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RECONSTRUCTION OF EPIPALEOLITHIC SETTLEMENT AND "CLIMATIC REFUGIA" IN THE ZAGROS MOUNTAINS DURING THE LAST GLACIAL MAXIMUM (LGM)

1. Introduction

The Iranian Plateau is an important geographical unit located in a key potential region for the Pleistocene population dispersals across Eurasia (Trinkaus *et al*. 2008; Heydari-Guran 2014, 2015; Vahdati Nasab, Ariamanesh 2015; Ghasidian 2019; Ghasidian *et al*. 2019; Zanolli *et al*. 2019; Heydari-Guran, Ghasidian 2020). Despite its important location and a long history of archaeological investigations, Paleolithic period on this plateau remained less explored compared to other parts of the Old World (Dennell 2009; French 2021; Shoaee *et al*. 2021). This is particularly true for the Epipaleolithic period.

Previous surveys in the Zagros Mountains resulted into the discovery of a number of Epipaleolithic sites in the different parts of the Iranian Plateau (reviewed in Shoaee *et al*. 2021). Although one might expect more intense human communities in the last Paleolithic phase, the archaeological research documented fewer Epipaleolithic sites than in the Upper Paleolithic. This might be due to the less frequent research in the Epipaleolithic period. In addition, the discovery of these sites was not the main target of Paleolithic researches. Almost all of them were the result of side-discovery of other research questions and interests for the late Pleistocene through Holocene investigations (Jayez 2021). We still do not know the dawn and demise of this period in the Iranian Plateau. The lifeways and site distribution during Epipaleolithic remained relatively unknown even in the Zagros, where our knowledge on the Paleolithic is more detailed than the other parts of the Iranian Plateau.

Ecological/eco-cultural niche models (Banks 2017; Guisan *et al*. 2017) are known as one of the most effective and practical tools to reconstruct distribution of a specific culture or hominin species and to study environmental determinants of their occurrences (Banks 2017; Benito *et al*. 2017; Yousefi *et al*. 2020a). In fact, eco-cultural niche models use occurrence data and paleoenvironmental variables to calculate probability of a specific culture or hominin species' presence in a defined geographic region (Guisan *et al*. 2017). Thus, coordinates of archaeological sites which are associated with the Epipaleolithic artefacts together with climatic data characterizing Earth climate during the LGM can be used to reconstruct a specific culture or hominin distribution during this era. This approach was frequently used to reconstruct different hominin species distribution at different geographic

regions (Banks *et al*. 2011; Franklin *et al*. 2015; Benito *et al*. 2017; Yousefi, Shabani, Azarnivan 2020). The aims of this study are as follows:

– Modelling of Epipaleolithic sites distribution for the Zagros Mountains.
– Determine the most influential climatic and topographic factors in shaping Epipaleolithic site distribution.
– Identifying Epipaleolithic humans climatic refugia during the LGM.

2. Materials and methods

2.1 *Study area*

The study area in this research includes the whole Zagros Mountains (Fig. 1). These mountains were occupied by different hominin species during the Pleistocene period (Zanolli *et al*. 2019). The paper will focus on the data available on the Epipaleolithic era from Northern Zagros located in Iraqi Kurdistan to the Southern Zagros Mountains.

2.2 *Epipaleolithic occupations data*

To reconstruct Epipaleolithic humans distribution during the LGM in Zagros Mountains, we used coordinates of archaeological sites which are associated with the Epipaleolithic artefacts. For this reason, we conducted a literature review and assessed all related published papers. Besides, one of the authors of this manuscript (S.H. Guran) provided unpublished coordinates of the Epipaleolithic locations based on his survey into the area.

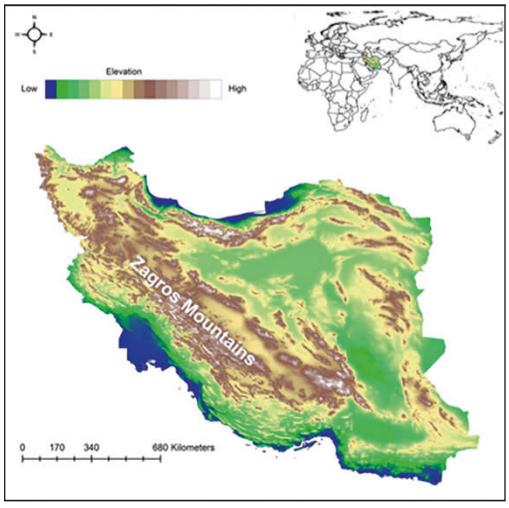

Fig. 1 – Study area, Zagros Mountains.

