


GIS ANALYSIS OF THE SPATIAL DISTRIBUTION OF EUROPEAN BISON (*BISON BONASUS L.*) IN VÂNĂTORI NEAMȚ NATURAL PARK, ROMANIA, BETWEEN 2014 AND 2019

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ABSTRACT:

The European bison (*Bison bonasus L.*) is a species that has been successfully reintroduced in several European countries and requires ongoing monitoring to protect and restore its biodiversity. This study examines the population dynamics of free-ranging European bison in the Vânători Neamț Natural Park in Romania, taking into account various local biotic and abiotic factors. Data collected from the collars of several European bison from 2014 to 2019, as well as vector maps of the study area, was used for the analysis. Furthermore, the study identifies the influence of slope and altitude on the distribution patterns of the European bison throughout the seasons. While a confluence of biotic and abiotic factors shapes exploration behavior, the study underscores that food supply and land use exert the most pronounced impact on the sustainability and growth of the European bison population. Despite an exhaustive analysis of correlations between various biotic and abiotic factors with recorded temperatures, no significant results reflecting discernible trends or linkages induced by temperature were obtained. The analysis of GPS collar data revealed that, in the research area, the European bison inhabited areas with forest vegetation for about 74% of their time and places without it for 26%. Over 80% of the localization patterns were found in wooded areas, with fewer than 20% found in non-forest areas, year after year. The age class distribution research shows that the European bison have a significant preference (more than 55%) for old-growth forests that are older than 100 years. This preference is present in all seasons except winter, when the preference for these types of forests decreases. On the other hand, forests that are younger and less than 60 years old are preferred in the summer and spring, which offers important information on the diverse habitat preferences of the European bison population.

Key-words: GIS; telemetry; dynamics; forest structure; spatial analysis.

1. INTRODUCTION

Europe's largest land mammal is the European bison, which faced extinction in the wild during the early 20th century. Fortunately, the species was reintroduced to the wild in the latter half of the century, and thanks to sustained conservation efforts, its status has gradually improved. In fact, following a recent assessment, the European bison is now classified as Near Threatened on the IUCN Red List of Threatened Species, (2022). As of the end of 2022, there are 10,536 individuals, with 1,727 in captivity, 584 in semi-freedom, and 8,225 in the wild. (**Table 1**).

The European bison is a crucial species for biodiversity conservation and ecosystem restoration. Its consumption of plants, herbs, and woody species contributes to the maintenance of a varied landscape, creating new ecological niches for other species to thrive in.

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Table 1.

Number of free-ranging European bison in Europe.

European Country	Number of european bison	Percent from the total (%)
Bulgaria	15	0,2
Azerbaijan	27	0,3
Germany	41	0,5
Slovak republic	58	0,7
Romania	256	3,1
Lithuania	280	3,4
Ukraine	395	4,8
Russia	2172	26,4
Poland	2394	29,1
Belarus	2587	31,5
Total free livings	8225	100,0

As a result, the European bison plays a key role in nature conservation by ensuring the preservation of a mosaic structure of ecosystems and landscapes (Jaroszewicz & Piroznikow, 2008).

Despite extensive research, the European bison's preferences for specific habitat types remain controversial and not well understood (Kuemmerle et al., 2018). However, recent trends suggest a reevaluation of the plasticity of this species, revealing a much higher degree of adaptability than previously assumed (Rafał et al, 2023). Initially, it was believed that the European bison relied heavily on forest ecosystems, which is why efforts to reintroduce them to the wild were focused on extensive forest stands (Rafał et al, 2023; Karcov et al., 1903; Pucek et al., 2004; Kerley et al., 2012; Krasieńska et al., 2013, Krasieńska et al., 2014). However, recent research suggests that the European bison is actually a "refuge species" that has been forced to retreat to forested areas due to landscape changes and the impact of human activity, such as the conversion of natural ecosystems into agricultural land. Experts now recommend that the optimal trophic supply for the European bison is a mix of forests with meadows and glades (Kuemmerle et al., 2018; Kerley et al., 2012; Bocherens et al., 2015; Hofman et al., 2019; Kuemmerle et al., 2012a; Kuemmerle et al., 2012b; Kuemmerle et al., 2020).

The European bison is a species that has been reintroduced into the wild for several decades and can only be found in a few locations in Europe. However, despite being present for so long, its behaviour in the wild is not yet fully understood. One area of controversy is the dietary preferences of the European bison. Some studies have revealed that the European bison mainly prefers herbaceous plants (Mendoza et al., 2008).

Adaptation to a forest environment is represented by the ability to digest more developed lignin than other ungulates (Gębczyńska et al., 1974). The utilization of forest species in their early stages, including seedlings and deciduous trees, has been documented with regards to the consumption of bark, wood, leaves, and shoots (Cătănoiu, 2012). Past studies, which were influenced by the theory that the European bison mainly feeds on herbaceous cover, tended to underestimate the importance of forest species in their diet. However, recent scientific research has highlighted a significant percentage of these species in the European bison's diet. GIS simulation models have shown that the European bison was widespread in areas covered by forest stands. This suggests that the consumption of shoots and buds is an essential part of their diet (Kuemmerle et al., 2011).

The seasonal movements of European bison are influenced by the quality and quantity of their food sources, as well as their access to them at different times of the year. The type of ecosystem and its suitability as a shelter also play a role in their movements. Similar analyses have been conducted for both European bison (Hebblewhite et al, 2008; Van Beest et al., 2010) and American bison (*Bison bison*) (Rivals et al., 2007; Thomas et al., 2021). However, detailed information regarding the specific habitat types preferred by European bison has yet to be accurately described, as previous studies have only covered periods of abundant foraging or vegetative rest without delving into the structure of the

forest stands and ecosystems preferred by these animals (Thomas et al., 2021; Schneider et al., 2013; Perzanowski et al., 2019).

