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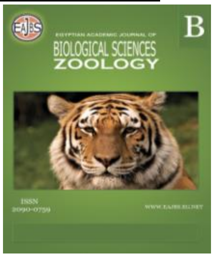

Prioritizing and Evaluating Conservation Areas: A case for the Threatened Ecosystem Engineer the Egyptian Dabb lizard *Uromastyx aegyptia* in the Eastern Desert of Egypt.

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ABSTRACT

The rapidity of the global biome changes caused by humans exceeds the slow resilience of ecosystems, especially fragile biomes such as deserts. Habitat destruction is the main threat to biodiversity loss, it is seventy times more threatening than climate change. Quantifying and mapping habitat destruction is essential for biodiversity conservation plans, as it quantifies the remaining habitats and prioritizes the most important and threatened habitats. Using remote sensing and GIS, The Egyptian Dabb lizard *Uromastyx aegyptia* distribution in the eastern desert of Egypt was modeled and its destroyed suitable habitats were mapped and quantified. Precipitation seasonality was the most important variable contributing to the species' habitat suitability as well as NDVI. Two regions were identified as suitable, nearly half (44%) of the northern suitable region is destroyed, and the rest is low-quality habitat. In the southern region, there is an expansion in energy projects that lies in the most important areas for Dabb lizard conservation. A great conservation opportunity could be seized if energy projects considered activating and implementing their biodiversity conservation plans.

INTRODUCTION

The rapid explosion of the human population resulted in the conversion of nearly two-thirds of the global biomes with biomes now dubbed anthromes (Millenium Ecosystem Assessment, 2005; Ellis & Ramankutty, 2008; Ellis e*t al.*, 2021). Biodiversity loss is the most critical environmental issue threatening valuable ecosystem services and human well-being (Ceballos *et al.*, 2015). Of the five major threats identified by the International Union for Conservation of Nature (IUCN), habitat destruction is the main driver for biodiversity loss, it represents 71.3% of the threats to the species identified as threatened with extinction; It is 70 times more threatening than climate change (Hogue &

Breon, 2022).

The Saharan desert is vulnerable to the anthropogenic impacts on its fragile biodiversity despite being isolated and inaccessible (Durant *et al.*, 2014; Brito *et al.*, 2014). Sahara's biodiversity is suffering from hunting, overgrazing, mining, agriculture and urban expansion in addition to the recent energy production (oil, gas and renewables) (Brito *et al.*, 2014; Duncan *et al.*, 2014). Egypt is not an exception, the eastern desert is experiencing rapid human development and biodiversity loss (Andersen, 2012).

Uromastyx aegyptia, is vulnerable in the IUCN red list (Wilms *et al.*, 2012) and is listed in the second Appendix of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2021). The ecology of this herbivorous lizard makes it an excellent model to be used for prioritizing conservation areas. The species is an ecosystem engineer that digs very deep burrows in the hard sand that could reach 10 meters in length and about 1.8 m in depth (Hussein, 1955). These burrows provide shelter to several other organisms (Williams *et al.*, 1999; Wilms *et al.*, 2010). As a result of excavating a deep burrow, it moves low salinity layers of soil to the surface, forming a low salinity mound of soil around its burrow entrance. These mounds promote annual plant growth, which provides food for itself and other herbivores such as gazelles and desert hares (Zahabian, 2018). The species also has a positive effect on the germination of the keystone Acacia tree *Vachellia tortilis* (Bouskila, 1986; Zahabian, 2018).

In Egypt, the nominate subspecies are distributed in the Sinai Peninsula and the Northern area of the Eastern desert till 27˚ N (Baha El Din, 2006). In the Eastern desert, the population is a large, isolated fragment from the rest of the range; The Suez Canal and Gulf of Suez in the East are isolating the western population of the species from the rest in the East.

Most of this species range in the eastern desert is not protected and is undergoing several development projects, large portions of which have been lost to quarrying for gravel and building material (Wilms *et al.*, 2012). Therefore, the objective of this study was to identify the factors related to this species distribution and prioritize conservation areas according to the habitat status and threats.

