Journal of Arid Environments 199 (2022) 104699

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Predicting current and future habitat refuges for conservation of wild goat (*Capra aegagrus* Erxleben 1777) under climate change in Iraq

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ARTICLE INFO

Keywords:
Species distribution modelling
Mammals
IUCN Red list
Protected area
Conservation planning
MaxEnt

ABSTRACT

The Wild goat (*Capra aegagrus*) has had less attention and study than many other mammals, especially in Iraq. We collected comprehensive data about this species in Iraq, a total of 36 records, in order to build species distribution models using Maximum Entropy and seven environmental variables. The results confirm that suitable habitat is limited to the northeastern part of Iraq, especially the Zagros mountains of Kurdistan region/Iraq. Elevation most influenced the predicted distribution. Habitat suitability under different future climate scenarios (RCP2.6 and RCP8.5 for 2050 and 2070) is stable but expands compared with the current period. Areas of marginally and highly suitable decrease, while suitable habitat increases compared to the present. Habitat suitability inside existing Protected Areas was significantly higher than outside. Applying IUCN Red List criteria at the national scale, the species was classified as Endangered. The main short-term threat is, against which urgent action is needed to avoid future declines. We conclude that climate change is not likely to be a long-term threat to the Wild goat in Iraq, but urgent action to stop poaching is needed to sustain many Iraqi mammals, especially the Wild goat. Our applied approach can help understand and conserve other critical species in Iraq.

1. Introduction

The increased pressures generated by human activities in form of climate changes and habitat fragmentation have caused serious threats for many species (Dawson et al., 2011). Climate change may be will have an extreme impact on our biodiversity, but the loss of the species depends on how these species respond for global warming, especially for critical species (Chapin et al., 2000; Mora et al., 2011; Kaky and Gilbert 2017). As a consequence, conserving species diversity and their natural habitats have become an international/global demand to ensure sustainability (Butchart et al., 2015). However, a dilemma that the scientific community still suffers from is that many regions are still understudied (Mora et al., 2011), and information about the distributions of many species is far from complete (Bini et al., 2006, Fivaz and Gonseth, 2014; Alatawi et al., 2020). This is important because many species are under the potential threats of climate change and other anthropogenic factors (Kaky and Gilbert, 2017).

For these and other reasons, studying species distribution modelling has gained considerable attention (Guisan and Thuiller, 2005) as it deals with the issue of incomplete data (Alatawi et al., 2020; Kaky, 2020). The technique has proven its ability to identify the best candidates for hotspots of habitat suitability under current and future scenarios, which can then be used in species conservation (El-Gabbas et al., 2016; Kaky and Gilbert, 2019; Alatawi et al., 2020), especially for less-studied species in relatively understudied habitats (for Egypt see El-Gabbas et al., 2016; Kaky and Gilbert, 2016; Kaky et al., 2020; for Saudi Arabia see Alatawi et al., 2020; for Iraq see Kaky, 2020; for Iran).

Climate change one of the main threats to biodiversity and global warming capable to driven species to extinct (Alkemade et al., 2011). Therefore, it is very necessary to study how the species respond to future climate change. Large mammals because of their large body and low population are more vulnerable to be extinct under climate change, poaching, and land use (Fisher and Owens, 2004). The influence of climate change on biodiversity is mostly connected with SDMs (Araújo et al., 2011), however, SDMs subjected for many limitations (Pearson and Dawson, 2004); but still one of the widely methods recently have been used to address effect of climate change. *Capra aegagrus* one of the species that loss their habitat suitability under climate change (Ebrahimi

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https://doi.org/10.1016/j.jaridenv.2021.104699
Received 15 March 2021; Received in revised form 14 November 2021; Accepted 6 December 2021
Available online 20 January 2022
0140-1963/© 2021 Published by Elsevier Ltd.