The European bison is a social animal that typically lives in groups of 10 to 50 individuals. These groups can be mixed or composed of only males, with the mixed groups containing females, young individuals, newborns, and adult males. On average, these groups contain 8 to 13 animals (Kraśiński & Kraśińska, 1992; 1994) and their structure, particularly the mixed groups, can change seasonally due to chance meetings and the exchange of individuals. Young males are the most unstable, frequently changing groups (Kraśińska et al., 1987).

Adult, solitary males use the largest spaces, while spaces used in winter are much smaller and influenced by weather conditions. In these conditions, bison gather around feeders, forming large mixed aggregations and small groups of males. The largest aggregation of bison was recorded in the Białowieża forest with one group reaching 100 individuals (Kraśiński et al., 1999).

Although rough terrain does not pose a problem for European bison, they prefer to conserve energy by following paths that they or other wild animals have previously used. They usually avoid the steepest slopes and large obstacles such as fallen trees, rocks and swamps. When moving in small groups, they follow a roughly single-file formation while respecting the hierarchical order. In contrast, larger groups move in a compact formation.

According to studies conducted by Perzanowski et al. in 2008 and Kraśińska & Kraśiński in 2007, the seasonal movements of female and mixed groups are typically limited to distances of 10 to 15 kilometers. Meanwhile, research on a single population of adult males in the Carpathian Mountains indicated that they typically travel 30 to 40 kilometers during a growing season (Perzanowski et al. 2008).

The movement patterns, times, and distances travelled by European bison have been studied in recent decades using telemetric methods, Geographic Information System (GIS), and specialized software for data processing (Roșca & Ceuca, 2023). In Romania, there are three populations of free-ranging European bison: more than 70 individuals in the Vânători Neamț Natural Park, about 145 individuals in the Armeniș area of the Țarcu Mountains (Caras-Severin County), and more than 50 individuals in the Făgăraș Mountains. In 2012, five European bison were first released in the Vânători Neamț Natural Park. New releases were carried out in 2013 (5 individuals), in 2014 (6 individuals), in 2015 (2 individuals), in 2016 (3 individuals), in 2017 (4 individuals), in 2018 (1 individual), and 2019 (4 individuals), in total 30 individuals (14M, 16F) (Cătănoiu et al., 2021; Dănilă et al., 2022). Of the 47 individuals in the wild in 2019, 30 were released and 17 were born in the wild.

Between 2005-2014, a number of 21 individuals were imported, coming from zoos in Elvetia (Goldau and Bern), Germany (Springe, Karlsruhe and Hardehausen), Sweden (Avesta, Boras and Skansen) and the UK (Howletts, Fort Lympne, Kingussie and Fota). To these were added 9 individuals from the reservations in România (Neagra Buceșani, Vama Buzăului, Vânători Neamț), so that in the period 2012-2019, 30 individuals (14 males and 16 females) were released, with ages ranging between 2 and 12 years.

This analysis aimed to study the distribution pattern of the European bison in the Vânători Neamț Natural Park based on biotic factors such as forest species, age classes, canopy closure, and grasslands, as well as abiotic factors such as altitude, slope, and temperature. The primary objective was to track the density and movements of European bison in the area over the year and different seasons. The second objective was to identify the frequency of European bison in specific stands based on their characteristics during different seasons. Additionally, the study aimed to determine the preference of European bison for specific orographic features in the area.

2. STUDY AREA

This study tracked the movements of free-ranging herds of European bison in and around Vânători Neamț Natural Park in Romania from 2014 to 2019 (**Fig.1**). The study area consists of eight communes and five forestry districts - Țargu Neamț Forest District, Vânători FD, Văratec FD, Pipirig FD, and Hangu FD, covering an area of more than 30100 hectares.