MATERIALS AND METHODS

1.Study Area:

The study area lies in the north of the eastern desert of Egypt, bordered by the Suez Canal, Gulf of Suez and the Red Sea in the east and the Nile delta and valley in the west (**Fig. 1**). It covers approximately 110,618 km^2 of mountains, wadis and Sabkhas but plains and wadis are dominating.

1.1. Distribution Data:

Distributional data were extracted and georeferenced from maps and published texts (Flower, 1933; Hussein, 1955; Marx, 1968; Rehak & Osborn, 1988; Goodman & Hobbs, 1994; Saleh, 1997; Baha El Din, 2006; Ibrahim, 2013). Forty-five unique records were extracted and converted to GPS coordinates using QGIS software in WGS 84 datum.Furthermore, seventy-four presence records were randomly collected using GPS in fieldwork conducted between 2018-2021 in the study area. Records were based on the sighting of the species, presence of burrows, tracks, or fecal pellets. To reduce the effect of sampling bias and account for spatial autocorrelation the 119 records were spatially filtered randomly with a 1 km minimum distance between each record using *spThin* R package (Aiello-Lammens et al., 2015) producing only 45 presence records.

1.2. Topo-Climatic Predictors:

Nineteen bioclimatic variables with a 30 arc-second spatial resolution (approximately 1 km resolution) were generated using CHELSA's monthly temperature and rainfall dataset (Karger *et al.*, 2017) for the period between 2000-2018. The 19 variables were generated using 'dismo' R package (Hijmans *et al.*, 2021). The topographic variable, slope, was derived from a 12.5 meter radiometrically terrain corrected digital elevation model of ALOS-PALSAR using SAGA software (Conrad *et al.*, 2015).The normalized difference vegetation index (NDVI) was used as a proxy for landscape greenness and food availability. NDVI was calculated using Landsat-8 surface reflectance collection two, level 2, tier-1 satellite data. The median of the 2013-2021 Landsat-8 image was calculated using Google Earth Engine (Gorelick *et al.*, 2017). Data were filtered to have a cloud cover of less than 1 % and a geometric mean root square error (GRMSE) of less than 10. Cloud shadow and water masks were applied using the Quality Assessment (QA) band. Then the median of all values at each pixel across the stack of all images was defined. This analysis was conducted in Google Earth Engine (Gorelick *et al.*, 2017).

Land surface temperature (LST) was computed from Landsat-8 as the median of 2013-2021 following the methodology of Ermida et al., 2020. All the variables were clipped to the study area borders, and the resolution and extent of all variables were adjusted to match bioclimatic data (~ 1 km^2). The Pearson correlation coefficient for all the variables was determined using SDM toolbox in ArcGIS 10.5 software. Variables more than r = 0.7 were considered correlated and thus excluded from the analysis to reduce the multi-collinearity (Table 1; Dormann *et al.*, 2013).

Table 1. Correlation matrix of predictors used in modelling procedures of *Uromastyx aegyptia*.

	BIO3	BIO4	BIO5	BIO6	BIO8	BIO12	BIO15	LST	NDVI	slope
BIO12	0.27	-0.66	-0.54	0	-0.34	1	-0.54	-0.53	0.47	0
BIO15	0.11	0.49	0.45	-0.03	0.19	-0.54	1	0.12	-0.05	-0.09
BIO3	1	0.31	0.3	-0.47	-0.15	0.27	0.11	-0.13	0.43	-0.19
BIO4	0.31	1	0.58	-0.56	0.22	-0.66	0.49	0.45	-0.31	0.05
BIO5	0.3	0.58	1	0.25	0.61	-0.54	0.45	0.58	-0.04	-0.15
BIO6	-0.47	-0.56	0.25	1	0.41	0	-0.03	0.13	0.1	-0.13
BIO8	-0.15	0.22	0.61	0.41	1	-0.34	0.19	0.6	-0.16	0.08
LST	-0.13	0.45	0.58	0.13	0.6	-0.53	0.12	1	-0.5	-0.01
NDVI	0.43	-0.31	-0.04	0.1	-0.16	0.47	-0.05	-0.5	1	-0.18
slope	-0.19	0.05	-0.15	-0.13	0.08	0	-0.09	-0.01	-0.18	1

