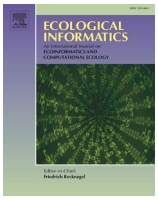
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Human-brown bear conflicts in Türkiye are driven by increased human presence around protected areas

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ABSTRACT

Human-wildlife conflict has become a major challenge to conservation efforts around the world. Brown bears (*Ursus arctos*), which globally suffer from reduced habitat suitability and quality, frequently conflict with humans. These animals need large home ranges to fulfil their habitat requirements. When space and food are restricted, brown bears frequently shift towards human-dominated landscapes that offer reliable food sources. Türkiye, a country with predominantly human-dominated landscapes, experiences frequent human-brown bear conflicts (HBCs). However, there has been no formal analysis of the nature and scope of these conflicts at the country level. Using HBC data from 2017 to 2022, we analyzed the spatial and temporal dynamics of HBC events in Türkiye , constructing a risk map based on anthropogenic variables and geographic profiling to identify the driving forces. HBC events did not show any annual or seasonal trends but displayed considerable variation across biogeographic regions, with the highest incidence concentrated along the Black Sea coast and in Eastern Anatolia. Sixty percent of all conflicts were due to bear foraging behavior in or near human settlements while 12 % were the result of human activity in forests, with 57% of all conflict events resulting in direct injury to either humans or bears. Our analyses showed proximity to villages, protected areas, farmland, and the human footprint to be pivotal factors influencing conflict risk. Approximately 21% of the country's territory is susceptible to human-bear conflicts, with a substantial portion (43%) of these risks manifesting within a 10-km radius around protected areas. In conclusion, our findings suggest that the high occurrence of HBCs in Türkiye primarily stems from the limited availability of natural habitats and resources for brown bears, compounded by increased human encroachment in and around core bear habitats.

1. Introduction

Brown bear (*Ursus arctos*) conservation in human-dominated landscapes has grown increasingly challenging (Hosseini et al., 2021; Lute et al., 2018). These charismatic apex predators play vital roles in ecosystems, acting as keystone megafauna, ecosystem engineers and seed dispersers (García-Rodríguez et al., 2021; Sakiyama et al., 2021). However, their extensive habitat requirements and space-use patterns are often hindered by expanding human settlements and anthropogenic activities. Consequently, brown bear habitats have been fragmented, leading to reductions in the contributions of brown bears to ecosystem services.

Over the past decade, the encroachment of human settlements and increased anthropogenic activities have disrupted numerous ecosystems inhabited by brown bears, shrinking their habitats and exacerbating human-wildlife conflicts (Morales-González et al., 2020). Such conflicts between wildlife and humans can be regarded as a significant challenge for biodiversity conservation (Kaiwen et al., 2022). The intrusion of humans into these habitats has not only limited space and resources for these animals but has also escalated conflicts (Bhandari et al., 2020; Dai et al., 2021). These issues are further compounded by the availability and ease of access to anthropogenic food sources, such as open garbage dumps, orchards, and beehives. Consequently, human-bear conflicts, including attacks on humans, property damage, and human-caused

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casualties, are increasing globally (Ahmad et al., 2022; Bombieri et al., 2019; Gantchoff et al., 2020; Parchizadeh et al., 2023). This situation not only makes brown bears more vulnerable to natural and anthropogenic environmental change but also fosters negative societal attitudes towards their conservation.

As a 783,562 km^2 land bridge, Türkiye serves as a major gene flow pathway between Europe, Asia, and Africa (Şekercioğlu et al., 2011a). Despite being almost entirely covered by three biodiversity hotspots (Caucasus, Irano-Anatolian, and Mediterranean), only a small fraction of Türkiye's land area is protected (NCNP, Republic of Türkiye, Ministry of Agriculture and Forest, 2022). Moreover, many of these protected areas are inadequately safeguarded and face threats from deforestation, construction, mining, and other violations of environmental law (Atmiş, 2018; Şekercioğlu et al., 2011a, 2011b). Türkiye's forests, estimated at 29% of its land area, are under siege from various human activities, causing fragmentation and degradation (Birben, 2020). From 2001 to 2020, Türkiye lost 545,000 ha of tree cover, a 5.4% decrease totally during this period (Harris et al., 2021). The economic significance of Türkiye's forests, with export revenues nearing 16 billion US dollars in 2023 (TİM, 2023), necessitates effective forest management but inadvertently intensifies habitat fragmentation and public access via road construction.

This multifaceted challenge confronts Türkiye's largest carnivore, the Eurasian brown bear (*Ursus arctos arctos*), with threats ranging from habitat degradation to poisoning, poaching, and road mortality (Ambarli et al., 2016). As brown bears are forced to live in increasingly human-dominated landscapes, bear-related incidents near human settlements are on the rise, posing a significant threat to human-brown bear coexistence (Chynoweth et al., 2016; Goursi et al., 2021; Kudrenko et al., 2020). Unfortunately, our knowledge of the spatial distribution and factors driving these conflicts in Türkiye remains limited (Chynoweth et al., 2016). Spatial information on human-brown bear conflicts (HBCs) can help us understand the ecological and anthropogenic factors responsible for these conflicts (Broekhuis et al., 2017) and develop conservation and management strategies to reduce HBCs (Hosseini et al., 2021; Khosravi et al., 2023). In contemporary ecological research, species distribution modeling has emerged as a pivotal ecological tool for understanding the relationship between environmental variables and species habitat use (Sillero et al., 2021). Beyond its traditional application, this methodology can also be used to understand the dynamics of human-wildlife conflicts, providing insights into the anthropogenic factors driving the escalation of such encounters (Khosravi et al., 2023). This study seeks to achieve two primary objectives: first, to quantitatively assess the spatial and temporal patterns of human-brown bear conflicts (HBCs) in Türkiye; and second, to employ distribution modeling to ascertain conflict risk probabilities across the nation, while identifying key anthropogenic factors contributing to these conflicts. Through this framework, we aim to illuminate the ecological and social dynamics facilitating human-brown bear conflicts in Türkiye and to inform new conservation strategies geared towards fostering coexistence between humans and bears within Türkiye's distinctive ecosystems.