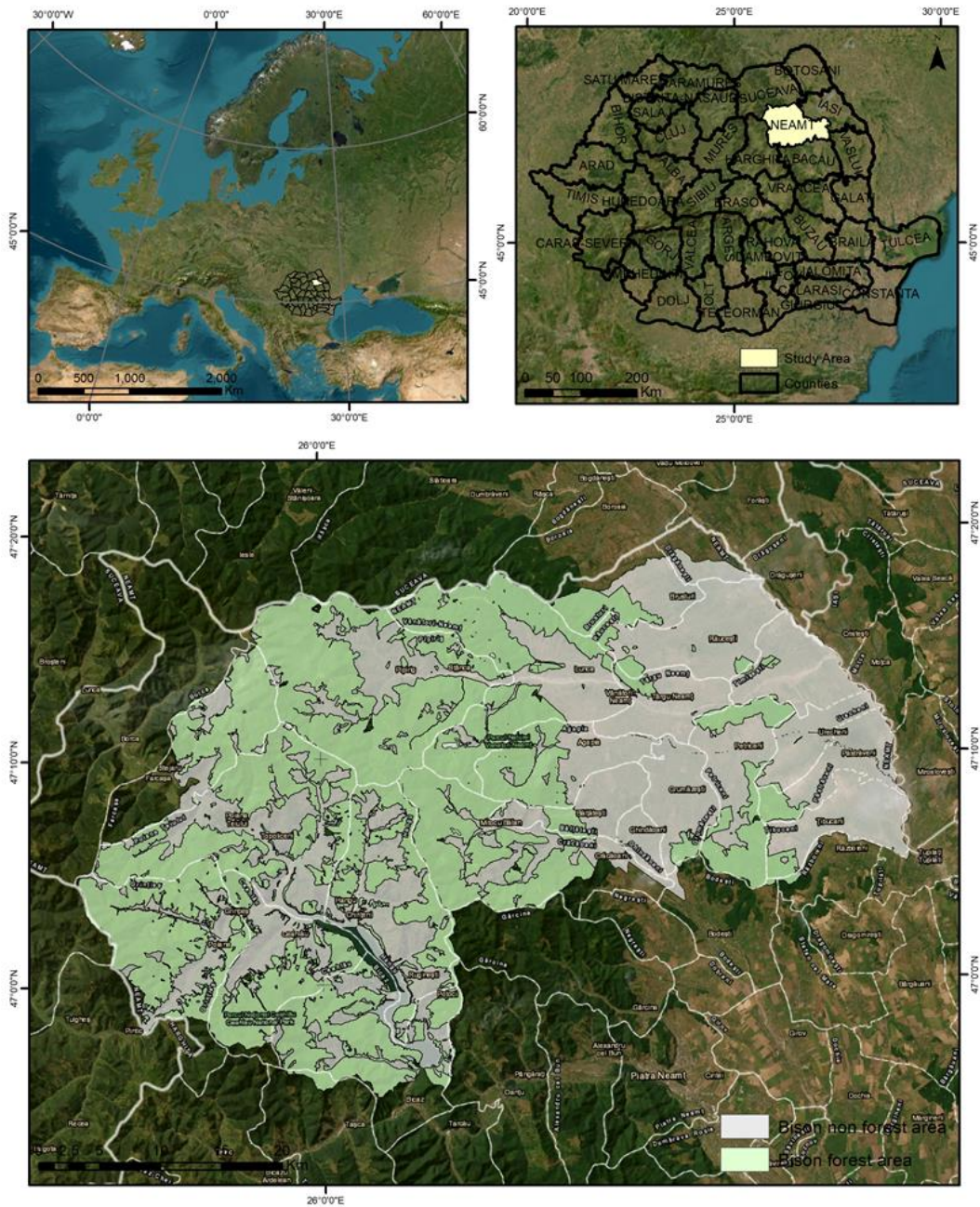


Fig. 1. Geographical position of the study area.

The study area was defined by delineating polygons at the extreme points where the bison were observed. The local forest administration provided cartographic data as vector layers describing forest stands by species, age, and canopy cover. The vector layers also include non-forest areas such as pastures, meadows, farm-land, villages, watercourses, etc.

Under the Forestry Code, any area with trees larger than 0.25 ha is classified as a forest. The forest management plan of each forest district, included in the study, included information about stand age, forest cover, and tree species composition (Romanian Forestry Code, 2008).

3. DATA AND METHODS

The analysis was based on data collected from GPS collars that were worn by four female and one male animal. The 5 specimens are part of the analyzed population and had the collars between 2014 and 2019. The Natural Park Vânători Neamț Administration has a standard operating procedure for tranquilizing animals, which was followed during this study. A veterinarian was present during the tranquilization process to ensure that the animals were not subjected to any unnecessary pain. The collars were activated and mounted according to the manufacturer's instructions and remained permanently on the same individuals.

Lotek collars with the following technical specifications were used: circumference of 115 cm for females and 130 cm for males; GPS, VHF with frequency between 145 MHz - 175 MHz; animal mortality detection sensor; optimal operation in range: - 300 C... + C 500 C; data collars was done at a pre-programmed interval of 2 hours resulting in 12 data collars per day. The data collars used in this study provided information on the date, time, latitude, longitude, altitude, slope, and ambient temperature. To download the data, the Lotek GPS Web Service site (Home Page - Lotek Web Service) was used, where the data for all the used collars was recorded. Thanks to the facilities offered by the site, data can be downloaded, for each column or cumulatively, for predetermined periods of time or for the entire period, in different formats (text, KML, KMZ, etc.)

Four collars were used to track the location of the entire herd, which were attached to the herd leader females. Adult males were given a separate collar as they are solitary and only join the herds during mating season. Given the small number of herds and adult males, there was no need for additional collars.

The recorded data was grouped on seasons, i.e., spring (01 March - 31 May), summer (01 June - 31 August), autumn (01 September - 30 November), and winter (01 December - 28 February).

Of the 44993 records, those with "NO SATS" (4904 data collars) and those located in the acclimatization pen for the period when the animals were in pre-release (4134 data collars) were removed and 35955 data collars was validated. Data collars submitted by individuals isolated in the pens for a given period was also removed.

During the first phase of the study, the areas where European bison were frequently found were divided into two types: forest and non-forest areas. The data collected from the collars were filtered by year, and the Concave Hull function was used to determine the area occupied by European bison for each year. The yearly areas were then separated into forest and non-forest areas.

Next, the European bison's preference for a particular type of forest was analyzed separately for each season based on their recorded positions on the forest stand parcels. The data for the forest parcels was assigned to the overlapping points, resulting in a total of 18581 points. The QGIS 3.28 software was used to process the vector data.

Individual tracks, seasonal movement and movement overtime maps were done ggmap and ggplot packages from R (R Core Team, 2022).

4. RESULTS AND DISCUSSIONS

4.1. Spatial dynamics over the period analysed

The data recorded from the collars of European bison between 2014 and 2019 was reported for two types of areas, forest and land without forest vegetation (**Table 2**). In 2014, the European bison frequented an area of 6811 hectares, out of which 4801 hectares were forest and 2010 hectares were land without forest vegetation. By 2019, their explored area had increased to 30,110 hectares (**Fig. 2, Fig. 3**). Out of this, 18,759 hectares were forested while 11,351 hectares were land without forest vegetation (**Fig. 3**).

Table 2.

Data collars records on forest and non-forest areas.

Year	Forest (data collars)	Nonforest (data collars)	Total (data collars)
2014	2037	457	2494
2015	7763	1976	9739
2016	4140	1436	5576
2017	5408	2164	7572
2018	6593	3211	9804
2019	745	25	770
Total	26686	9269	35955

Over the same period, the size of the area explored increased with the number of bison (**Figure 2 and Table 3**).

Table 3.

The dynamics of the bison population (cumulative values).