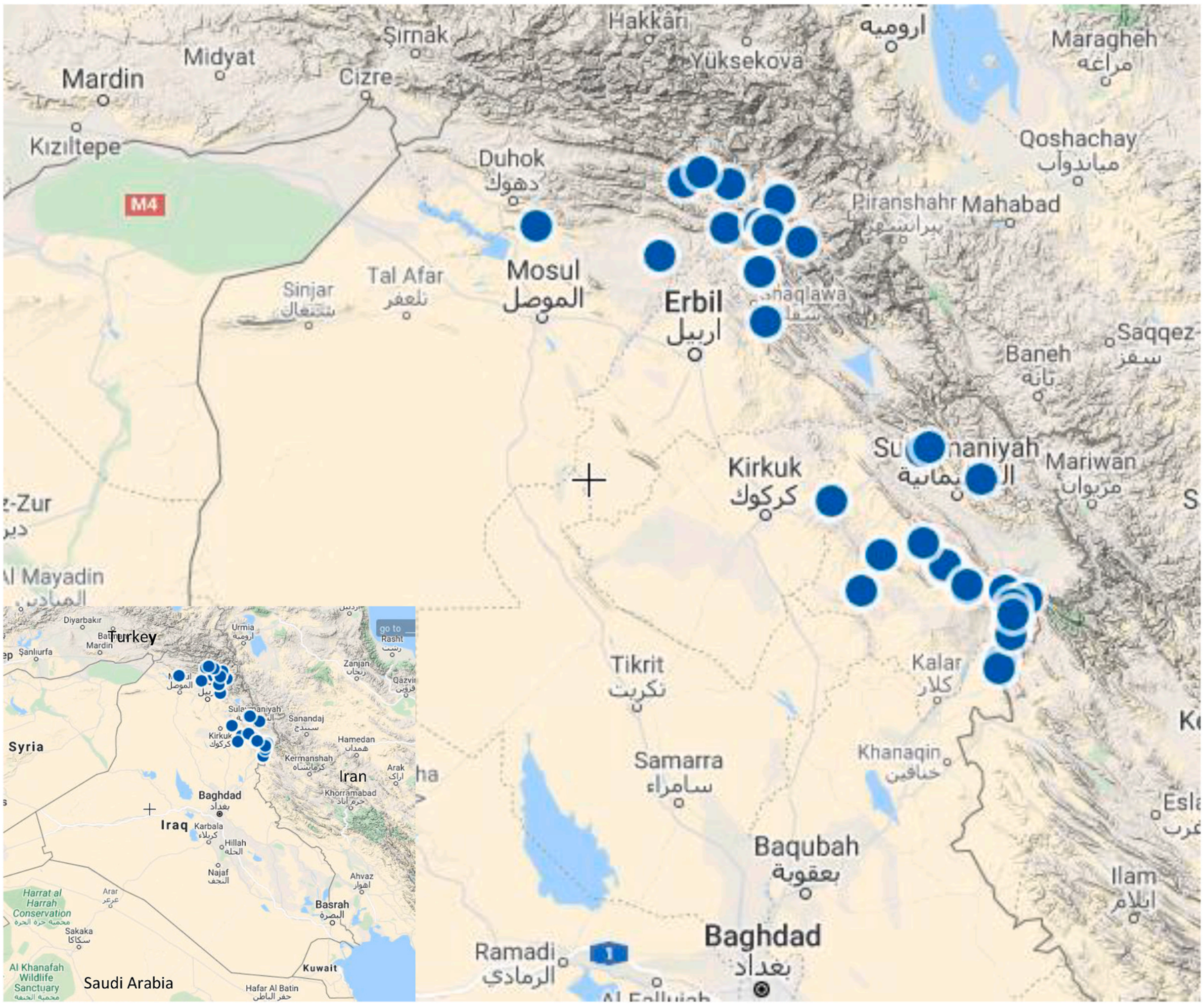

Fig. 1. Map of Iraq labeled with main cities where the *Capra agagrus* mainly located, the blue dots are the occurrence points. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Environmental variables used to run MaxEnt. The highlighted one were used after reducing collinearity using Variation Inflated Factors (VIF) to build the model, and their influence in the final model of distribution *Capra aegagrus.*

Variables
Altitude
BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

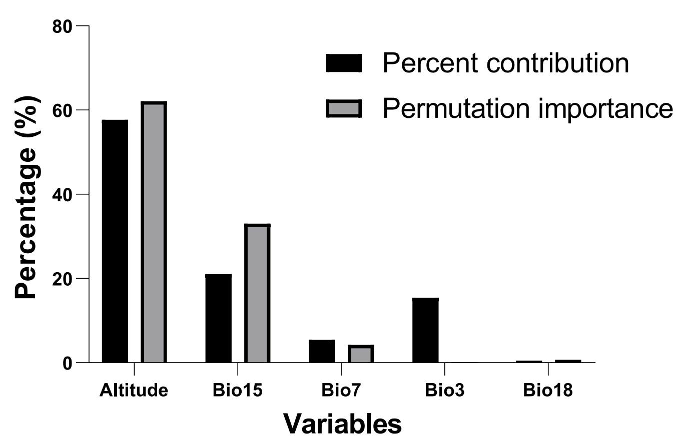

Fig. 2. Most influential environmental variables in the final model of MaxEnt, according to the both index percentage contribution and permutation important.

et al., 2019; Malakoutikhah et al., 2020; Salas et al., 2020).

The Wild goat (Weinberg and Ambarli, 2020) is an ungulate game species (Macar and Gurkan, 2009) widely but discontinuously distributed in Afghanistan, Pakistan, Iran, Turkmenistan, Turkey, Iraq, and the Caucasus region (Weinberg et al., 2008; Macar and Gurkan, 2009;

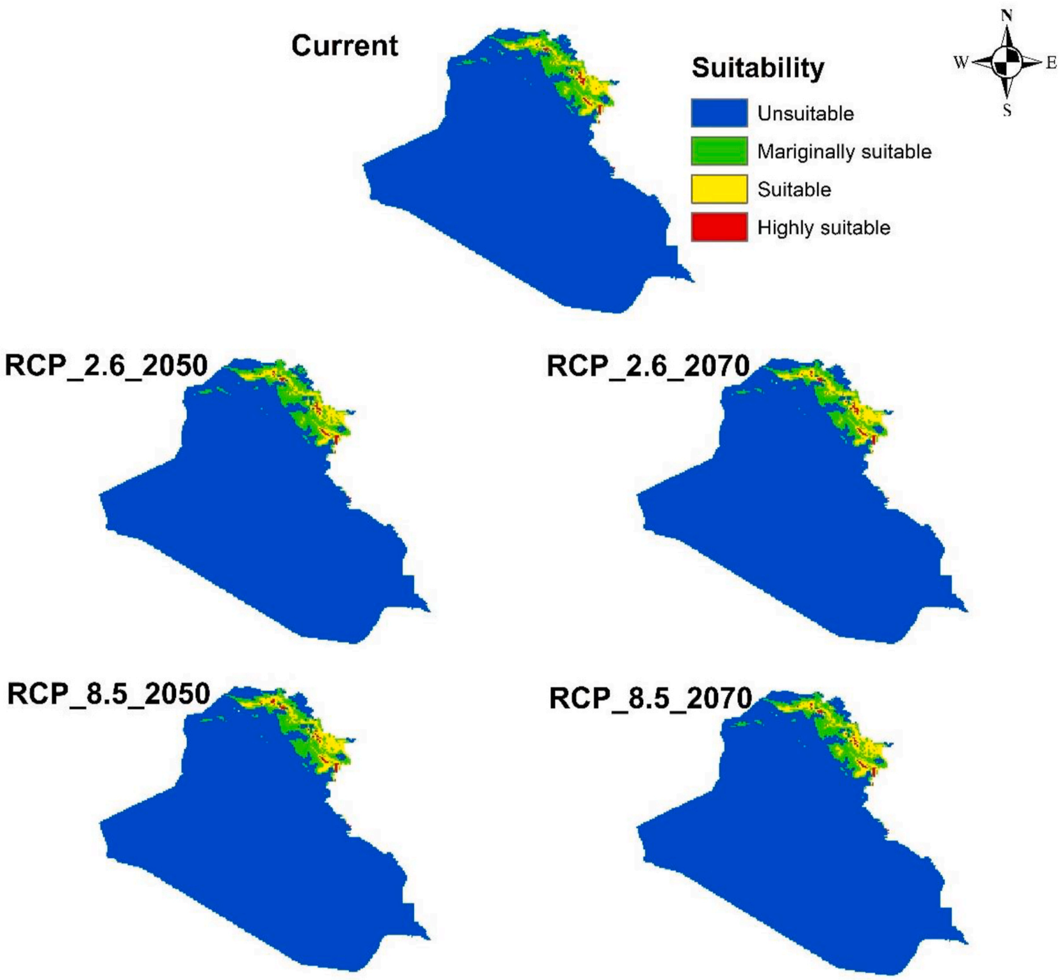

Fig. 3. Mean habitat suitability areas for *Capra aegagrus* in Iraq across four GCMs for present day and under different future scenarios (RCP2.6 and RCP8.5) in the 2050s and 2070s.