2. Material and methods

2.1. Data collection

To determine the dynamics of human-brown bear conflicts (HBCs) in Türkiye, we collected and reviewed publicly available data on brown bear-human encounters between 2017 and 2022. To this end, we conducted Google searches using the following keywords: "bear + sighting", "bear + attack", "bear + attack + human/barn/beehive/orchards/crops/fence/yard/damages", "bear + mortality" + "bear + road accidents" in Turkish. All conflict events were geo-referenced and in cases where location information was absent, we reached out to eyewitnesses or sought confirmation from the local village chief (Muhtar), who serves as the representative of the state in Turkish villages. When direct eyewitness accounts were unavailable, we assigned a georeferenced point randomly within a 5-km radius of the event location, following established practices (Kimmig et al., 2020). We classified conflicts into seven categories to classify the nature and cause of the conflict: i) damage to livestock; ii) damage to beehives; iii) damage to crops; iv) human-brown bear encounters in forested areas; v) road accidents involving bears; vi) poaching/illegal killing; and vii) other (miscellaneous incidents not falling within the aforementioned classifications). We used Chi-square goodness-of-fit tests to determine the significant differences between conflict types and whether the overall distribution of conflicts deviated from a uniform distribution. We also used the Chi-square test to test for significant differences between conflict events across years, seasons and the three major biogeographic regions in Türkiye: Euro Siberian, Irano-Anatolian, and Mediterranean (Davis, 1971; Noroozi et al., 2019).

2.2. Environmental layers

We used a combination of anthropogenic variables as environmental predictors, including human population density, housing density, the human footprint index and distance to farmlands, forests, protected areas, roads, villages and water resources (Table S1). Population density information, and the Human Footprint Index (HFI), which quantifies the cumulative impact of human activities on the environment (Venter et al., 2016), weredownloaded from the Socioeconomic Data and Application Center (SEDAC). Forest and farmland layers were extracted from the Corine Land Use Land Cover 2018 vector dataset. Housing density raster was generated by using Open Street Map. Motorways, primary, secondary and trunk roads and their linked attributes were selected and extracted from the Open Street Map. For the rivers, we used the HydroRIVERS database and extracted 1st to 4th order river attributes (Lehner and Grill, 2013). The protected areas layers were downloaded from the GeoData application of the General Directorate of Nature Conservation and National Parks of Türkiye (MOAF, 2019). The following categories of protected areas were extracted and used in our modeling approach: *national parks*; *nature conservation areas*; *special environment protection areas*; *wildlife enhancement areas* (equivalent to wildlife refuges or reserves); *locally important wetlands*; *nationally important wetlands*; *Ramsar wetlands*; and *preservation (protected) forests*. Finally, we generated distance layers for all our variables using the Euclidean Distance tool in ArcGIS (ESRI Inc., USA).

We used the Pearson correlation coefficient and the variance inflation factor to check for multicollinearity between the nine predictors (Dormann et al., 2013). We did not find any significant multicollinearity between predictors as all pairwise correlations were below $|r| < 0.75$ and the variance inflation factor for all variables was below 5 (Elith et al., 2006). Therefore, all nine variables were used as input in our modeling analyses (Table S1).

2.3. Human – Brown bear conflict risk modeling

Human-brown bear conflict risk modeling was based on 211 georeferenced conflict records (Fig. 1). To avoid spatial autocorrelation, we calculated the relatedness of environmental predictors within the occurrence records via a Mantel test using the *ecospat* package in R (Boavida et al., 2016; Broennimann et al., 2018). If there was more than one occurrence record at a distance shorter than the minimum significant autocorrelated distance (14.44 km), only one record was used in the analysis (Fig. S1). Ultimately, we retained 140 occurrence points that were used to model human-brown bear conflicts (Fig. S2).

We used Species Distribution Modeling (SDM) to determine the distribution of human-brown bear conflict risk probabilities across Türkiye using the *biomod2* package in R (Thuiller, 2014). Specifically, we employed eleven different SDM models based on the following algorithms: 1) Generalized Linear Model (GLM) (McCullagh and Nelder, 1989), 2) Generalized Additive Model (GAM) (Hastie and Tibshirani,

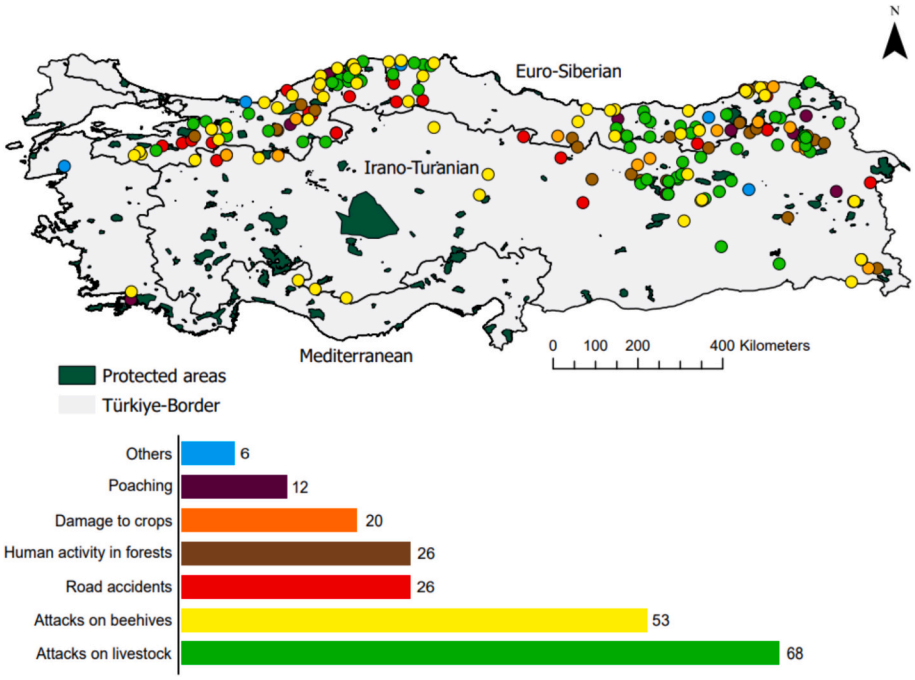


Fig. 1. Distribution and number of recorded conflict events and types across Türkiye between 2017 and 2022.