Year	Males	Females	Youth	Total
2014	6	10	4	20
2015	8	12	1	21
2016	11	13	1	25
2017	13	16	6	35
2018	16	20	3	39
2019	18	21	8	47

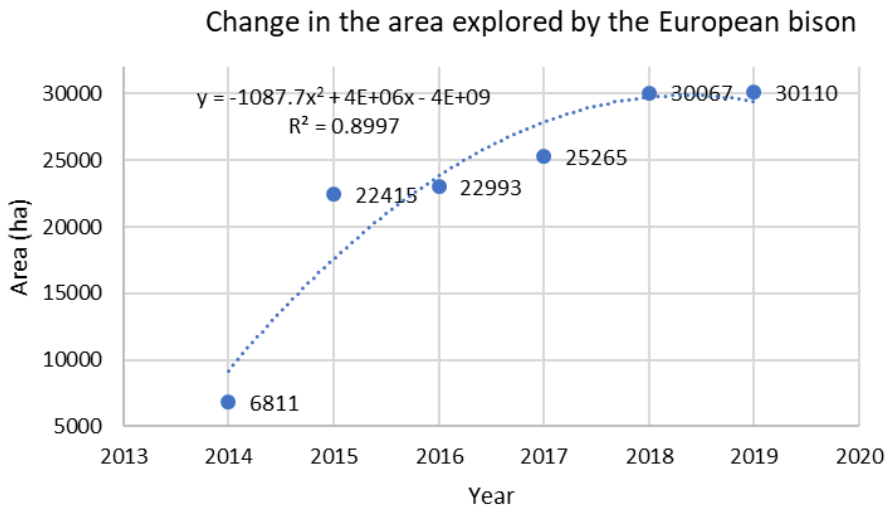


Fig. 2. The trend of dynamics of the explored area during the period analysed.

As shown in **Fig. 2**, there has been an increase in area surveyed by European bison during the initial two years. However, this trend has gradually decreased over time, with the curve flattening out towards 2020, despite the fact that the number of European bison is still increasing.

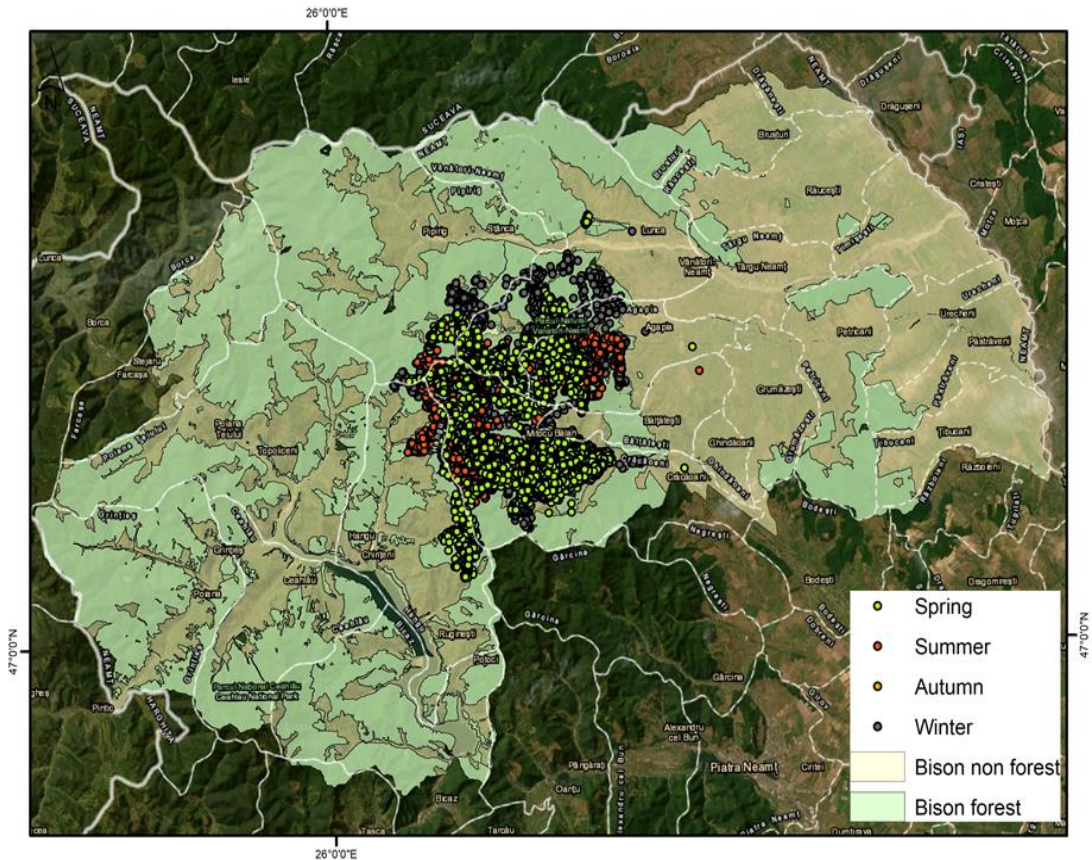


Fig. 3. Season localization in forest/non-forest land use for the whole period analysed.

The dynamics of the studied area was determined by the growth of the European bison population. The recorded GPS data reflects the position of bison herds that are led by adult females.

No data has been collected since 2019 as the transmitters stopped working due to battery depletion or physical damage. However, the rangers from the administration of the Vânători Neamț Natural Park and the forest districts in the area have been monitoring the herds of European bison. During the analyzed period, two stable herds were observed, which were only separated during the summer.

The exploration area has expanded since 2019, as evidenced by incidental observations documented with images and videos. However, the core range in 2019 remained approximately the same, despite the number of European bison increasing to over 70 in 2023. In terms of population density (number of individuals per 1000 hectares explored - forest and land without forest vegetation), a decreasing trend can be observed (**Table 4**).

Table 4.

Density of the herds of European bison.

Year	2014	2019
Density (individuals/1000 ha)	2,9 (20 individuals/6.8 thousand ha)	1,6 (47 individuals/30.1 thousand ha)

Bison concentration areas can also be observed using hot spot analysis, performed with the Getis-Ord G_i^* statistical tool of ArcGIS Pro 3.2.0 software that highlights hot spots and cold spots areas (**Fig. 4**).