Rahim, 2016; Al-Sheikhly et al., 2020; Weinberg and Ambarli, 2020). Historically, its distribution even reached Arabian countries (e.g., Lebanon, Syria, Jordan) but it became extinct in these countries (Rahim, 2016; Al-Sheikhly et al., 2020; Weinberg and Ambarli, 2020). There is a proposed re-introduction plan into Syria and Lebanon (Genov et al., 2009; Weinberg and Ambarli, 2020).

Over many years the conservation status of the Wild goat has been classified by the International Union for Conservation of Nature (IUCN) as Vulnerable due to the great threats that the species experienced (Weinberg et al., 2008). However, a recent new global assessment has downgraded it to Near Threatened (Weinberg and Ambarli, 2020) on the basis of its population trend, which is likely to be stable and probably increasing in its current range in present day. They even believe that if this trend continues the species may be moved to the Least Concern category. However, they concluded that the species is still facing major threats, and therefore it listed as Near Threatened on the precautionary principle.

The Wild goat generally inhabits mountain areas where there are outcrops and vegetation, and mostly feeds on grasses, shrubs, herbaceous plants (Weinberg and Ambarli, 2020). Goats normally try to avoid areas with humans (Genov et al., 2009), but in a few cases they can still be observed near villages (Raza et al., 2012).

In Iraq, there is a lack of knowledge about the Wild goat, and its overall distribution is still uncertain and vague, but it is believed currently to be fragmented/isolated (Al-Sheikhly et al., 2020; Weinberg and Ambarli, 2020) in different parts of Iraq (Al-Barazengy et al., 2015; Al-Sheikhly et al., 2015, 2020) with a rough estimate of approximately 2000 individuals (Weinberg and Ambarli, 2020). Most observations of Wild goats are from the northern and north-eastern regions (mainly Kurdistan), specifically on Zagros Mountain ranges: it is here that the largest populations occur (Rahim, 2016; Al-Sheikhly et al., 2020). Luckily, some areas where the Wild goat is known to exist have been proposed as Key Biodiversity Areas in Iraq (Raza et al., 2011, 2012).

Globally, various factors cause population declines, including habitat degradation, fragmentation and anthropogenic activities, but poaching in the form of uncontrolled and/or illegal hunting is considered to be one of the biggest threats especially in Iraq (Weinberg and Ambarli, 2020). Nevertheless, trapping, overgrazing by domestic livestock and habitat degradation are also other major threats (Raza et al., 2012; Al-Sheikhly et al., 2020; Weinberg and Ambarli, 2020). Furthermore, in 2011 a fatal virus disease, Peste Des Petits Ruminants Virus (PPRV), appeared in Iraq, causing some fatalities among Wild goats (Rahim, 2016).

A lot of work needs to be carried out in Iraq to achieve a good comprehensive knowledge about its distribution, and hence, to develop a plan for its conservation. Regrettably, the unstable politics of the last four decades has caused a shortage of ecological survey work, leading to large gaps in up-to-date information about all of Iraq's wildlife, but especially for species in a critical situation, such as the Wild goat. However, recently there have been some local efforts to study Wild goat in Iraq and to increase community awareness about its importance.