1.3. Modelling Procedure:

Maxent version 3.4.4, a species distributing modelling (SDM) algorithm was used for modelling, in which 80 % of the forty-five spatially filtered presence records were used for training and 20 % for assessing the model accuracy. The auto feature was used and the model was replicated 100 times using bootstrapping iterations and random seed in order to get an average estimate (Phillips *et al.*, 2006). A bias correction file was constructed for the presence points (Phillips *et al.*, 2009).

The output is an average of one hundred replications; as Maxent produces a continuous raster map of habitat suitability with values ranging from 0 to 1 (0 indicating a non-suitable, one indicating high suitability). This raster map was binarized into suitable/unsuitable areas using 'maximum test sensitivity plus specificity logistic threshold.' This threshold was found to maximize the sum of sensitivity and specificity of the model and therefore was considered for converting the continuous raster to binary suitable/unsuitable polygons (Liu *et al.,* 2016). A majority filter (kernel radius: ten, threshold 1%) was implemented to exclude single pixels that caused the noise to the model results (QGIS Development Team, 2014).

The performance of the model was evaluated using Area Under the ROC (receiver operating characteristic) curve (AUC); The AUC is a threshold independent measure of a model's ability to distinguish presence from Pseudo-absence (or background). The AUC ranges from 0.5, not different from random to 1, with perfect discrimination between presence and absence (Peterson *et al.,* 2012; Konowalik & Nosol, 2021).

1.4. Variable Importance:

The jackknife test is used to assess the variable importance to models (Elith *et al.,* 2011). In this test, a number of models were created. First, the training gain of models was measured for the only single variable model; followed by measuring the training gain of another model with all the remaining variables excluding that very variable used before. Variable importance would be maximal if its gain is high with only this variable and its gain low without this variable.

1.5. Habitat Destruction:

The northern predicted range was examined using the high-resolution satellite imagery of google earth pro software and destroyed habitats were manually delineated as polygons using the screen digitization. In which areas that are urban/industrial expansions, quarries, or agriculture were considered destroyed habitat. Linear features such as roads, off-road trails, or powerlines were not included in the digitization process. A binary map of destroyed/ not destroyed habitats was produced.