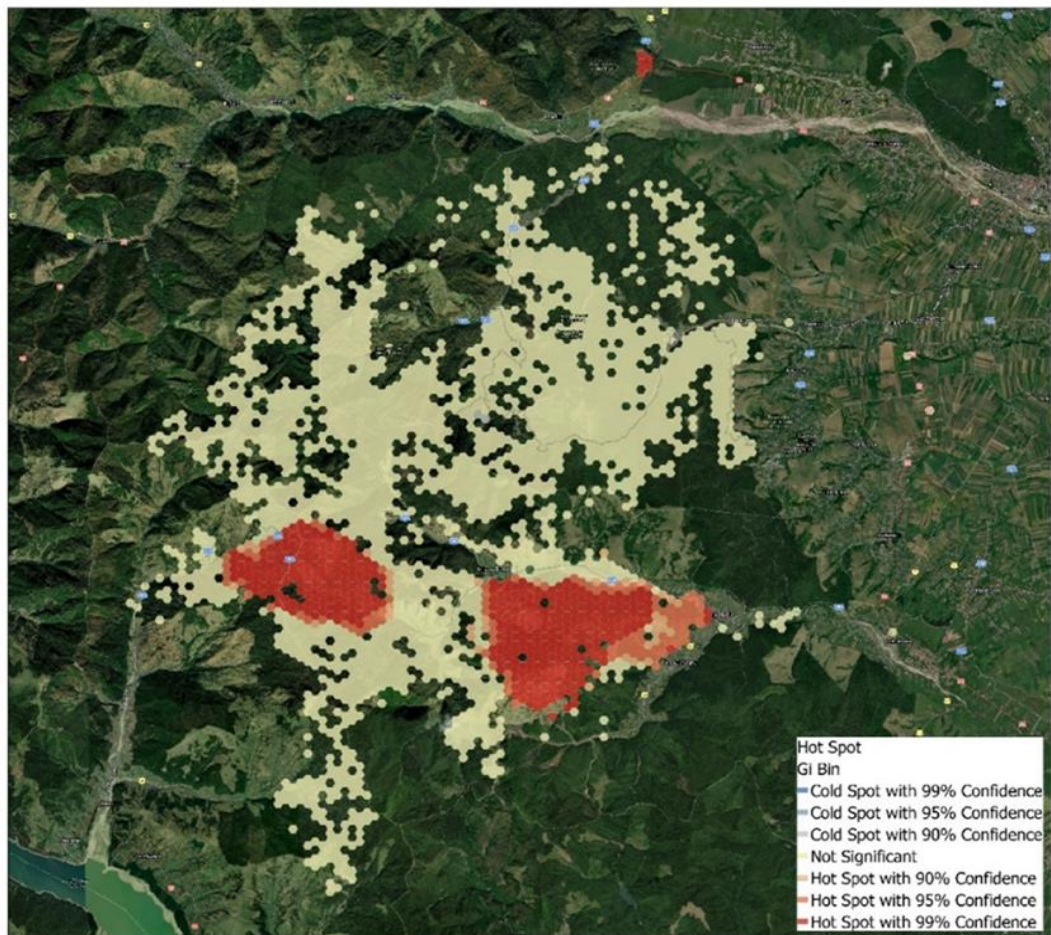


Fig. 4. Spatial distribution in the area explored by the European bisons.

4.2. Biotic factors. Type and structure of forest stands

The processing of the GPS collar data showed that the European bison in the study area spent, on average, about 74% of the time in forested areas and the remaining about 26% of the time in areas without forest vegetation (**Table 2**). In all seasons, regarding European bison stationing in the forest were observed minor percentage variations in frequency amongst seasons (**Table 5**).

Table 5.

Dynamics of records (data collars) by season, forest vs. non-forest land.

Season	Forest (Data records 26686)	Non-forest (Data collar records 9269)
Spring	28%	43%
Summer	27%	31%
Autumn	25%	5%
Winter	20%	21%
Grand total	100%	100%

During spring and summer, European bison tend to prefer areas with meadows and pastures. However, in autumn and winter, they tend to stay in forested areas. This behaviour can be observed in regions without forest vegetation. Bison localization, amongst years, was over 80% on forested areas and less than 20% in non-forest areas, as shown in **Table 6**.

Table 6.
Area explored by forest vs. non-forest European bison by season and by each year.

Season/year	2014 (2 E. bison - 1 ♀ and 1 ♂)		2015 (4 E. bison - 3 ♀ and 1 ♂)		2016 (2 E. bison - 1 ♀ and 1 ♂)		2017 (2 E. bison - 2 ♀)		2018 (3 E. bison - 3 ♀)		2019 (1 E. bison - 1 ♀)	
	Forest	No forest	Forest	No forest	Forest	No forest	Forest	No forest	Forest	No forest	Forest	No forest
Spring			10566	1846	5011	1068	10084	2436	8429	1852	1492	72
Summer	3636	715	6982	2156	4175	1342	7271	1611	7795	1221		
Autumn	1353	427	4026	315	2972	279	2783	309	7298	578		
Winter	77	30225	4351	591	1566	100	1770	455	1434	365	332	11
Total	5066	1153	25926	4908	13723	2789	21907	4810	24955	4016	1823	84
%	81	19	84	16	83	17	82	18	86	14	96	4
Total (ha)	6219		30834		16512		26718		28972		1907	

There is a clear preference of European bison for mixed coniferous-beech and pure beech forests, which accounts for over 90% of all observations (**Table 7**).

Table 7.
European bison's preferences in regard to forest stand composition (%).

Year / Forest species composition	2015	2016	2017	2018	2019	Average for period 2014-2019
Norway spruce stands (<i>Picea abies</i>)	0	0	0	0	0	0
Norway spruce and (<i>Picea abies</i>) silver fir (<i>Abies alba</i>) stands	12	8	3	3	6	6
Mixed stands (Norway spruce, silver fir and beech)	15	45	30	38	28	31
Silver fir (<i>Abies alba</i>) stands	0	6	3	2	3	3
Silver fir (<i>Abies alba</i>) and beech (<i>Fagus sylvatica</i>) stands	40	16	30	45	47	36
Beech (<i>Fagus sylvatica</i>) stands	32	25	34	13	15	24
Total	100	100	100	100	100	100

The age class distribution indicates that European bison have a higher preference for old-growth forests that are over 100 years old (more than 55%) as compared to younger forests. This preference is consistent across all seasons except winter, where the preference for such forests is relatively low. However, in summer and spring, younger forests that are less than 60 years old are preferred (**Fig. 5**).