A good starting point was made by the Nature Iraq team, funded by

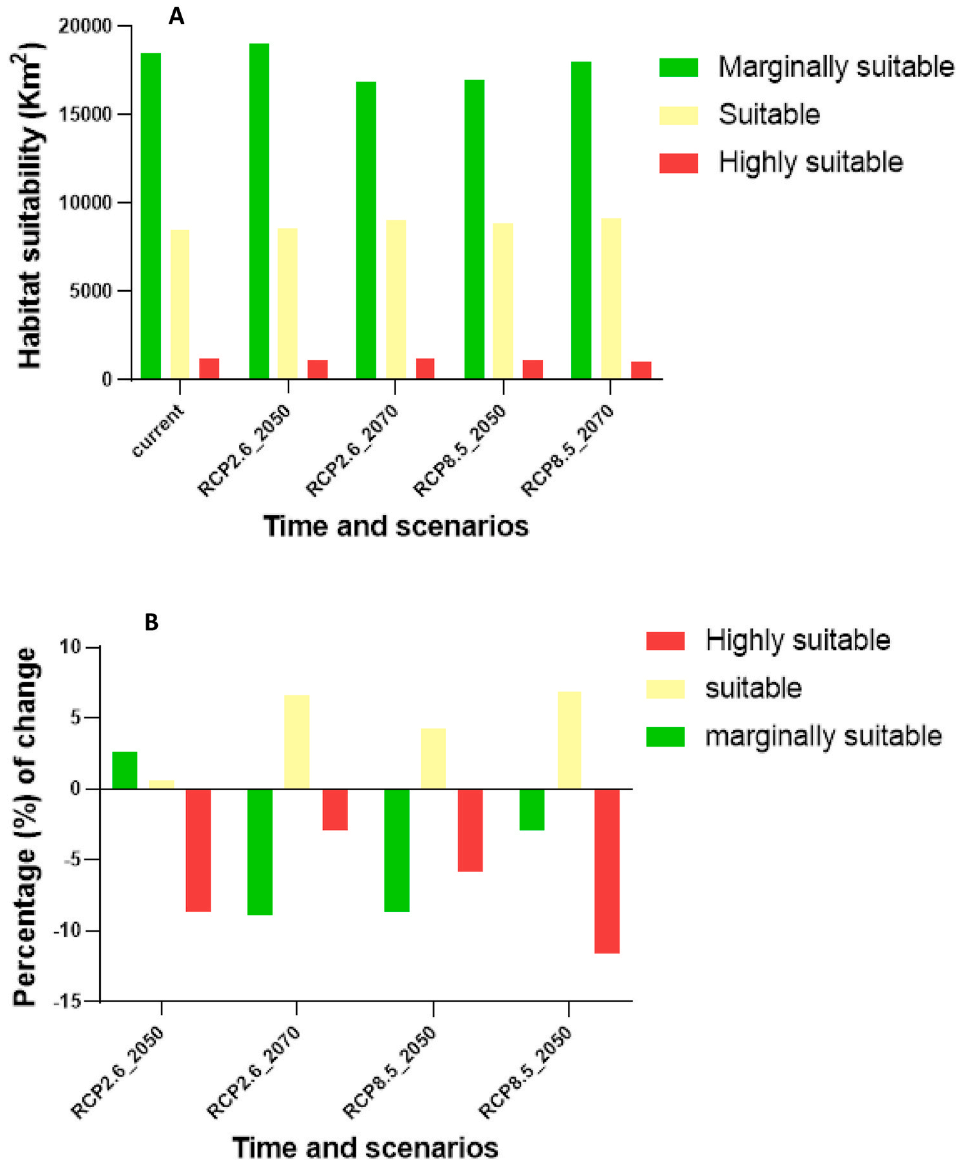

Fig. 4. A) The area of habitat suitability (No. of grid cells ~ 5 km) for current and under different future climate scenario. B) The percentage of habitat suitability change between current and different climate scenario.

the Conservation Leadership Program. They conducted surveys of Wild goats in different hotspot sites (e.g., Qara Dagh and Peramagroon mountains) and successfully recorded them in several locations (Raza et al., 2012). A recent study by Al-Sheikhly et al. (2020) considerably extended the known distribution into new eastern and south-eastern parts of Iraq, along the Iranian border but still within Zagros Mountain ranges. In addition, Al-Barazengy et al. (2015) reported a new observation of Wild goat from Alqosh Mountain, in the northern part of Mosul province. So far, we are only aware of one study that used species distribution modelling to model Wild goat in Iraq: Rahim (2016) modelled it under current conditions, showing that Kurdistan (see Fig. S4) is more suitable than the rest of the country.

We ultimate aim is to understand Wild goat distribution and the threat that climate change represents, and hence contribute to its conservation in Iraq. We want to help local decision-makers and guide conservation efforts such as the Key Biodiversity Areas project.

2. Methods

2.1. Study area and species data

Iraq (Fig. 1) has a total area of 437,831 km^2 located in middle east, has borders with Turkey from north, Iran from east, Syria and Jordan from west, and Saudi Arabia and Kuwait from south. The climate is mainly subtropical and semi-arid, but Mediterranean in the north and north-east (FAO, 2003). We collected all the location records for *C. aegagrus* from different sources: literature, museum data, expert observation, interviews with hunters, and online open sources such as the GIBF database (www.gbif.org). As a result, we obtained 36 occurrence points across Iraq, mostly located in the Kurdistan region of Iraq. All the records were checked with experts to be confident of the localities, and we deleted all ambiguous locations and duplicate points, retaining just one record in each grid-square (~4-km^2) to avoids models that are overfit to calibration data (Sillero, and Barbosa 2021).

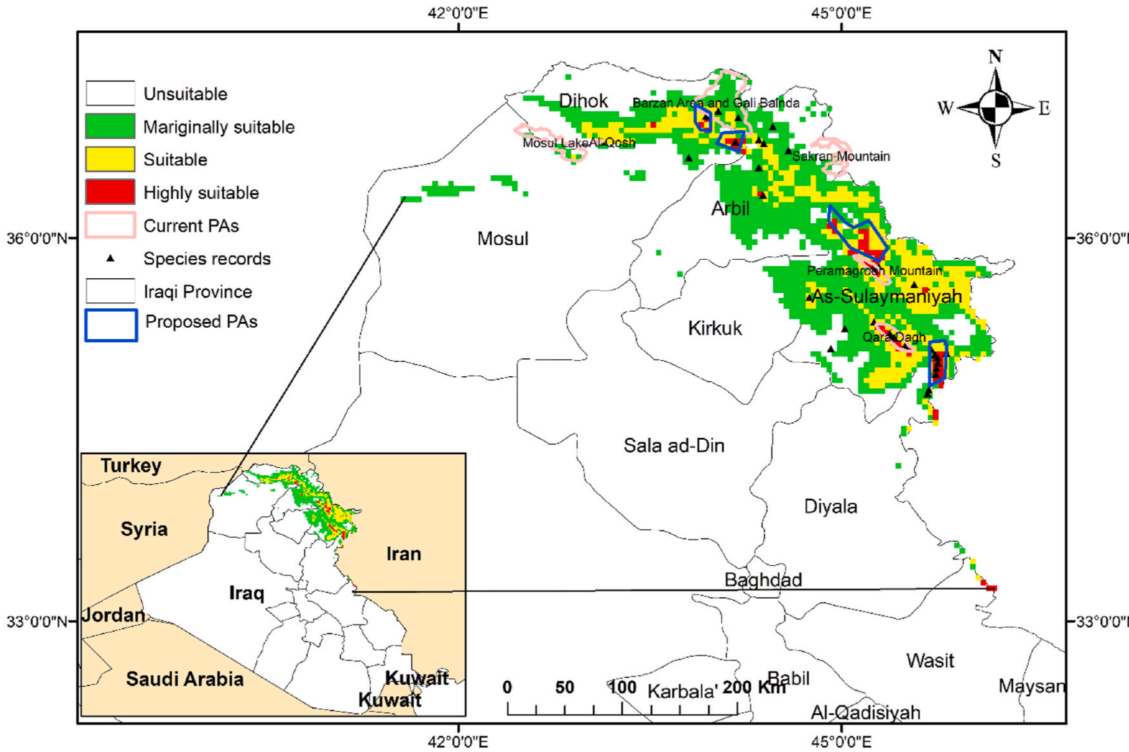

Fig. 5. Proposed new areas for future conservation regardless of different future climate scenarios. The blue polygon areas are proposed areas for future conservation and most suitable habitat based on current and all future climate conditions that predicted by the models. The pink polygons are Iraqi PAs that used in the analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2.2. Environmental variables

The environmental niche of a species is influenced by climatic factors, which are consequently used in species distribution modelling. The current and future climate data (Table 1: bioclimatic variables) were downloaded from the WorldClim database v2 at 2.5-min spatial resolution (Fick and Hijmans, 2017). Bioclimatic variables were generated from the monthly temperature and precipitation values of weather stations in order to obtain more biologically meaningful predictors (Fick and Hijmans, 2017), and represent averages for the years 1970–2000. Multicollinearity among the 19 bioclimatic variables was assessed by applying Variance Inflation Factor (VIF), excluding those with VIFs greater than 10 using the *sdm* package in R (Naimi and Araújo, 2016). As a result, five of the 20 variables were retained to run the models (see Table 1).