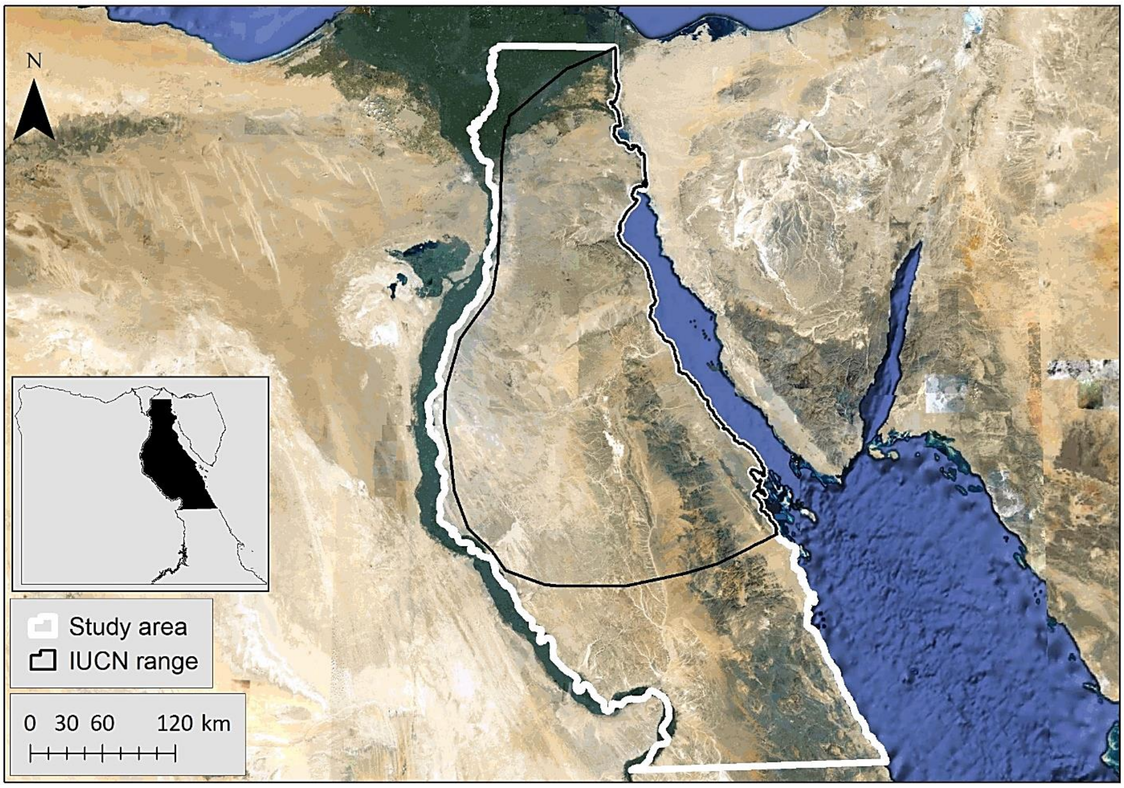

Fig. 1. The study area and the *Uromastyx aegyptia* IUCN range.

1.6. NDVI Time Series:

The suitable range polygons were used to illustrate the NDVI time series between 1984-2022. The NDVI time series was calculated using Landsat TM, ETM+ and OLI satellites surface reflectance collection 1, Tier-1 in google earth engine. Because of the subtle significant difference between the spectral characteristics of Landsat ETM+ and OLI, harmonization was conducted using the coefficient provided in (Roy *et al.*, 2016) The data were filtered to encompass cloud cover of less than 10 % and geometric mean root square error (GRMSE) less than 10. A cloud, cloud shadow masks were applied using the Quality Assessment (QA) band. Then the interannual median of all values at each pixel across the stack of all images was defined for the spring season each year using Google Earth Engine.

RESULTS

Model Assessment and Variable Importance:

The average test AUC for the model was 0.85 (±0.053 SD) and the average training AUC was 0.931 (±0.015 SD) (Fig. 2). Precipitation Seasonality (BIO15) is the most important variable when used in isolation and also decreased the gain when omitted, suggesting this variable had the most information that is not present in the other variables (Fig. 3). NDVI had the highest (25.4%) permutation importance followed by Precipitation Seasonality (20.6%) while Max Temperature of Warmest Month (BIO5) had the lowest permutation importance (1.9%) (Table 2).

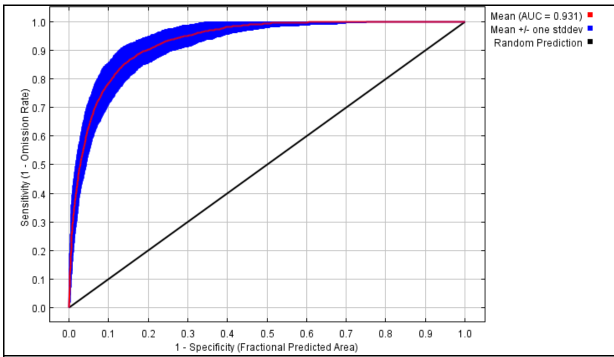

Fig. 2. Receiver operating characteristic curve with area under the curve (AUC) for model performance assessment.