Upon initial observation, it is evident that European bison exhibit a strong preference for older forests that are over 100 years old. Conversely, forests that are between 60 and 100 years old are often avoided. Moreover, the European bison prefer stands with a forest canopy cover ranging between 0.4 and 0.9, with more than 85% exhibiting a strong affinity towards such stands. The preference for such stands is highest during the summer months, while interest declines during the autumn and winter months, as demonstrated in **Fig. 6**.

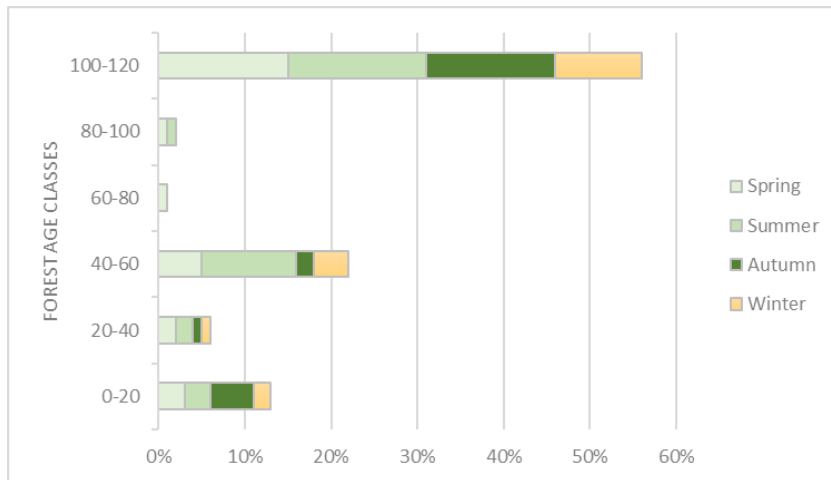


Fig. 5. European bison's preferences in regard to forest stand age classes and seasons (%).

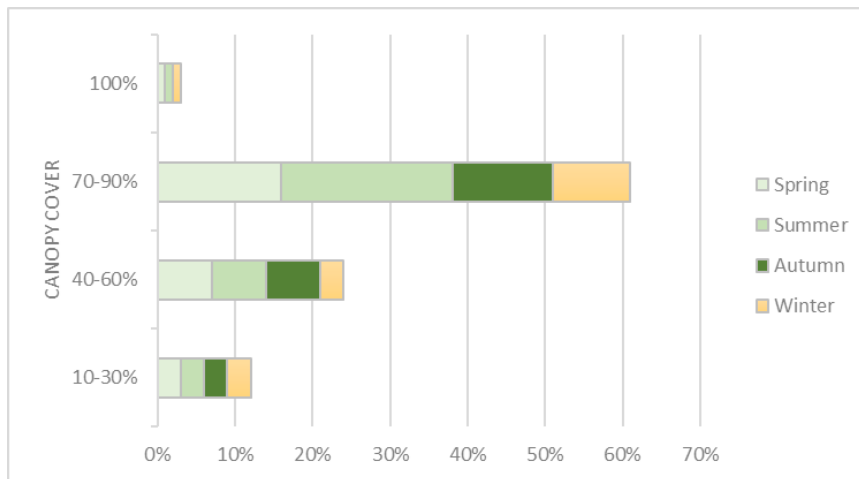


Fig. 6. European bison's preferences in regard to canopy closure and seasons (%).

The European bison tend to avoid forests with a dense canopy cover, or stands that have a closed canopy cover which are not well represented. The forests with a canopy closure of less than 90% and more than 100 years old are the most significant areas of interest (**Fig. 1**).

4.3. Abiotic factors. Land orography

The data collected from the collars worn by European bison has provided some interesting insights into their preferred altitude classes and slopes in the studied area. The analysis indicates that the bison tend to use areas above 600 meters, with a higher intensity in areas above 900 meters (as shown in **Fig. 7**). However, the use of different altitude classes varies depending on the season. During spring, the European bison are found in altitudes ranging from 600 to 900 meters, while in summer they are found at higher altitudes - over 700 meters. In autumn, they prefer even higher altitudes above 800 meters, and in winter, they tend to stay in lower altitudes.

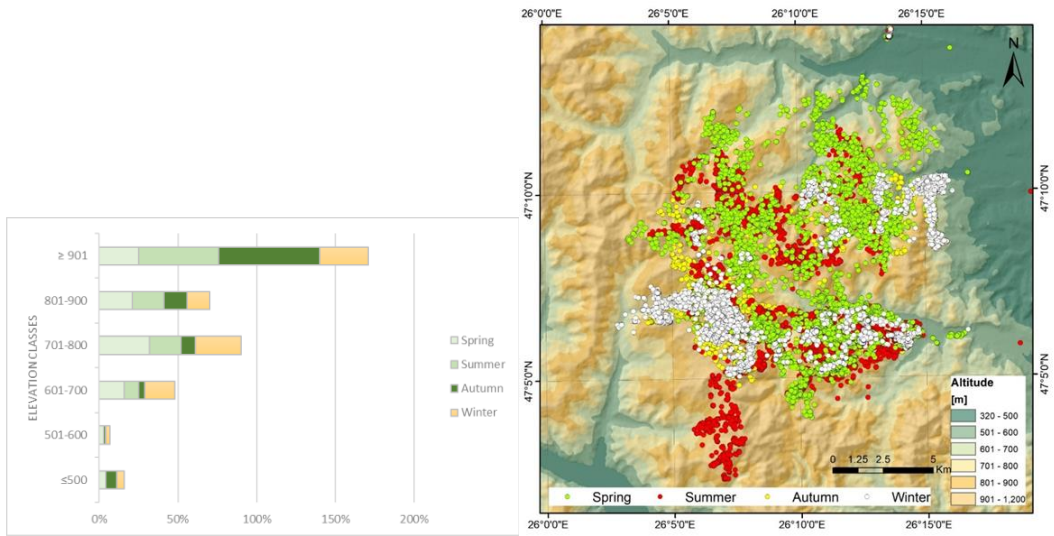


Fig. 7. European bison's preferences on altitude classes and seasons.