The model using the current environmental variables was projected into future climates for two future times (2050 and 2070) using two different emission scenarios 'representative concentration pathways' (RCP 2.6 and RCP 8.5). Each prediction was derived from three different Global Circulation Models (GISS_E2-R, HadGEM2-ES, and MIROC5) these models chose based on their suitability for our study and areas (see, McSweeney et al., 2015), and the results averaged.

2.3. Ecological niche modelling

Maximum Entropy (MaxEnt ver 3.4.1) software (Phillips et al., 2006) was chosen to run the models, because it has been extensively used with presence-only data with demonstrably good results (Fois et al., 2018; Rahimian Boogar et al., 2019; Kaky et al., 2020). The default settings in MaxEnt have been shown to achieve a good performance (Phillips and Dudik, 2008). Thus, the logistic output format was used, with the following settings: regularization multiplier = 1, maximum iterations = 1000, convergence threshold = 10^{-5}, minimum training presence threshold to convert the probability maps to binary). Ten-fold cross-validation [K = 10] with 10 replicates were used to average over prediction errors: the records were divided into K equal-sized sets of points, one of which is used for evaluation and the rest for calibration of the model (following Kaky and Gilbert, 2017; Kaky, 2020). Every set is utilized once as an evaluation dataset in each of the ten replicates, and every occurrence point appears exactly once in an evaluation dataset (Peterson et al., 2011).

Two statistics were used to evaluate model performance, the Area Under the Curve (AUC) (Pearce and Ferrier, 2000), and the True Skill Statistic (TSS) (Allouche et al., 2006). AUC scores range between zero to 1, where any score close to 0.5 indicates that the model is no better than random, while scores close to 1 indicate an excellent model. TSS scores range between −1 and +1, where any score closes to −1 means the model performance is no better than random, while scores close to +1 imply that the model is very good (Allouche et al., 2006). The resulting habitat suitability maps were classified into four categories: highly suitable (0.7–1), suitable (0.5–0.7), marginally suitable (0.2–0.5), and unsuitable (0–0.2), following Guo (2017). In addition to the.

After the model fitting and evaluating, an additional step has done to increase the model performance and to test whether the model significantly better than random (Rase & ter Steefe, 2007). Therefore, based on randomly sampled points across Iraq of equal sample size (n = 36) for wild Goat we fitted a series of null models. Then, boxplot generated of AUC values were generated by running the models 100 times, and the significance of observed wild goat AUC scores was tested using one sided 95% confidence interval of the null model to see if the wild goat model achieves significantly better than random ((Rase & ter Steefe, 2007). Rase & ter Steefe, 2007 suggested to run the null model 999 times (Rase & ter Steefe, 2007), while, our the results from the null models stabilized before this number was reached, so additional model runs beyond 100 were believed unnecessary.

Then, we test whether the models predict a novel climate conditions when projecting wild goat under climate change. Maxent can deal with problem with a way called "clamping" "which treats variables outside