2017), 3) Maximum Entropy (MAXENT) (Phillips et al., 2017), 4) Random Forest (RF) (Breiman, 2001), 5) Artificial Neural Network (ANN) (Lek and Guégan, 1999), 6) Multivariate Adaptive Regression Spline (MARS) (Leathwick et al., 2005), 7) Generalized Boosted Model (GBM) (De'ath, 2007; De'ath and Fabricius, 2000), 8) Classification Tree Analyses (CTA) (Vayssières et al., 2000), 9) Flexible Discriminant Analysis (FDA) (Hastie et al., 1994), and 10) Surface Response Envelope (SRE) (Busby, 1991).

Modeling was performed by generating 1000 random pseudo-absence points and splitting the collected data into training (80%) and testing (20%) datasets (Huang et al., 2023; Pant et al., 2021; Salinas-Ramos et al., 2021). To avoid sampling bias, pseudo-absence points were generated three times for each model and cross-validated per model using bootstrapping (Carvalho et al., 2021). We evaluated and compared the performance and accuracy of each model using AUC (area under the receiver operating curve) and TSS (true skill statistic) (Araújo and New, 2007). True skill statistics value changes between −1 and + 1, with positive values indicating a perfect fit, while AUC values range from 0.5 to 1, with higher values indicating improved accuracy and predictive power (Fielding and Bell, 1997).

To determine risk probabilities across Türkiye and to reduce the uncertainty among models, we constructed a final ensemble conflict risk model by weight averaging the ten different algorithms as implemented in the *biomod2* package (Thuiller, 2014). By combining predictions from several different modeling approaches, ensemble models have been shown to produce more robust results when compared to individual models (Buonincontri et al., 2023; Erickson and Smith, 2023). We averaged predictions across three replicated runs for each model and selected model runs with a TSS > 0.5 for generating the ensemble model. We classified the predicted risk probabilities generated by the ensemble model into 5 classes: no-risk areas (< 0.2), low-risk areas (0.2–0.4), moderate-risk areas (0.4–0.6), high-risk areas (0.6–0.8) and extreme risk areas (> 0.8).

To better understand conflict risk probabilities and human activity around protected areas, we created two separate buffered layers around each protected area: a layer spanning an area of i) a 5 km radius and ii) a 10 km radius from the center of each protected area. We then determined conflict risk probabilities, housing density and the HFI index within these layers. Finally, we presented the contribution of each variable to our ensemble model and used response curves to visualize the relationship of each variable to the predicted risk assessment.

3. Results

3.1. Spatio-temporal patterns of human-brown bear conflicts

We compiled 211 human-brown bear conflict events in Türkiye between 2017 and 2022 (Fig. 1). Across the six years, the annual number of HBC events averaged 35.2 ± 15.5 (range: 25–65). Except for a significant increase in 2021 ($n = 65$, $X^2 = 35.14$; $df = 1$, $P = 3.07e\text{-}09$), the number of yearly HBC events did not deviate significantly from the mean (Fig. 2, Table S2). As expected, the number of conflict events was low in winter, corresponding to the hibernation period of most brown bears in the study area. Conflict events increased significantly from winter to spring ($X^2 = 13.02$, df = 1, $P < 0.01$), but remained relatively stable afterwards, as the number of conflict events did not differ significantly between the spring, summer and fall seasons ($X^2 = 2.31$, $df = 2$, $P = 0.32$) (Fig. 2, Table S3). Overall, within the time frame of the study, HBC events across Türkiye did not display any pronounced annual or seasonal trends.

Differences in the frequencies of different conflict types (excluding "others") throughout Türkiye were highly significant ($X^2 = 99.69$, $df = 5$, $P < 2.2e\text{-}16$) (Table 1). Damage to livestock ($n = 68$) represented the highest number of conflict events followed by damage to beehives ($n = 53$), damage to crops ($n = 20$), human-brown bear encounters in forests ($n = 26$), road accidents (n = 26) and illegal killing ($n = 12$) (Table 1). The total number of conflicts showed considerable variation across biogeographic regions (Table 1), but did not correlate with area size ($r = 0.07$; $P = 0.95$). Despite having the smallest area, the highest number of conflicts were observed along the Caucasus and Western Black Sea habitats of the Euro-Siberian region ($n = 130$, 146,694 km^2, 0.080 conflict events per 100 km^2), and this was significantly higher than the number of events recorded in the Irano-Turanian region ($n = 77$, 480,937 km^2, 0.017 conflict events per 100 km^2) ($X^2 = 13.57$; $df = 1$; $P = 2.30e\text{-}04$). In contrast, very few conflict events were observed in the Mediterranean region ($n = 4$, 153,073 km^2, 0.003 conflict events per