Large-bodied mammals tend to avoid steep slopes over 25°, with maximum favourability ranging from 5° to 15° (Fig. 8).

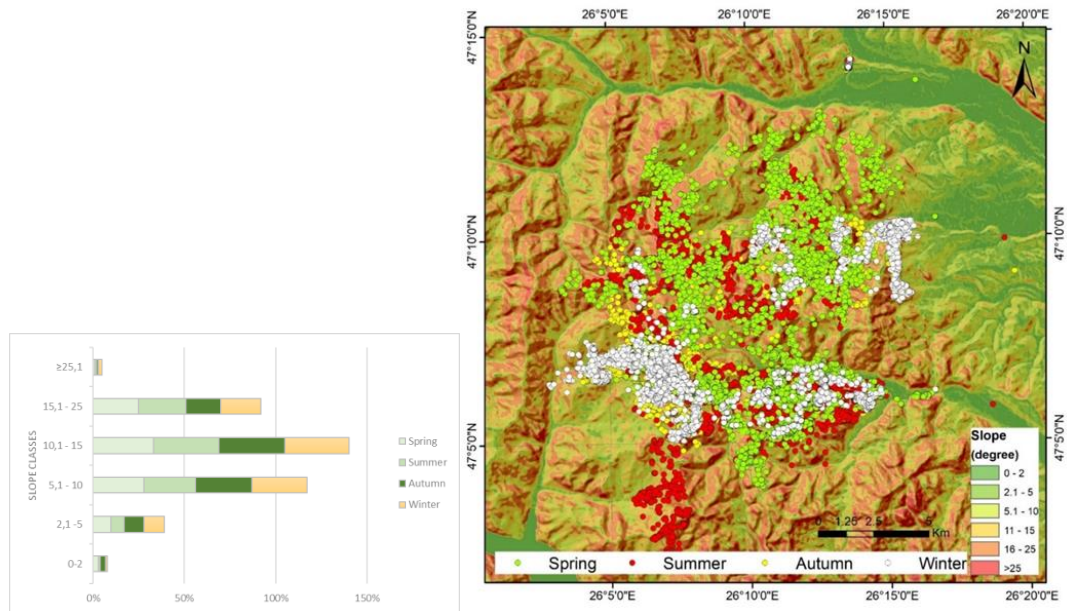


Fig. 8. European bison's preferences on slope classes and seasons (%)

When determining the suitability of a particular area for the European bison, altitude and slope are taken into consideration as limiting factors. It has been observed that during the growing season, the European bison can navigate slopes greater than 25°, while they tend to seek out lower slopes during the off-season (Fig. 8).

5. DISCUSSION

The area exploited by the European bison has more than quadrupled in 5 years due to successive releases and the appearance of free-born calves. The increase in the territory is imposed by a large amount of food required for an adult European bison, about 19.5 kg of dry plant matter per day (Jaroszewicz et al., 2008; Schmitz et al., 2015), i.e. 30 - 45 kg fresh green mass (Perzanowski et al., 2013; Sobczuk et al., 2016). In the Vânători-Neamț Natural Park, the territory has expanded and the number of the European bison has changed, leading to a change in their density which is now calculated at 1000 hectares. The initial density of 2.9 individuals per 1000 hectares has decreased to 1.6 individuals per 1000 hectares in 2019. However, the population density in the "core" area covered by the European bison has increased to about 2.3 individuals per 1000 hectares in 2023, with a total of 70 individuals observed in 30.1 thousand hectares. The park administration reports that the area travelled by the bison could be higher, about 95,000 hectares, based on documented incidental observations after the collars were out of use. The European Action Plan (Olech et al., 2022), in conjunction with the continental analysis of favourable areas for the European bison, associates continuous areas of more than 20000 ha (Kuemmerle et al., 2011), with ensuring the conditions for the existence of a herd of at least 50-60 animals, thus resulting in a density of 3 - 4 European bison/1000 ha.

The carrying capacity of the European bison has only been determined in a few locations in Europe and under specific conditions. For example, in the case of the Bialowieza Forest, if the density of the European bison exceeds 5-6 individuals per 1000 hectares, supplementary feeding is required. Additionally, there were recorded declines in fertility in the European bison when densities exceeded this threshold (Kraśnińska et al., 2013). Considering the Polish experience on bison reintroduction program, the carrying capacity in the Carpathian Mountains has been estimated at 4 European bison/1000 ha (Kuemmerle et al., 2011; Perzanowski et al., 2005). This value coincides with estimates made for the bison herds in Yellowstone and Wood Buffalo National Parks (Plumb et al., 2009) and with the suggested carrying capacity for bison in Central Europe (Kraśnińska et al., 2007). In the case of the Vânători Neamț Natural Park, the analysis of the areas used more intensively by the European bison, determined by the Kernell method (for the per-centage of 95%), showed that for a herd of 45 free-ranging individuals, 160 km² (16000 ha) returned, which represents approximately 3 European bison/1000 ha, a value close to that mentioned in previous studies (Dănilă et al., 2022).

Spatial distribution of the European bison in relation to biotic factors. The European bison is a herbivorous - ruminating, primary consuming, large mammal, so its daily, seasonal, and annual activity depends on the food resource. The European bison are not a territorial species and are constantly searching for food, so they have a wide range of options in selecting certain habitat types (Kraśnińska et al., 2013). The diet of the European bison is very diverse and includes more than 170 herbaceous and woody plants from all plant families of the European temperate wild flora (Jaroszewicz et al., 2008). Recent studies demonstrate the broad spectrum of herbaceous and woody species consumed by the European bison (Rafał et al., 2023; Kowalczyk et al., 2019).

