14.1	73.5	44.4
Rarău Massif	35.9	13.5	41.5	13.7	137.2	27.5
Giumalău Massif	35.5	8.5	32.2	9.8	74.0	32.5
Tatarcii Peak	35.4	14.6	37.4	13.2	97.7	30.4
Ceahlău Massif	34.8	11.2	35.2	11.8	92.7	30.8

Regarding the determination of the level of predictability for the proposed model within the present study, the value of the ROC curve was determined for the territories at the level of which there are hunting grounds where *Rupicapra rupicapra* specimens are known to live. In this case, the sensitivity of the model represents the true positive rate, meaning that there is the possibility that the studied species benefits from good developing conditions and this can be validated in the field through the direct observations carried out during the inventories.

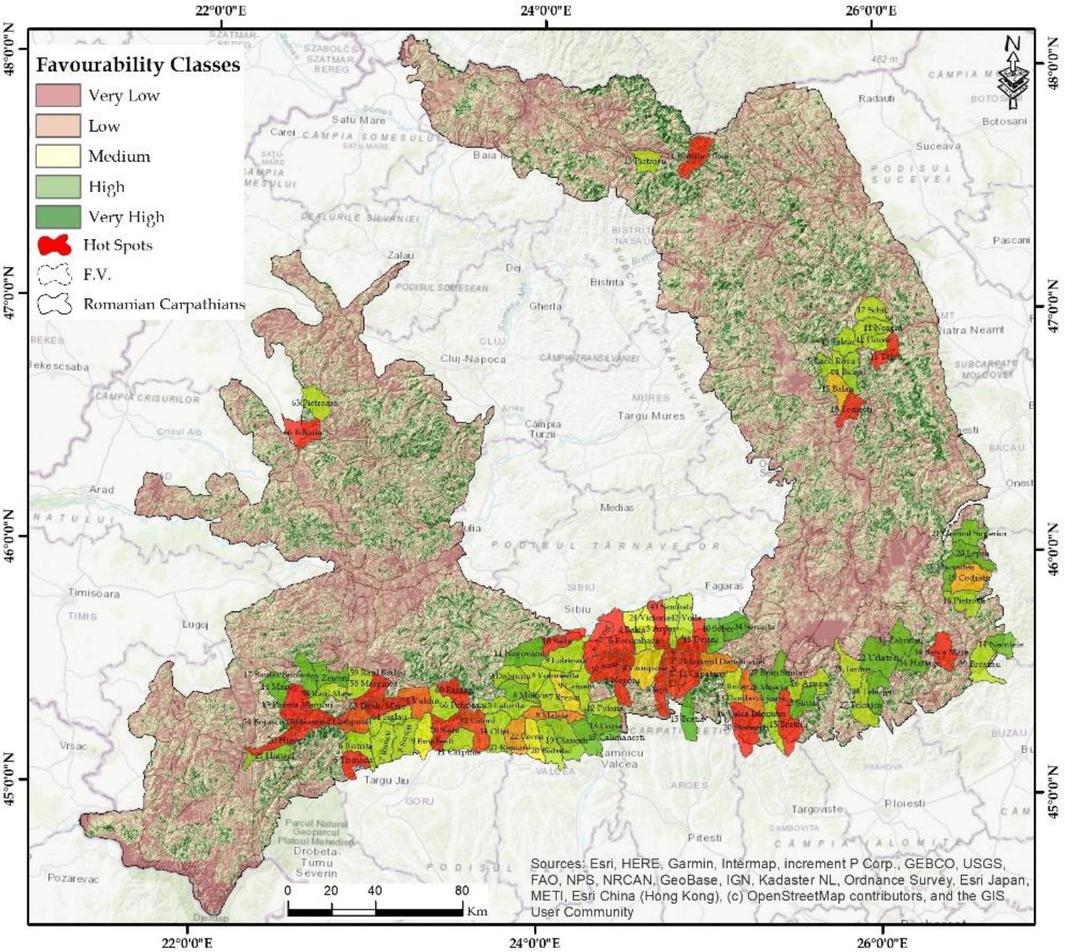

Fig. 7. Hotspot analysis at the level of hunting ground with *Rupicapra rupicapra* herds.

The specificity of the model consists in the probability that the result of the modeling is negative through the invalidation in the field of the existence of the chamois at the level of the areas which are classified by the model in high classes of its existence. Thus, the calculated value under the ROC curve (Relative Operational Curve) is 0.819 (AUC=0.819, 95% confidence interval: 0.71-0.87, p<0.001) (**Fig. 8**).

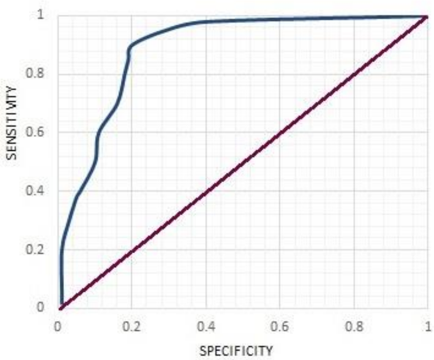

Fig. 8. ROC curve for the model.

This was calculated because we tried to identify the accuracy level of the present model. Thus, a higher value than 0.8 of the area under the ROC curve and its graphical position near the left corner of the system of coordinates indicate a high value of sensitivity and a reduced true positive rate. Thus, we may conclude that the implemented model to determine favorable and restrictive areas for the chamois at the level of the Romanian Carpathian territory has a satisfying precision of the obtained results.