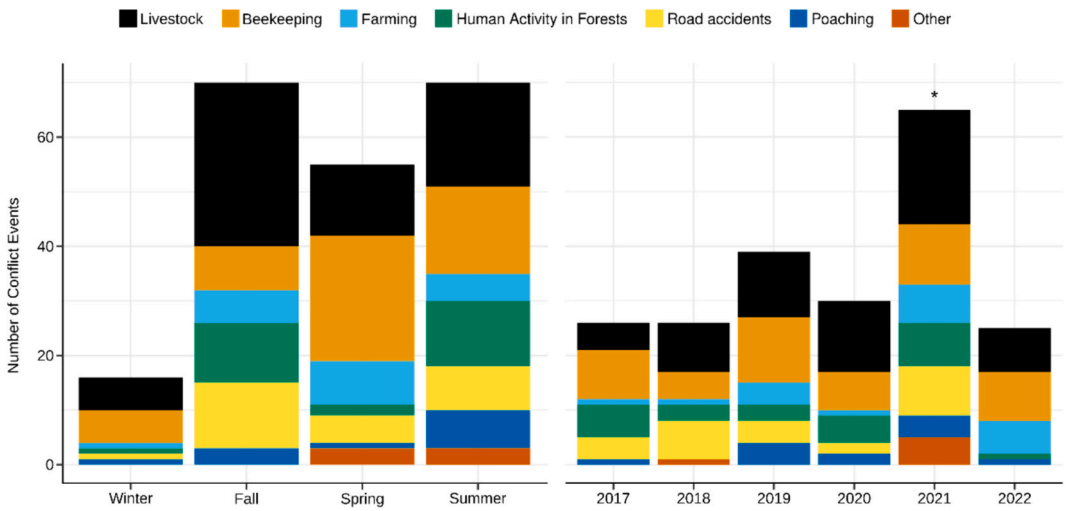


Fig. 2. Number of conflict events across seasons and years from 2017 to 2022 in Türkiye. *Denotes statistically significant deviation from the mean based on a Chi-square test of goodness of fit.

Table 1
The number and frequency of human-brown bear conflict events within Türkiye and the three biogeographic regions, including the results of Chi-square tests* of the null hypothesis that the percentage contribution of each conflict type does not differ between the Euro-Siberian and Irano-Turanian regions.

Conflict	Number	Euro-Siberian	Irano-Turanian	Mediterranean	X^2, df = 2	*P*-value
Livestock	68 (32.2%)	43 (33.1%)	25 (32.5%)	–	6.1	0.138
Beekeeping	53 (25.1%)	37 (28.5%)	14 (18.2%)	2 (50%)	10.4	0.0013
Damage to Crops	20 (9.5%)	8 (6.2%)	12 (15.6%)	–	0.8	0.3711
Human activity in forest	26 (12.3%)	13 (10%)	13 (16.9%)	–	–	–
Road accident	26 (12.3%)	19 (14.6%)	7 (9.1%)	–	5.5	0.019
Poaching	12 (5.7%)	6 (4.6%)	5 (6.5%)	1 (25%)	0.1	0.763
Others	6 (2.8%)	4 (3.1%)	1 (1.3%)	1 (25%)	–	–
Total	**211**	**130**	**77**	**4**	**13.57**	**2.30e-04**

* The Mediterranean region was excluded from the Chi-square tests due to small sample sizes.

100 km^2) (Table 1). The frequency of occurrence of conflict types also differed between the Euro-Siberian and Irano-Turanian regions, as damages to livestock and beehives and road accidents were significantly higher in the Euro-Siberian region (Table 1).

Among the 211 recorded conflict events, 79 (37.4%) included direct attacks on humans, which left 69 people injured and 12 people dead. The majority of the conflict events resulting in attacks on humans were the result of human-brown bear encounters in forests (n = 59, 74.7%) stemming from various human activities in forested areas including animal husbandry (n = 34), picking mushrooms (n = 9), hiking (n = 8), picking berries (n = 4), beekeeping (n = 2), and logging (n = 2). However, attacks on humans as a result of human-brown bear encounters in farmlands or crop areas were also quite common (n = 14, 17.7%). Conversely, 43 conflict events (20.4%) resulted in brown bear casualties, which left 14 bears injured and 33 dead. The main conflict events causing brown bear casualties were road accidents (n = 24) and illegal killing (n = 11).

3.2. *Conflict modeling and anthropogenic factors affecting human – Brown bear conflicts*

Among the ten algorithms examined, SRE, CTA, and ANN exhibited the lowest AUC and TSS values. The best-supported models based on both AUC and TSS were GBM, Maxent, and GLM (Fig. S5). When considering the ensemble model, which aggregated predictions from all ten models, the weighted average AUC and TSS scores were 0.87 and 0.62, respectively, underscoring the model's overall good discriminatory power (Fig. S5). In terms of the factors contributing to conflict risk, the ensemble model highlighted four primary influencers: distance to villages (37%), distance to protected areas (18%), distance to farmland (16%), and human footprint (13%) (Fig. 3). Response curves of the top four predictors showed that conflict risk decreased with increasing distance to villages and protected areas, but showed a bell curve relationship with distance to farmland and human footprint (Fig. 4) Fig. 5.)

A total of 164,311 km^2 of area (21% of the country) was determined to be under human-brown bear conflict risk. High-risk areas were mostly concentrated along the Black Sea coast and in Eastern Türkiye (Fig. 6), with 7.5% of conflict-risk areas lying inside protected areas (Fig. S7). 24.5% (191,780 km^2) and 14.2% (111,188 km^2) of the country were classified as low to moderate-risk areas, respectively, while 8.47%

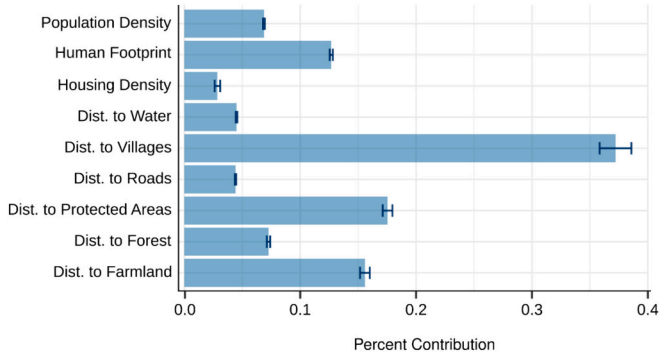


Fig. 3. Percent contribution of anthropogenic variables to the final ensemble model for predicting human-brown bear conflicts across Türkiye. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