According to recent studies conducted it has been shown that species belonging to the Bison genus can easily adapt to consuming a wide variety of plants and plant parts, whether they are in a green or dry state. The European bison, in particular, is known to consume herbaceous plants from both wild and cultivated flora, as well as the buds, leaves, lily pads, and twigs of various woody species.

The Vânători Neamț Natural Park area provides an ideal environment for the growth of the European bison population. The data collected from GPS collars have shown that these animals are highly active in the forest ecosystem, accounting for about 74% of the annual activity. The European bison prefer certain types of forests in this area, as shown in **Table 7**.

The analysis of GPS signals also revealed that bison mainly stay near the plains and prefer to remain within the forest, about 1 km from the lineage in spring and 2-3 km in summer. They tend to

stay close to the forest boundary on open ground that lacks forest vegetation, not straying more than 1 - 2 km. This behaviour is influenced by the greater availability of food in the transition zone between two different ecosystems (Magurran et al., 1988). About 70% of the recorded data show their presence in mixed coniferous-beech forests and about 21% in pure beech stands. The frequency of stands consisting only of resinous species is very low, less than 9% (**Table 7**).

The study also found that the bison tend to explore old-growth forests with a canopy closure of less than 0.9 (> 55%). Studies carried out by (Kraśńska et al., 1987) in Białowieża Forest show similar behaviour of the bison in the area of Neamț. The preference for mixed stands (80%) and the same seasonal commuting of the European bison to areas without forest vegetation (23%) are noted.

The European bison's movement patterns show that the size of the areas they cover varies annually and seasonally. These differences can be attributed to reports from different locations, as well as the number and activity of transmitters used during the year and season. However, during the spring season, the European bison's feeding behaviour is quite apparent as they browse through larger areas to obtain and digest fresh food from the new growing season. (**Table 6**).

The European bison have adapted to different situations depending on local biotic, abiotic, and anthropogenic conditions. For example, the population of the Knyszynska Forest, in the winter season, is cantoned only in agricultural habitat. In contrast, the population in the Bieszczady Mountains spends more than 90% of its time in the forest (Rafał et al., 2023). In the Bieszczady National Park, more than 90% of reports of free-ranging bison were recorded in areas covered with forest vegetation in winter and summer. In the immediate vicinity, in Poloniny National Park in Slovakia, amidst numerous abandoned lands, forest use is only 50% in summer and 75% in winter (Pčola et al., 2008).

The European bison prefer forest-type environments, especially coniferous-hardwood and pure deciduous mixed forests (Pčola et al., 2008; Zikmund et al., 2021).

This exploratory behaviour is induced by foraging ethology and food abundance (Kowalczyk, 2019). Mixed stands of conifer and beech trees, as well as pure stands of beech, offer more food for the European bison compared to pure conifer stands. Older stands, which are less uniform, produce fruit occasionally and support a more diverse and attractive herbaceous and shrubby vegetation for the European bison during summer and autumn. However, in spring and summer, the European bison prefers the cooler micro-climate of younger forests. Generally, the European bison seeks shelter in the forest throughout the year and during all seasons. In the spring and summer, the European bison can be observed more frequently in open areas, such as meadows and pastures, with fresh and abundant food sources.

Spatial distribution of the European bison in relation to biotic factors.

Abiotic factors, directly and indirectly, influence the feeding behaviour of the European bison. The succession of seasons, influenced by changing diurnal temperatures, induces daily and seasonal foraging movements (Schmitz et al., 2015). On the other hand, altitude and slope are limiting factors that determine the exploration behaviour of the European bison. The altitudes most frequented by the European bison are 500 - 800 m (Pčola et al., 2008) with low to medium slopes (Kuemmerle et al., 2011).

If in the Bieszczady Mountains in the Polish Carpathians and the Eastern Carpathians (Vânători Neamț Natural Park) free-ranging European bison have reached their upper altitudinal limit (1200 m altitude), in the much higher Țarcu Mountains in the Romanian Carpathians, they have also explored the alpine barren zone, at altitudes higher than 2000 m (Cătănoiu et al., 2012; Dănilă et al., 2022). Similar behaviour is in the Caucasus region, where the European bison descend into the wooded valleys in winter and seek food in the alpine meadows at more than 2000 m altitude in summer.

It has been observed that in the Vânători Neamț Natural Park, more than 60% of the records of the European bison are during the autumn season and at an altitude above 900 meters. This observation can be confusing as the natural tendency would be for the percentage of sightings in autumn to decrease towards the value recorded in spring.

However, research conducted in Banff National Park explains that the European bison prefer to spend more time at higher altitudes on steeper slopes. They consistently return to higher elevations during each growing season because the fodder at higher altitudes is nutritionally superior and tastier compared to the forage at lower altitudes during summer and early fall (Banff National Park, 2023). Another explanation could be related to the higher number of GPS records from higher altitudes. Also, the absence of sheep herds and reduced anthropogenic activities in autumn may explain the movement of the European bison to higher elevations.

After analyzing the correlations between various biotic and abiotic factors with the recorded temperatures, we did not obtain any significant results that reflect certain trends or linkages induced by temperature.

6. CONCLUSIONS

Since 2012, the Vânători Neamț Natural Park forests have been home to European bison. The herd has grown, and with it, the area explored by the bison has increased. However, the density of the bison population has decreased due to the faster increase in the area of movement compared to the rate of herd increase. Consequently, the area surveyed by the European bison tends to expand relatively slowly. The minimum density recorded in 2019 was 1.6 individuals per 1000 hectares, gradually increasing towards the European average optimum values of 3-4 European bison per 1000 hectares.

As a large mammal, the European bison needs large spaces and constantly searches for food. The amount of space required for movement is determined by the food provided by forest, grassland, and meadow ecosystems, and less by the food quality. The slope and altitude, in correlation with the vegetation type, also influence the exploratory behavior of the European bison.

Climatic variables such as temperature and precipitation are of little importance in characterizing the ecological niche of the European bison because of the extent of its historical range. Factors relating to trophic supply and anthropogenic activity, such as vegetation type and land use, are essential.

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