2.3 *Paleoclimate data*

Two general atmospheric circulation models (GCM), the Community Climate System Model (CCSM4) and the Model for Interdisciplinary Research on Climate (MIROC), were used to generate past climate scenarios (averaged values). Climate data from these models were used to reconstruct Epipaleolithic humans distribution.

2.4 *Epipaleolithic settlement modelling using ensemble approach*

To reconstruct the Epipaleolithic settlement distribution, we used five algorithms: Generalized Linear Models (GLM, Mccullagh, Nelder 1989), Generalised Additive Models (GAM, Hastie, Tibshirani 1990), Generalised Boosting Models (GBM, Ridgeway 1999), Maximum Entropy Modelling (MAXENT, Phillips *et al.* 2006), and Random Forest (RF, Breiman 2001). Then we applied an ensemble approach (Araújo, New 2007) to combine the predictions generated by different individual Species Distribution Modelling (SDMs) into a single final distribution model in R software version 3.3.3 (R Core Team, 2017). Performance of the models was assessed by area under the receiver operating characteristic curve (AUC) (Fielding, Bell 1997). This metric is widely used in SDM studies and its values range from 0 to 1 with a value of 0.5 indicating that the performance of the model is not better than random, while values closer to 1.0 indicate better model performance (Swets 1988).

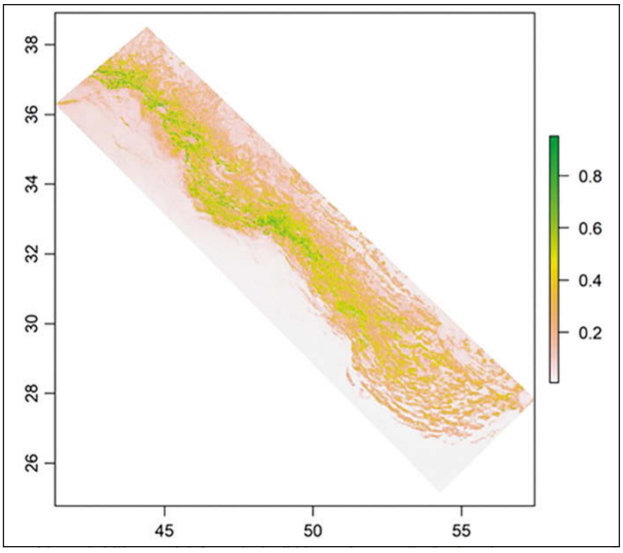

Fig. 2 – Habitat suitability model for Epipaleolithic settlement distribution in Zagros Mountains.

3. Results

All the models developed in this study performed well based on the AUC values. The results showed that central parts and western slopes of the Zagros Mountains were the most suitable areas for Epipaleolithic settlement during the LGM (Fig. 2). Topographic complexity was the most important variable in shaping the Epipaleolithic settlement distribution (Fig. 3) showing a positive association (Fig. 4), meaning that areas with higher topographic diversity were more suitable for Epipaleolithic communities. Annual precipitation was the second most important predictor for the distribution of Epipaleolithic humans with a positive correlation showing that areas with higher precipitation were more suitable for them. Reconstructed dispersal corridors of the Epipaleolithic humans in the Zagros Mountains are visualized in Fig. 5.

4. Discussion

Here we presented the reconstructed distribution and corridors of the Epipaleolithic humans in Iran. Suitable patches identified for the Epipaleolithic, generally are similar to those identified for other the Paleolithic periods of Zagros, particularly the Kermanshah region (Heydari-Guran, Ghasidian 2020; Yousefi *et al.* 2020a, 2021).

Topographic complexity, precipitation and elevation were the most important variables in shaping the Epipaleolithic settlements in the Zagros Mountains. These findings are in accordance with previous studies that identified topographic complexity as main determinant of the Paleolithic groups distribution on the Central Iranian Plateau. Elevation was identified as the most influential predictor of past distribution of the Middle Paleolithic hominin in the Kermanshah Region. Previous studies have shown that areas with higher topographic complexity in the Zagros Mountains have high mammal species (Kafash *et al.* 2021; Yousefi *et al.* 2022a). Thus, areas with higher topographic complexity and precipitation were more suitable for Epipaleolithic humans having higher biodiversity and more access to larger variety of food resources (Heydari-Guran 2014; Stein *et al.* 2014).