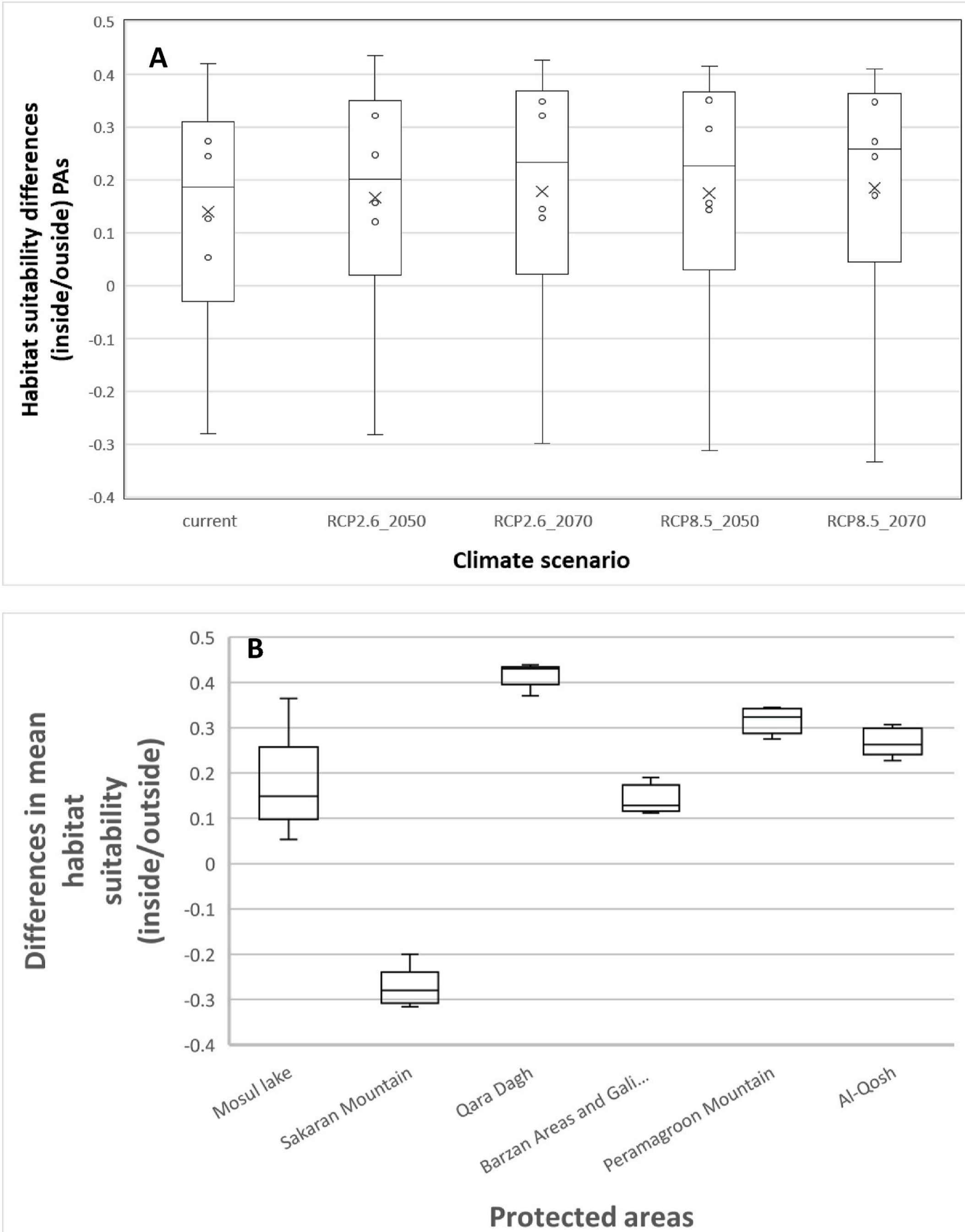

Fig. 6. The boxplots show the variation in the data. A) Mean differences in habitat suitability [inside – outside] across all PAs for current and future scenario (RCP2.6 and RCP8.5 in 2050 and 2070). B) Mean differences in habitat suitability [inside – outside] for each PA across all time and future scenarios.

the training range as if they were at the limit of the training range" (Phillips, 2006). Maxent can produce a map of clamping whenever a model is projected that show where clamping has had a large effect (Phillips, 2006). Therefore, cautions need to interpret the results.

The resulting habitat suitability maps were used to measure the effectiveness of the Iraqi Protected Areas (hereafter PAs) in conserving Wild goats, by calculating the suitability inside/outside each PA under current and future scenarios. With a total of 23 PAs, which cover about 1.5% of the Iraqi land area (UNEP-WCMC, 2020), we selected 6 PAs located within the habitat suitability range of *C. aegagrus*, i.e., in mountain areas. We created a buffer of 50 km around each PA to represent the habitat suitability outside, and the paired inside-outside difference for each PA was calculated. These differences became the response variable of a Generalized Linear Model using scenarios (RCP2.6 or RCP8.5) and time (current, 2050 and 2070) as predictors, as well as the interaction between the two (following Kaky and Gilbert, 2019a; Kaky et al., 2020), implemented in R 3.4.3 (R foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org).

2.4. IUCN Red List assessments

IUCN Red List is a comprehensive checklist of species under threat of extinction according to the IUCN Red List Categories and Criteria. The last assessment of IUCN Red List, *C. aegagrus* was classified globally as Near Threatened with a stable population trend (Weinberg and Ambarli, 2020). We carried out a regional assessment of *C. aegagrus* in Iraq for the

Table 2
IUCN Red List assessments for *Capra aegagrus* based on occurrence records, and under future climate change scenarios (average of all scenarios).

Time	EOO km^2	AOO km^2	IUCN Category and Criteria	Assessment status
Current based on records	23,581	132	B2a,b(v)	EN
Current based on model	93,500	44,350	A3c	LC
RCP2.6_2050	90,300	43,500	A3c	LC
RCP2.6_2070	89,000	40,700	A3c	LC
RCP8.5_2050	89,900	42,100	A3c	LC
RCP8.5_2070	88,500	39,750	A3c	LC

Note: Because of the percentage differences between current and any future scenarios not exceed 10%, then based on IUCN assessments the species classified as Least Concern (LC). This statement is true for both cases: first, the actual gap time between current and future scenario, second, based on 10-years lifespan, except the number will slightly changing according to 10-year lifespan.

first time, following the IUCN recommendations and appropriate Categories and Criteria. To do this, we calculated the Extent of Occurrence (EOO) and Area of Occupancy (AOO) based on 2 × 2 km (4 km^2) grid-cells, as recommended by IUCN (2020), using the Geospatial Conservation Assessment Tool (GeoCAT) (http://geocat.kew.org) and the occurrence records (see Fig. S1). EOO is defined as "the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy"; AOO is "a scaled metric that represents the area of suitable habitat currently occupied by the taxon" (IUCN, 2019).

The IUCN concept of a 'location' is defined as "a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present" (IUCN, 2019). In this study poaching is considered as the main threat to *C. aegagrus* based on hunter interviews, local authorities, and the Environmental Protection Organization of Garmain (EPOG). Accordingly, the size of a location was explained based on the area covered by the threat, perhaps containing one or more sub-populations (see IUCN Standards and Petitions Committee, 2019: 60–61). Location was calculated based on the habitat suitability maps for the current and future scenarios using the binary maps of MaxEnt models.

In this Red List assessment, Criterion B (small geographic range) was used in the form of the EOO or AOO, with at least two of the following three conditions: 1) severely fragmented or few locations; 2) continuing decline; and 3) extreme fluctuations (for more detail, see IUCN Standards and Petitions Committee, 2019). Here we depend on the number of locations and continuing decline: our evidence for continuing decline is the ongoing and increasing threat of illegal hunting, which leads to decline (Kaky and Gilbert, 2019b; Kaky et al., 2020 unpublished data: see Table S1). To classify the species under criterion B, it was therefore enough to meet the appropriate criteria for one of the two range metrics (i.e., AOO or EOO) (Kaky and Gilbert, 2019b; IUCN Standards and Petitions Committee, 2019).

Under current and future scenarios, the assessments could use Criterion A, population declines (IUCN, 2019), especially under category A3 for projected population decline. The lifespan of *C. aegagrus* is about 10–15 years, and hence predicted changes were scaled to the standard 10 years (IUCN, 2019). The estimated change in habitat suitability was calculated based on the differences between the current prediction and each future scenario for each of EOO and AOO, expressed as percentage. Then these percentages were used to classify the species based on IUCN Red List criteria (following Kaky and Gilbert, 2019b): Least Concern (LC) loss <30%, Vulnerable (VU) loss >30%, Endangered (EN) loss >50%, and Critical Endangered (CR) loss >80% (IUCN, 2019). Predicted future changes (%) calculated in range size of the species under future climate scenarios used the same grid-cell size of 2 × 2 km, using the down-scaling method as recommended by IUCN (IUCN, 2019: 51–56). All means are quoted with standard errors.