In order to discover the correspondence between the favorability classes provided by each category of factors for *Rupicapra rupicapra* and the modelled classification of cumulated favorability, modelled within the present study, we extracted point values randomly distributed within the hunting grounds where the inventory of the real number of chamois specimens was carried out (**Fig. 9**). Thus, we can notice the enlarged patch for biological factors due to their diversity at the level of the validation area, as well as a high validation rate of the influence of topographic characteristics, especially for the high and very high favorability classes. Indeed, improvements can be brought at the level of the database used in modelling by adding the factors linked to the spatial distribution of natural enemies, the numerical control of specific predators (lynx and wolf) or to the negative influence of poaching. These are aspects that may be improved in future studies on territories that have a reduced surface, so that the generation these high-quality databases may be realistically carried out.

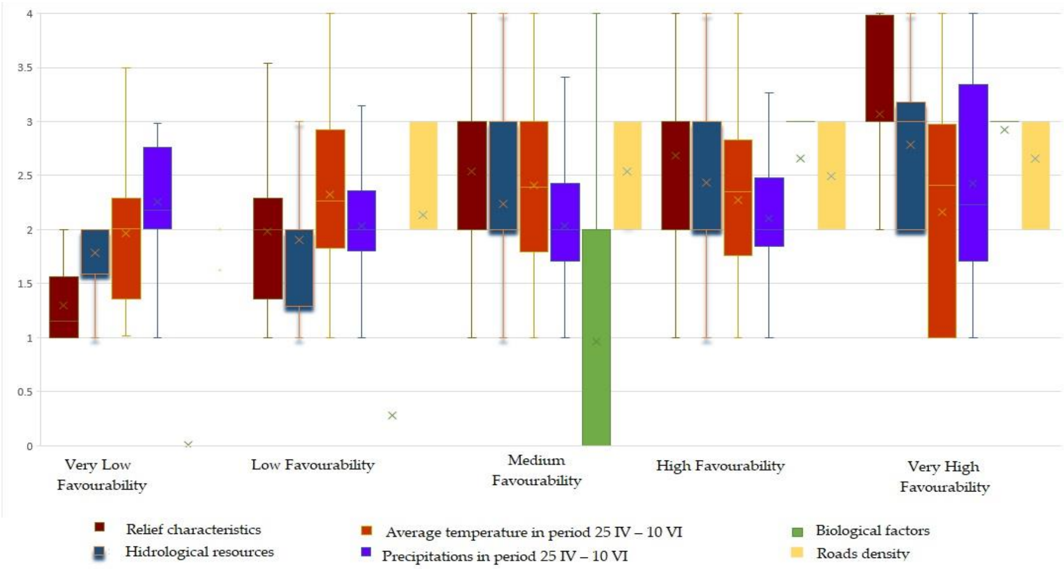

Fig. 9. Comparative box plot of used factors.

6. CONCLUSIONS

The studies that were carried out regarding the number of chamois specimen highlight periods of time when the species faced important losses in the number of specimens, as well as periods when the population increased and the discrepancy between sexes was present. Therefore, we draw attention on the necessity of conserving the numbers of chamois specimens, especially in the places where strict protection is provided to natural predators as well, such as the lynx or the wolf, and on the necessity of identifying those territories that provide good living and developing conditions for the natural growth of the species with respect to repopulation. The constant monitoring of the specimens by using modern investigation methods and by presenting the evolution of the real number of chamois specimens in the Romanian Carpathians may also serve for the sensibilization of various target groups in or-der to bring awareness regarding the negative effects that overgrazing and anthropic interventions have on this species. Thus, this serves at educating the population and it implicitly promotes conservation activities for the species considered to be a symbol for the high mountainous territories. The current strategy applied for the management of *Rupicapra rupicapra* implies measures taken from the administrative offices of the natural parks, the managers of hunting grounds or authorities in such a way that a durable conservation of the species is achieved.

Thus, the present study supports the measures of repopulation/relocation of specimens in areas that provide the best developing conditions for the chamois. To these, stricter regulations are added. These regard overgrazing in the high mountainous areas, the control of natural pests and predators, active involvement in managing the hunting grounds and the involvement of volunteers to create special areas for food and salt sources, as well as the creation of limitative temporary niches for tourist activities in the living habitats of the chamois ‐ aspects that can also be carried out by using modern techniques of spatial analysis and G.I.S. The creation of national GIS databases for the hunting grounds, together with the number of chamois specimens, also represents a strength, thus allowing the updating of databases regarding numbers of specimens, the calculation of density (per hectare, per hunting ground or massif) and, last but not least, it allows the possibility to create some detailed databases regarding the morphometric characteristics of the individuals, their health condition, the presence of illnesses, etc. that may be available for all institutions involved in protecting and conserving this species in Romania. The access to the databases that induce favorability or restriction to the species is extremely important when we aim at the repopulation or revigoration of the species in areas where the chamois population is declining (it is necessary to be repopulated with specimens coming from massifs with similar characteristics), but at the same time when it is necessary to identify potential living habitats for this species. The variables are intrapopulational. In order to reduce errors in the favorability modeling for *Rupicapra rupicapra* and to calibrate the favorability for black goats according to their actual numbers for territories where their numbers are known, we draw attention to the quality of the databases used in the modeling. Future studies aim at carrying out additional measurements for all chamois populations that live in the Romanian Carpathians in order to identify the influence of the level of favorability of different types of habitats on the quality of trophies and the maintenance of genetic diversity of populations.

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