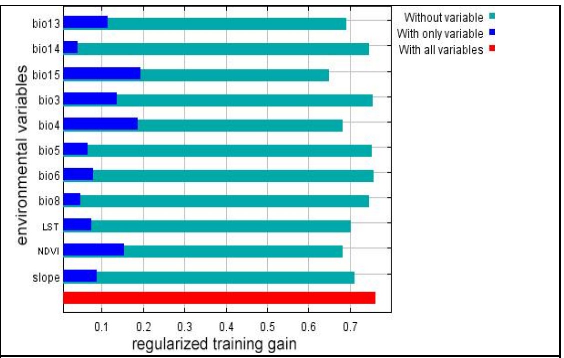

Fig. 3. Jackknife plot for training gain.

Table 2. Permutation importance and percentage of contribution of each variable to the model

Variable	Variable definition	Contribution %	Permutation
NDVI	Normalized difference vegetation index	11	25.4
BIO15	Precipitation Seasonality	17.9	20.6
BIO13	Precipitation of Wettest Month	11.2	17.1
BIO4	Temperature Seasonality	19.8	11.5
LST	Land Surface Temperature	6.6	9.1
SLOPE	Slope in degrees	9.8	4.1
BIO14	Precipitation of Driest Month	4.8	4
BIO8	Mean Temperature of Wettest Quarter	4.9	2.3
BIO6	Min Temperature of Coldest Month	2.1	2.1
BIO3	Isothermality	9.2	2
BIO5	Max Temperature of Warmest Month	2.7	1.9

1.7. Priority Conservation Areas:

Two regions (northern and southern) were identified as having the highest topo-climatic suitability (Fig. 4 A). Confidence interval (certainty map) and standard deviation (uncertainty map) maps (Fig. 5) show areas of high certainty. The northern region (7110 km^2) extends between Cairo and Suez and is bordered in the south by Al Galala Al Baharya Plateau. The southern region (10855 km^2) encompasses Wadi Araba Area, the plains west of the Gulf of Suez and until 50 km North of Hurghada city in the south and upstream of Wadi Qena (122 km^2).

1.8. Habitat Destruction:

Forty-four percent of the northern region was destroyed habitat. Urban expansion, excluding roads and off-road trails, and quarries represented the majority of the destruction. While agricultural expansions were confined to the area North of Suez, and it is minor in comparison to quarrying (Fig. 6; 8). The southern region also suffered destruction from quarrying and oil exploration and extraction projects and more recently windfarms (Fig. 7), with oil rigs and wind farms representing 0.1% and 11.2 %, respectively.

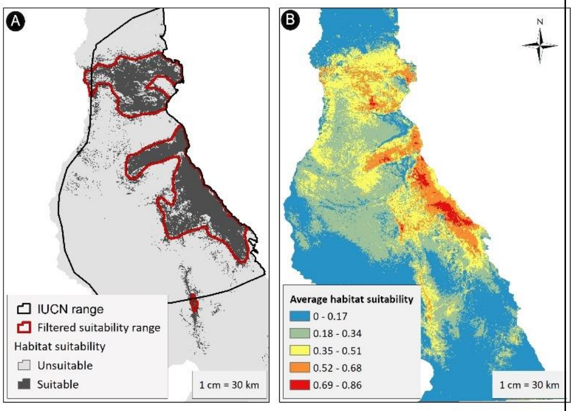

Fig. 4. The binary map of suitability against the IUCN range shows the two regions of suitability(A), the continuous topo-climatic suitability (b)

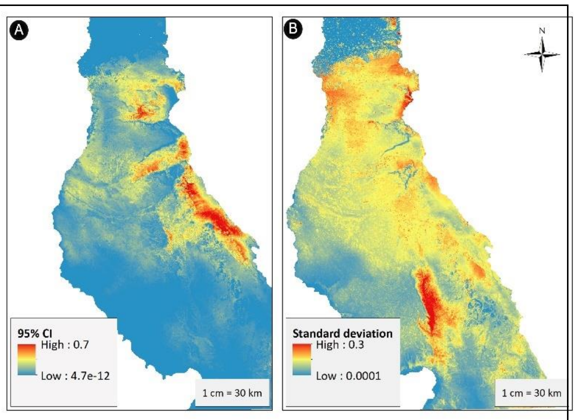

Fig. 5. Ninety-five percent Confidence interval map of the predictive model (A) and standard deviation uncertainty map (B)