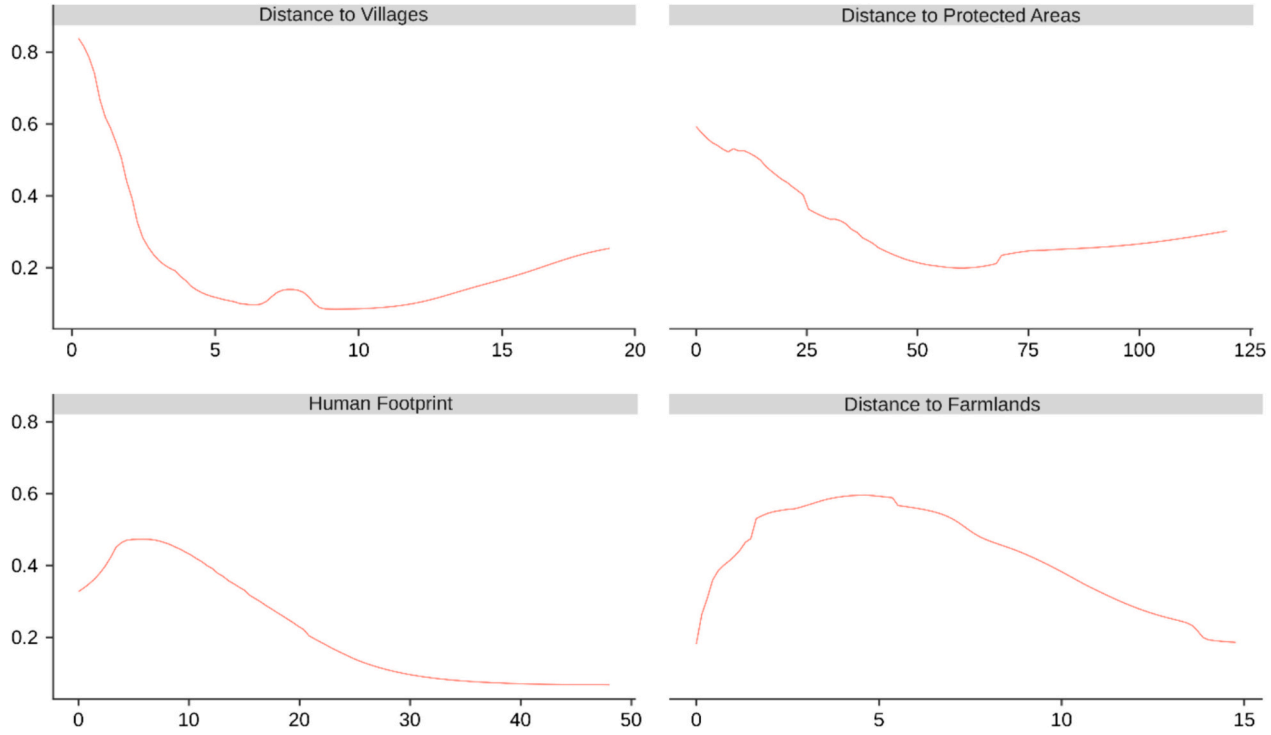


Fig. 4. Response curves of the top 4 anthropogenic variables in the ensemble model for predicting human-brown bear conflicts across Türkiye. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