3. Results

MaxEnt showed satisfactory results based on both evaluation metrics; the mean AUC values of the test data set were 0.97 ± 0.018 and mean AUC values for train data set was 0.98 ± 0.020, while mean TSS score for test data was 0.84 ± 0.055 and 0.87 ± 0.07 for train data set. The models achieved significantly better than random based on significant level 0f 0.05 (using q 95% one sided C.I.) when compared to the AUC values for null hypothesis (Fig. S7). altitude, precipitation seasonality (bio-15), and Temperature Annual Range (BIO5-BIO6) (bio-7) were important predictors in the final distributional model (Table 1 and Fig. 2). The results show that the species prefers climate conditions of rainfall between 500 and 2000 mm, and the species can survive till temperature 42 °C (Fig. S2).

The current prediction shows that the area of Zagros Mountains in the Kurdistan region of Iraq has the most suitable habitat and therefore can be considered a refuge for *C. aegagrus* in Iraq (Fig. 3). In particular, the results indicated high suitability in the northeast of Sulaymaniyah, especially in the Peramagroon and Qara-Dagh PA areas, and more highly suitable patches southeast of Sulaymaniyah, especially around Darbandikhan town toward the Iranian border, and some patches north of Erbil, especially Barzan PA (Figs. 3 and 6 and Fig. S3). Under current conditions the model predicts the areas of marginally suitable, suitable, and highly suitable land for *C. aegagrus* in Iraq which mostly located in Kurdistan region (see Figs. 3 and 4 and S3).

Habitat suitability under future climate scenarios was calculated using the same process, and the results derived from averaging the three global circulation models. The predicted areas of marginally suitable and suitable habitat categories for C. aegagrus decreased under both future scenarios (RCP2.6 and RCP8.5) for 2050 and 2070 compared with current time see (Fig. 4). While, predicted suitable habitat category areas were expanded significantly compared with current time under both future scenarios (RCP2.6 and RCP8.5) for 2050 and 2070 for more details see (Fig. 4). There were slight differences among the predictions of future scenarios, but all the future maps highlighted the Zagros mountains as the most suitable refuge for Wild goats (Fig. 3, Fig. S3), especially around Erbil, Sulaymaniyah and Dohuk, and some patches close to Mosul and to Al-Qosh PA, as well as some highly suitable patches north of Diyala (especially around the village of Sartak: for more details, see Figs. 3 and 5 and S3). The results suggest some new areas for future conservation planning (Fig. 5). Then, clamping maps showed the projecting of climate change scenarios under different climate change scenarios for wild goat, and the maps show that clamping has obviously had high effect on the species (Fig. S6).

The paired *t*-test show significant differences in mean habitat suitability inside compared to outside the existing PAs (mean [inside-outside] = 0.165, 95% confidence limits 0.076 to 0.24, paired t = 3.83, df = 29, p = 0.0008). The GLM showed that this difference was not affected by year ($F_{2,27}$ = 0.135, p = 0.88) or future scenario ($F_{2,27}$ = 0.13, p = 0.90). The mean differences between inside and outside PAs for current and future scenarios are small (Fig. 6A), but the differences for each PA included in this assessment are more marked (Fig. 6B).

Finally, the national IUCN Red List assessment based on the occurrence records and the modelling, using the GeoCAT tool, show that the species can be classified as Endangered (EN) at the national scale: the EOO was 23,581 km^2 (NT), and the AOO was 132.000 km^2 (EN) (see Table 2). Under current and future scenarios predictions, the species was classified as Least Concern (LC) (Table 2).

4. Discussion

Many areas are still defined as understudied in terms of their species diversity and geographical distribution (Bini et al., 2006). Species in these areas are potentially in danger due to the acceleration of different anthropogenic factors (e.g., habitat destruction, climate change, poaching). Iraq is a really interesting case study as it is full of many important and endangered species but with limited information about their numbers, such as our studied species, the Wild goat.

Our results indicate that habitat suitability is high mostly in the north and north-east of Iraq, along the Zagros Mountains in the Kurdistan region. Here the area is known to be topographically suitable and annual rainfall occurs at higher rate in comparison to the rest of the country. Surprisingly, the modelled future climate-change scenarios for 2050 and 2070 seem not to have a great influence on the predicted habitat suitability.

The first national IUCN assessment indicates that the species is classified as Endangered, but climate change should not impact on the distribution. We therefore conclude that poaching is the issue to address, and should be immediately controlled to ensure the sustainability of the Wild goat in Iraq.

Among the five variables used to analyse Wild goat distribution, Altitude appears to be the most influential variable on its distribution. In Iraq, precipitation rates in general are noticeably higher in Kurdistan than in the rest of Iraq (Rahim, 2016), allowing a relatively constant, diverse and thick vegetation cover through the year, which presumably is required in its diet (Weinberg and Ambarli, 2020). Our analysis suggests that suitable annual rainfall for the Wild goat is between 500 and 2000 mm (Fig. S2). Rahim (2016) also found that precipitation (bio-19) was among the most important contributors in his SDM to explaining Wild goat distribution in Iraq.

In Iran, Esfandabad et al. (2010), Sarhangzadeh et al. (2013), and Morovati et al. (2014) suggested that steep slopes, water sources and rocky substrates/cliffs all contributed to the suitability of the habitat for Wild goats, and in Turkey, Süel et al. (2019) also suggested that topographical factors (e.g., ruggedness, elevation) had an influence on Wild goat distribution. The aim of our modelling is to investigate the potential effect of future climate change on the habitat suitability if Wild goats, and so have used bioclimatic variables and elevation to figure out the suitable range size for wild goat distribution in Iraq, especially, the wild goat recorded from high elevation than other areas in Iraq.