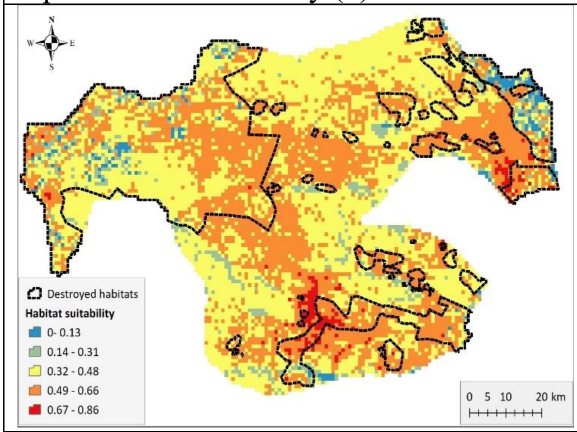

Fig. 6. the spatial distribution of the destroyed habitats in the northern region.

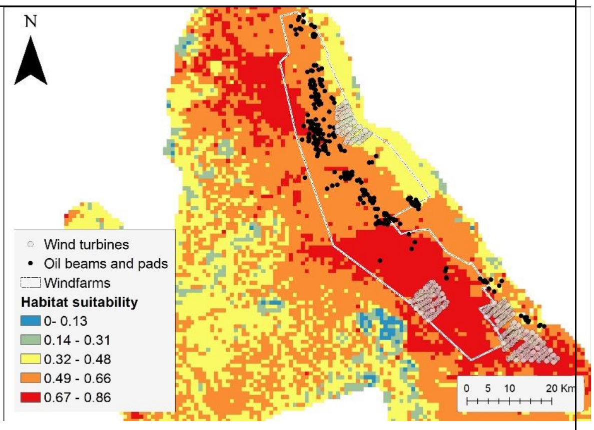

Fig. 7. distribution of oil beams and windfarms against habitat suitability within the southern region.

1.9. Characterization and Mapping of The Fundamental Ecological Niche:

The topo-climatic variables that shaped the habitat suitability of *Uromastyx aegyptia*, were NDVI between 0 and 0.1 and slope between 0-4 %, as the species prefers flat habitats with very light vegetation. Therefore, the optimal habitat is flat areas with relatively low vegetation cover that experience very high variability of rain and temperature. The niche's precipitation of the wettest month is roughly 236 mm.

1.10. NDVI Time Series in The Suitable Areas:

Overall, there is a gradual decline in the vegetation cover during the past four decades, with year-to-year fluctuations (Fig. 9).