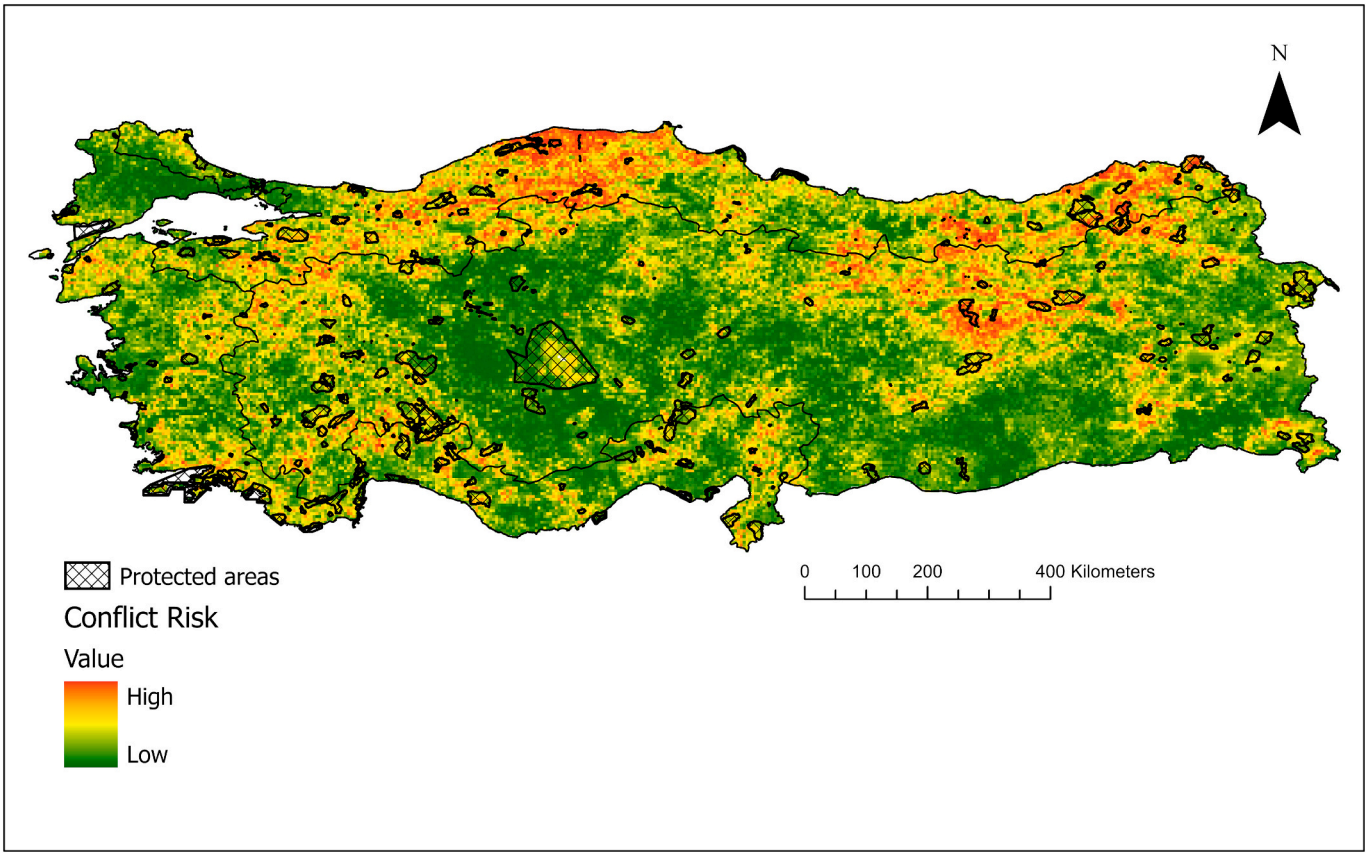


Fig. 5. Ensemble model for risk probability of human-brown bear conflict across Türkiye. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

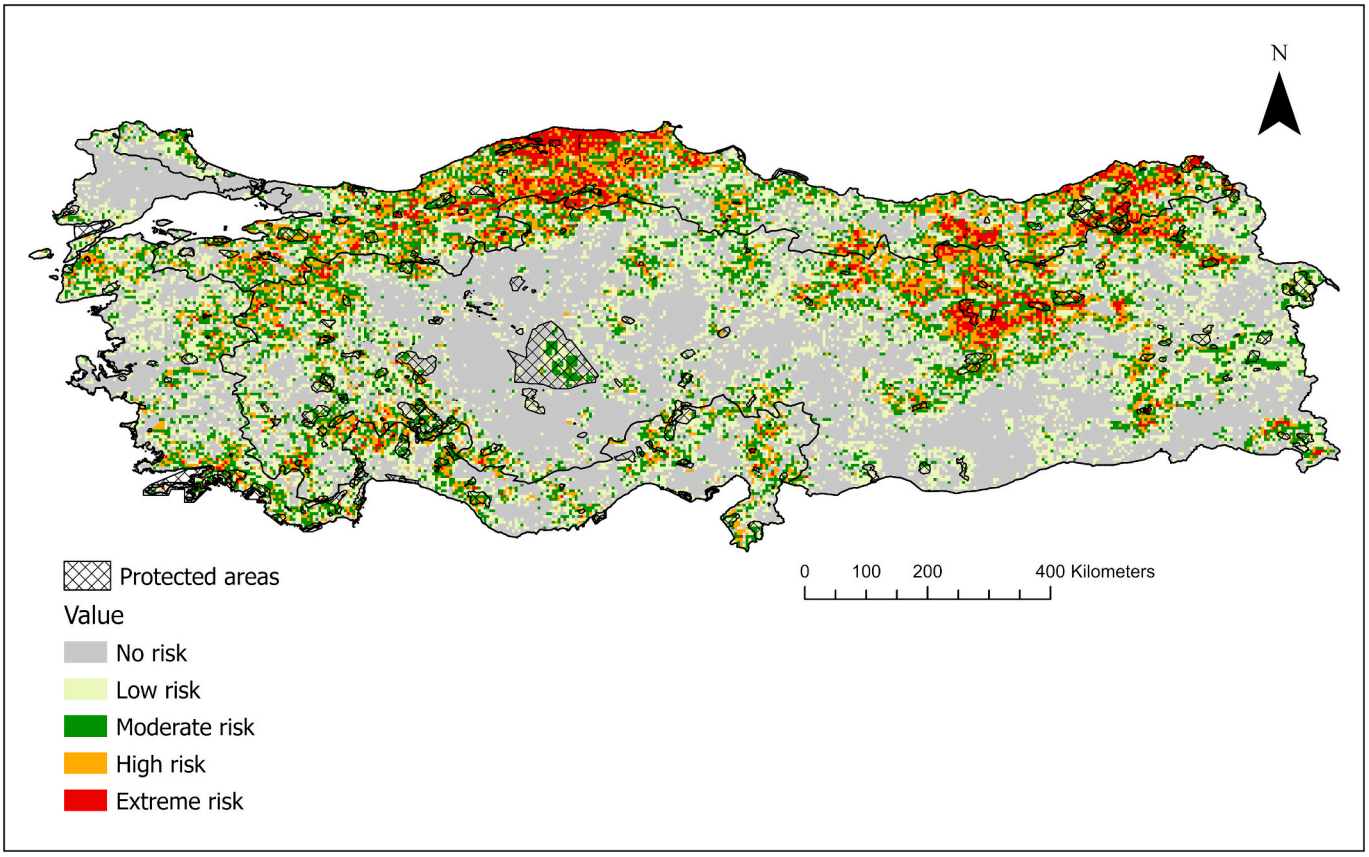


Fig. 6. The scaled conflict risk probability across the country.