An interesting and important outcome of this study is that the different climate change scenarios did not greatly influence the predicted habitat suitability; actually, the areas of suitable and highly suitable habitat increased, with a slight northward latitudinal shift north of Erbil, and eastwards longitudinal shift to the northeast of Sulaymaniyah, especially toward the Iranian border (Fig. 3). We consider this finding of a potential increase in habitat suitability is a promising result that should be borne in mind before any long- or short-term conservation action is enacted. Our finding contradicts the results of similar studies from Iran: Malakoutikhah et al. (2020) and Ebrahimi et al. (2019) found that Wild goat is predicted to lose a large portion of its habitat suitability due to climate change in central Iran and across Iran, respectively. For a related species, the Asiatic Ibex (*Capra sibirica*) in eastern Tajikistan, Salas et al. (2020) found that under climate change it was predicted to lose about 18% of its current habitat suitability by 2070. Wild goats can migrate to cope with changing conditions (Esfandabad et al., 2010; Al-Sheikhly et al., 2020), so it is possible that in Iraq it may shift or adapt to live in different environmental conditions. Our results explicitly emphasize the importance of the Kurdistan region for the conservation and restoration of the Wild goat population, and this confirmed by previous studies as key biodiversity areas (Raza et al., 2011, 2012).

Protected Areas are the main tool for mitigating the biodiversity crisis, and are also vitally important for conserving species experiencing high disturbance (Watson et al., 2014; Malakoutikhah et al., 2020). Iraq's 23 PAs occupy about 1.5% of its land surface (UNEP-WCMC, 2020), well below the target that Iraq signed up to under the Rio Convention (CBD) of expanding national PA networks to cover 17% of the land. Currently, the CBD nations are looking at a new framework for global biodiversity conservation post-2020, where the target is for PAs to encompass 30% of the land by 2030 (Ward et al., 2020), Iraq thus faces a big challenge to achieve this target. Our evaluation of the performance of PAs in terms of the habitat suitability for Wild goats shows that the existing PAs contain better habitat than the land around them.

We propose some important new PAs and extensions of existing PAs based on high suitability values under all future climate conditions, located around Peramagroon PA and areas to its northeast, around Qara Dagh PA in Sulaymaniyah province, towards the Zimnako and Baranan mountains around Darbandikhan, and some more isolated patches north of Erbil and north of Diyala (see Fig. 5). Conservation is starting to gain more attention as many areas have been proposed and highlighted as Key Biodiversity Areas on the basis of their perceived importance to ecological and biological diversity (Ararat et al., 2009; Rubec et al., 2009). Based as it is on established scientific procedures, we are confident that our evaluation can help in locating new Key Biodiversity Areas, especially in the northern regions, and in establishing corridors between suitable habitats and current PAs to facilitate movement when needed. Globally just 10% of PAs are well connected, and Iraqi PAs are not well connected (Ward et al., 2020).

The IUCN Red List is one of the most important frameworks for evaluating threatened species (IUCN, 2019). However, most developing countries lacking up-to-date data for assessment (Kaky and Gilbert, 2019b) and therefore integrating this framework with SDMs can be helpful (Elith et al., 2006; Kaky and Gilbert, 2019b), especially when there is a lack of financial support for fieldwork (Fivaz and Gonseth, 2014) or the population sizes are completely unknown (Fois et al., 2015). Cassini (2011) started using SDMs for IUCN assessments globally and nationally: they can predict the EOO, making Red List evaluation more reliable (Syfert et al., 2014). A new study suggests that SDM maps agree with maps drawn by experts, but contain more detail and reduce both commission and omission errors (Mainali et al., 2020).

We have performed the first national assessment of the Wild goat within Iraq. Using the occurrence records the species was classified as Endangered based on AOO, while according to the EOO the species is Near Threatened. In contrast, our conservation assessment based on future changes in the habitat suitability maps suggested that Least Concern was the correct classification. This indirectly supports the new assessment made by Weinberg and Ambarli (2020), downgrading the Wild goat to Near Threatened from Endangered (Weinberg et al., 2008). Based on our contact with hunters, even if the species shows an increasing trend, any assessment should be treated with care and needs to bear in mind the current unstable political situation, which definitely impacts wildlife.

Iraq is a country rich in biodiversity with a distinctive geographical location and characteristics, such as the presence of the Tigris and Euphrates rivers. Unfortunately, in terms of wildlife we can express Iraq as a 'black box' hidden for many years. The political instability since 1980 has directly and adversely affected knowledge of Iraq's wildlife (Raza et al., 2012; Kaky, 2020). For instance, Raza et al. (2012) had to change a field trip site to survey Wild goat distribution due to security concerns in one of the selected sites. Kaky et al. (2020) had to select sites to observe Goitered Gazelle very carefully to ensure the safety of participants. Security and safety concerns have prevented many other researchers from conducting their studies. Therefore, it is very important to maintaining conservation planning during the conflicts and wars, to decrease level of biodiversity losing (Conteh et al., 2017; Dudley et al., 2002). Then, such country like Iraq need to evaluate their capacity and conservation level in term of wars and conflicts (Conteh et al., 2017; Dudley et al., 2002) by preparing a good budget and efforts for future conservation assessments (Conteh et al., 2017; Jacobsen and Hanley, 2009). Species distribution modelling can maximize the usefulness of the existing data to enable action to happen as soon as the political situation permits.

Conserving species requires good information about distribution to model habitat suitability accurately (Alatawi et al., 2020). Studies of the Wild goat in Iraq are still developing (Raza et al., 2012; Al-Barazengy et al., 2015; Rahim, 2016; Al-Sheikhly et al., 2020), and using modern techniques like species distribution modelling can significantly help increase conservation efforts. Poaching is clearly the main short-term threat that should be immediately controlled. Future research might focus on the impact of competition with livestock for food resources, particularly on its distribution.

CRediT authorship contribution statement

Emad D. Kaky: Conception and designed, Conceptualization, data collect, Data curation, data analysis, Formal analysis, draft written, Writing – original draft. **Abdulaziz S. Alatawi:** draft written, Writing – original draft. **Aram A. Jaf:** data collect, Data curation, data analysis, Formal analysis. **Francis Gilbert:** Conception and designed, Conceptualization, draft revised and finished, Writing – original draft, data analysis, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

There is no any kind of conflicts among the authors.

Acknowledgement

We thank Sulaimani Polytechnic University Research Center for their support to Emad Kaky in finishing this project; the University of Tabuk in supporting Abdulaziz Al-Aatawi; and Garmian University for supporting Aram Jaf. We would like to thank Victoria Nolan for her help and advice, and the Environmental Protection Organization of Garmain, Nimat Malow and Najeeb Omar for new information and localities in the region.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaridenv.2021.104699.

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