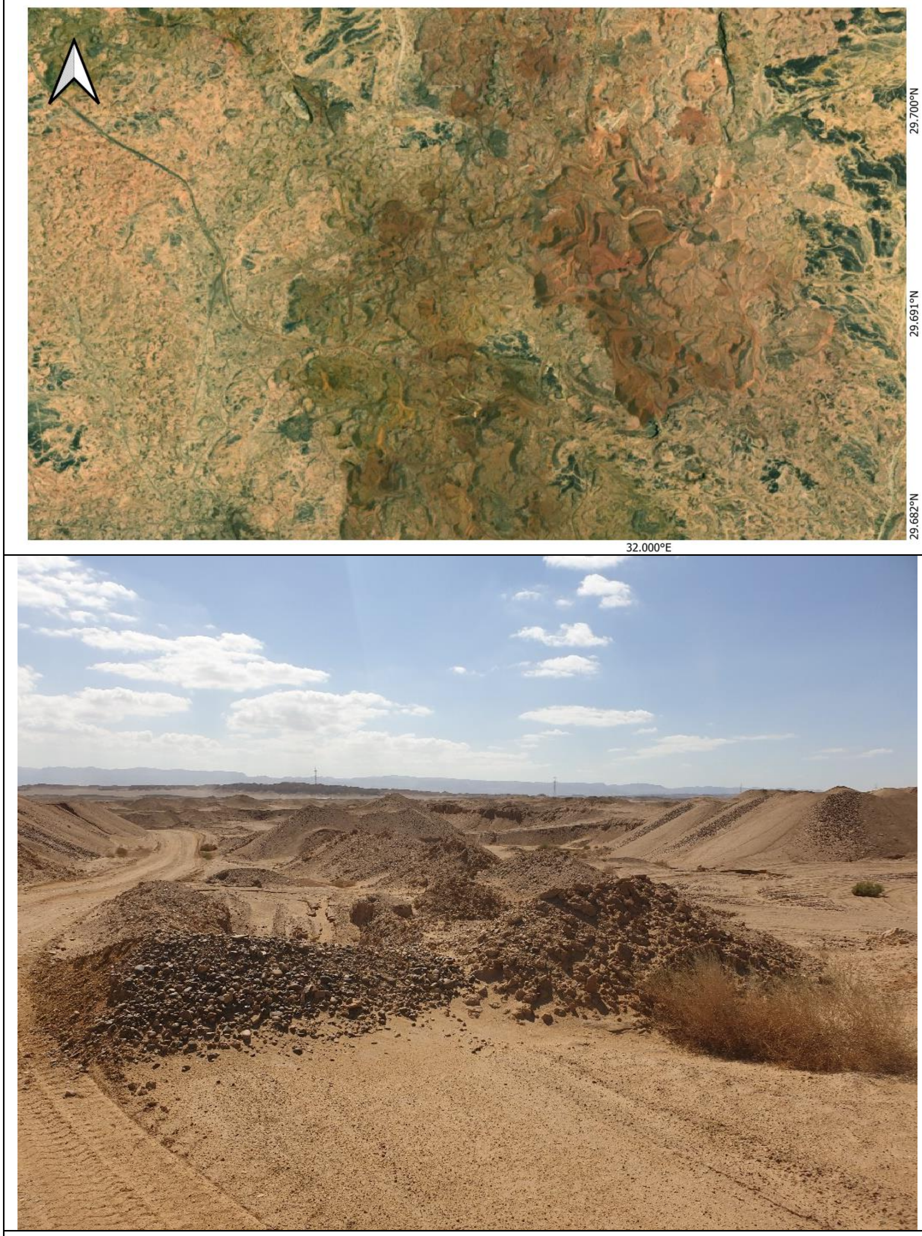

Fig. 8. A satellite snapshot showing the nature of habitat destruction the species is facing(top). The destruction due to quarrying (bottom)