(66,327 km^2) and 3.3% (25,729 km^2) were classified as high to extreme risk areas respectively (Fig. 6). Furthermore, analysis of two buffered layers, one with a 5 km radius and the other with a 10 km radius from the centers of protected areas, revealed that 24% of all conflict risk areas fell within a 5 km radius of these protected zones. This percentage increased to 43% when considering a 10 km radius (Fig. S7). Buffered layers also revealed high human activity (Human Footprint Index >10) and a high number of human settlements (>6000 settlements) around protected areas (Table S4).

4. Discussion

To our knowledge, this is the first comprehensive study to document and assess nationwide patterns of HBCs in Türkiye. Brown bear is one of Türkiye's most abundant and widely distributed large mammals, and human-brown bear conflicts are common across the country (Can and Togan, 2004; Chynoweth et al., 2016). Several factors have been proposed to explain the frequent occurrence of HBCs in Türkiye, including habitat fragmentation and patchiness, increased development and construction in forest habitats and higher bear numbers, especially along the Black Sea region of Türkiye (Ambarli et al., 2018).

Human-wildlife conflicts are usually inevitable whenever humans and animals share the same space (Bombieri et al., 2023; Chynoweth et al., 2016; Nayeri et al., 2022). Our data corroborates this notion, as high-risk conflict areas and the bulk of conflicts (98%) were clustered along the Black Sea coast and in Eastern Anatolia (Fig. 6). These regions have historically been associated with rural and forested areas characterized by human settlement and activity (Koc et al., 2015).

While no formal study has counted bear numbers in Türkiye, the Black Sea and Eastern Anatolia regions are known to support relatively large bear populations, with the total number of individuals across both regions estimated to be around 2000–3000 (Ambarli et al., 2016). In contrast, the Mediterranean region, estimated to support around 200 to 300 bears, had little record of human-bear conflicts ($n = 4$) and was generally classified as a low-conflict risk area (Fig. 6).

Although our findings suggest a correlation between high bear populations and conflict frequency, prior studies show that reducing population sizes (i.e., harvesting) has little impact on the levels of HBCs, especially in regions where the availability of natural foods and foraging space is restricted (Acharya et al., 2017; Bautista et al., 2023; Elbroch and Treves, 2023; Zarzo-Arias et al., 2021). When space and food are restricted in natural habitats, wide-ranging mammals and especially bears, can shift towards human-dominated landscapes which offer predictable and reliable sources of food with reduced foraging cost (Bautista et al., 2023; Kemahlı et al., 2023). For many species requiring large undisturbed areas, the increasing human footprint along the edges of protected areas is a global problem (Wittemyer et al., 2007, Wahab et al., 2021, Nabanita et al., 2023). For instance, it has been previously reported that two significant anthropogenic factors influencing the range size of African elephants are the intersection of human footprint with protected areas (Wall et al., 2021). It appears that the shared use of the same space between humans and elephants is a fundamental cause of human-elephant conflicts (Shaffer et al., 2019, Joshi et al., 2023, Bhagabati et al., 2024), which is also likely to be the case for Anatolian brown bears. Similarly, the conversion of core leopard habitats into human-modified areas has been reported to drive conflict cases (Yadav et al., 2021). On the other hand, human activities such as beekeeping and livestock herding carried out in protected areas and/or areas with high vegetation cover significantly increase the frequency of conflicts for many carnivores because they involve the use of the same resources in overlapping spaces (Naves et al., 2018).

Protected areas in Türkiye represent little coverage of natural bear habitats, with only 6.3% and 4.6% of all forested areas within the Euro-Siberian region and Eastern Anatolia being protected, with some of these

forests being legally logged (Atmiş, 2018). In fact, logging forests is considered a type of protected area in Türkiye. Additionally, the immediate vicinity of these protected areas in Türkiye is densely populated, with 26% of all human settlements situated within a 10 km radius of these areas (Table S4). Therefore, it is not surprising that brown bears, which have typical home ranges of around 14.07 and 83.25 km^2 in Türkiye (Ambarli et al., 2016), frequently interact with human settlements near their core habitats in search of space and natural resources. Our models illustrate that conflict risk is relatively low within protected areas (7.8%), but this risk sharply rises to 43% within a 10 km radius around these protected zones. Indeed, the most important factor associated with HBCs in Türkiye was distance to villages (37%), with distance to farmland (16%) also having a strong contribution (Fig. 3). These findings underscore the considerable dependence of Turkish brown bears on human resources, as 67% of all conflicts in our dataset were linked to foraging activities within human settlements (including damages to livestock 32.2%, beehives 25.1%, and crops 9.5%). This situation has already been reported in other parts of the world. For instance, data from 1999 to 2017 shows that damages to beehives is the most significant economic loss imposed by brown bears in Italy, followed by damages to livestock (Vivo and Mattia, 2023). Additionally, agricultural damage caused by brown bears can also extend to corn fields, gardens, orchards, grass silage, and vineyards (Krofel and Jerina, 2012), and increased degradation of natural brown bear habitats by agricultural expansion is known to exacerbate conflict rates (Can et al., 2014). Moreover, heightened human activity in bear habitats escalates the risk of such conflicts. For example, the gathering of wild foods by humans has emerged as a significant driver for human-sloth bear conflicts in India (Dutta et al., 2015). Penteriani and Melletti (2020) classify major drivers of HBC as: 1) availability of anthropogenic food, 2) natural food shortages, 3) impacts of human activities on the landscape, 4) climatic and meteorological events, 5) differences in conflict management, and 6) reduced human tolerance. In the context of Türkiye's human–brown bear conflicts, it appears that the availability of anthropogenic food, natural food scarcity, and human activities in the landscape are pivotal drivers.

Additionally, conflicts arising from brown bear foraging activities, such as damages to orchards, are commonplace in Turkish villages (Chynoweth et al., 2016) but receive far less media coverage. Therefore, if anything, our data set is an underestimate of human-brown bear conflicts caused by bear foraging activity within human settlements. While analyzing media-driven data, we should also consider that some news may exaggerate the attack risk posed by predators, an issue which was considered in other studies as well (e.g. Bombieri et al., 2019; Lennox et al., 2018).

Apart from proximity to villages and farmland, the other most important factors explaining patterns of HBCs in Türkiye were distance to protected areas (18%) and the human footprint index (13%) (Fig. 3). These factors reflect the substantial amount of human activity within and around core protected areas and forests (Chynoweth et al., 2016), which accounted for 12.32% of all conflicts in Türkiye (Table 1). While most human-induced conflicts stemmed from direct activities of humans in forested areas, such as logging, poaching, and recreation (e.g., trekking, berry picking, mushroom gathering, camping, etc.), accidental road kills also amounted to an important percentage (Table 1). Overall, the human footprint within and around protected areas in Türkiye is notably high, with an average Human Footprint Index of 9.81 $\pm$ 5.80 (Table S4). Given that an HFI score of $\geq$6 typically signifies human settlements (Venter et al., 2016), this value is alarmingly high for areas that should be subject to strict regulation regarding human activity. High levels of human activity within and around core protected areas may also account for the relatively high rate of brown bear attacks on humans, as 37.4% of all conflicts in Türkiye resulted in some form of altercation. As Penteriani and Melletti (2020), reported, that attacks on humans globally are mainly because of an encounter with a female bear with cubs (47%), sudden encounters with bears (20%), dog presence (17%), bear attacking after being shot or trapped (10%), and predatory attacks (5%).

The annual rate of bear attacks on humans in Türkiye was calculated to be 13.2 attacks per year, surpassing continent-wide rates in North America (11.4 attacks/year) and Europe (10 attacks/year, excluding Romania) (Bombieri et al., 2019). Apart from human casualties, bear casualties were also high, with 20.4% of all encounters ending with harm to bears. The majority of these were the result of road accidents (n = 24). Roads are major ecological traps in many parts of the world and can lead to increased human-wildlife conflict by restricting wildlife movement and concentrating human activity in otherwise wild or natural areas (Falcucci et al., 2009; Lamb et al., 2017). This holds in Türkiye, particularly in the Black Sea region, where roads increasingly traverse forests, and road construction in forested areas continues to rise. Ha and Shilling (2017) findings underscore the significance of factors such as total forest area and road density in explaining the spatial variation of wildlife-vehicle collision, with distinct patterns observed among taxonomic groups. Notably, the study emphasizes the importance of understanding these patterns for effective planning and implementation of mitigation measures, highlighting the utility of the spatial modeling approach in delineating high-risk areas for wildlife-vehicle interactions.

To a lesser extent, poaching is also a concern in Türkiye, as we documented 11 instances of brown bear mortality due to illegal hunting. This is likely an underestimate, given that hunting brown bear is illegal in Türkiye and therefore likely to be underreported substantially.

Moreover, it is crucial to recognize the socio-economic dimensions of human-brown bear conflicts in Türkiye. While conservation efforts often focus on ecological factors, the socio-economic context plays a significant role in shaping these conflicts. Rapid urbanization, agricultural expansion, and changing land use patterns have profound implications for human-wildlife interactions. In many rural areas of Türkiye, traditional livelihoods reliant on agriculture and pastoralism intersect with wildlife habitats, leading to increased conflict risks (Chynoweth et al., 2016). Additionally, disparities in resource access and competing interests among stakeholders further exacerbate the tensions. Addressing human-brown bear conflicts requires a holistic approach that considers not only ecological factors but also socio-economic dynamics. Community-based conservation initiatives that involve local stakeholders in decision-making processes can foster mutual understanding and cooperation, leading to more sustainable outcomes for both humans and bears. Raising public awareness from different age groups regarding the HBC drivers demonstrating the preventive strategies can considerably improve the effectiveness of HBC prevention programs (Penteriani and Melletti, 2020).

5. Conclusion

Large mammals like brown bears, which are increasingly forced to adapt to human-dominated landscapes (Morales-González et al., 2020) often face challenges surviving within small conservation areas and heavily rely on external habitats for sustenance and resources. This dynamic inevitably gives rise to heightened human-wildlife conflicts, particularly when human activity within and around protected regions is unregulated. As our study shows, this appears to be the primary driver behind the elevated numbers of HBCs in Türkiye. Core habitats and migration routes of brown bears increasingly intersect with human settlements in Türkiye, and human activity is largely unchecked around these areas. Moving forward, conservation efforts should concentrate on identifying core brown bear habitats and movement corridors that can meet the essential requirements of this species. Simultaneously, expanding the boundaries of protected areas is imperative to minimizing human-wildlife conflicts. Moreover, our findings underscore the pressing need for stricter regulations on human activities within protected regions, including logging, resource gathering, livestock grazing, and recreational pursuits, especially if we want to reduce unwanted

outcomes such as human or brown bear mortality.

In summary, our study underscores that the high incidence of HBCs in Türkiye predominantly arises from limited protected area coverage, insufficient natural habitats and resources available to brown bears, and the escalating encroachment of human activities in and around vital wildlife habitats. Addressing these critical factors will be pivotal in preserving sustainable bear populations in Türkiye and achieving a harmonious coexistence between humans and brown bears.

CRediT authorship contribution statement

Ercan Sıkdokur: Writing – review & editing, Writing – original draft, Software, Formal analysis, Data curation. **Morteza Naderi:** Writing – review & editing, Writing – original draft, Supervision, Software, Investigation, Formal analysis, Data curation. **Elif Çeltik:** Data curation. **M. Çisel Kemahlı Aytekin:** Writing – review & editing. **Josip Kusak:** Writing – review & editing, Supervision, Conceptualization. **İsmail K. Sağlam:** Writing – review & editing, Writing – original draft, Conceptualization. **Çağan H. Şekercioğlu:** Writing – review & editing, Supervision.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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