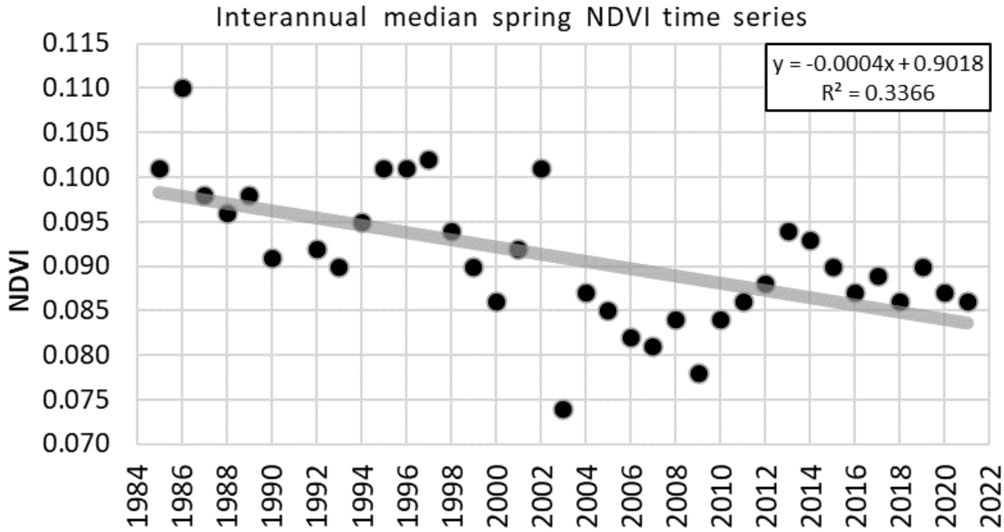

Fig 9. Four decades of NDVI trends in the suitable regions of *Uromastyx aegyptia*

DISCUSSION

We were able to predict the current distribution of the Egyptian Dabb lizard, which suggests that our maps could be used to survey the occurrence of this species in the predicted geographic area as suggested by (Newbold *et al.,* 2010). The IUCN range is 69,375 km^2 while the predicted suitability range is 18,084 km^2, *i.e.,* 26% of the IUCN range (Fig. 4A). This work suggests that the species may be more vulnerable than originally thought as the extent of occurrence (EOO) derived from SDM may be more representative of the species distribution (Syfert *et al.,* 2014).

The northern area is of great conservation importance since the species is expected to shift its range northward in response to climate change (Kechnebbou *et al.,* 2021). The predicted impact of the future climate change on The Egyptian Dabb lizard in Egypt was quantified as 50-80% loss of climatically suitable habitats under two future climatic scenarios, Business as usual and moderate scenario (El-Gabbas *et al.,* 2016). However, we quantified, 44% of the northern area as destroyed habitat. Considering habitat destruction is essential when assessing species response to climate change and assessing the conservation status of the species.

The southern area of high suitability sites occurs within areas designated for future windfarms and oil production. The windfarm regions might act as a potential protected landscape since is it designated for only windfarms (S. Baha Eldin, pers. comm.). It was found that windfarms had a minor impact on side-blotched desert lizard *Uta stansburiana* in the USA but the anthropogenic disturbances associated with windfarms such as roads, road types and intensity had negative effects on that lizard (Keehn *et al.,* 2019). *Uromastyx* burrows were sometimes found close to off-road trails and asphalt roads, which exposes the lizards to hunting (pers. obs., AN). New roads and off-road trails could cause further fragmentation of the habitat, reduce connectivity between populations, increases human accessibility and block the natural flow of flood water (Gibbs & Shriver, 2002; Benítez-López *et al.,* 2010; Brehme *et al.,* 2013).

The southern area is having oil production-exploration and windfarms sites with an extensive off-road network that probably causes fragmentation and degradation to the habitat, a satellite automated change detection is recommended to reveal and quantify the Spatio-temporal changes in the habitats (Evans & Malcom, 2021).

For an herbivorous species within a habitat of highly variable temperature and rainfall, the presence of food resources is critical to its survival. The observed decline in the vegetation index (NDVI) from year to year might be a response to either climate change or to the loss of habitats or both of them, thus disentangling the main causative factor is vital for conservation plans.

Except for the thirty-one km^2 protected area (Wadi Degla, petrified forest protected areas) in the East of Cairo, the majority of the species range in the eastern desert is not protected. Even the protected areas near Cairo have experienced disturbances and habitat loss. For example, half of the petrified forest protected area has been converted to an urban area and Wadi Degla protected area has been legally reduced in size due to increased quarrying activities (Prime ministerial decrees 2074/2018; 2953/2015; 1441/2017).

Our results suggest that *U. aegyptia* is likely more vulnerable in Egypt than originally thought. The distribution in the eastern desert is experiencing habitat destruction, drought, and commercial exploitation. The protection offered by protected areas is negligible when compared to the species' distribution in the eastern desert. Thus, conservation of this species will require comprehensive field surveys to further determine the actual distribution in relation to the currently available habitats, monitoring disturbances, working with local developers and stakeholders, and law enforcement to minimize collection and disturbances (Baha El Din, 2006).

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