Ecological niche models have been employed in several studies in identifying past climatic refugia of different taxonomic groups (Walker *et al.* 2009; Fuentes-Hurtado *et al.* 2016; Yousefi *et al.* 2020b; Barratt *et al.* 2021; Mulvaney *et al.* 2022). These studies highlighted usefulness of ecological niche models in reconstructing species palaeodistribution and climatic refugia (Walker *et al.* 2009; Fuentes-Hurtado *et al.* 2016; Yousefi *et al.* 2020; Barratt *et al.* 2021; Mulvaney *et al.* 2022). In this study, we showed that middle and northwestern parts of the Zagros Mountains have had high probability of being climate refugia for Epipaleolithic humans during the LGM. Zagros Mountains are known as important refugia for vertebrates of Iran like reptiles, mammals

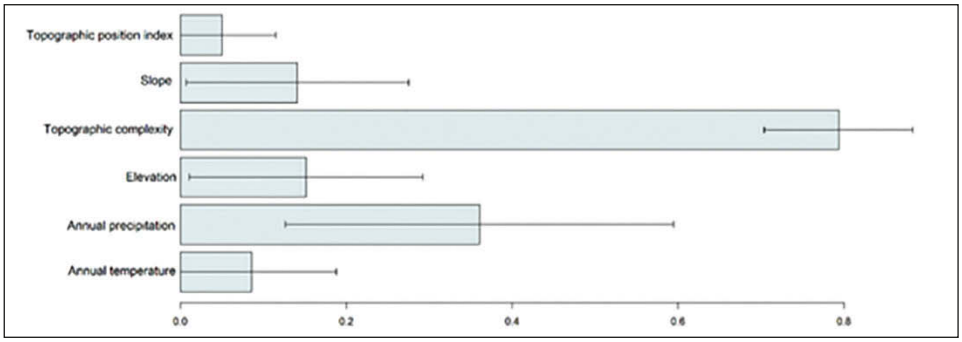

Fig. 3 – The relative importance of each variable in shaping Epipaleolithic settlement distribution.

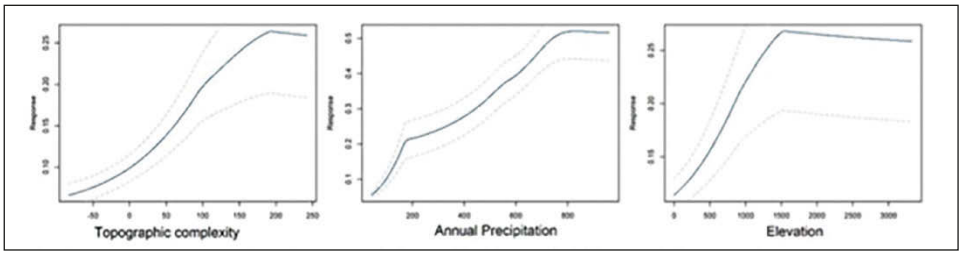

Fig. 4 – Response curve showing association of habitat suitability and the most important environmental variables.

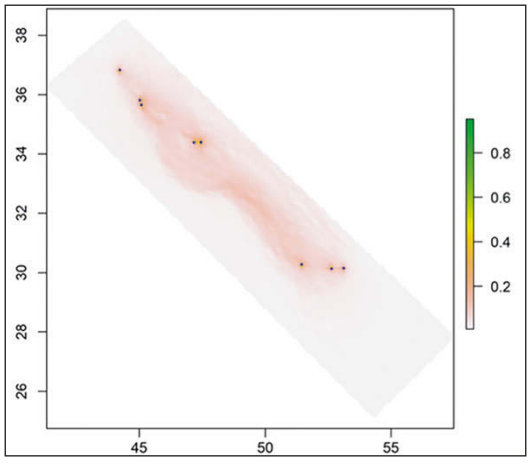

Fig. 5 – Movement corridors of the Epipaleolithic humans in Zagros Mountains.

and birds (reviewed in Yousefi *et al*. 2023). These mountains played equally an important role in survival, not only of human societies, but also of other species that have been hunted and exploited by ancient humans.

The corridors reconstructed based on the habitat suitability model shows areas that may have been used as dispersal corridors by the Epipaleolithic societies during the LGM. We recommend these areas as important target areas for archaeological field observation to further assess validity of these results and identification of Epipaleolithic occupations. Through this study we identified Epipaleolithic climatic refugia during the LGM, thus, the most promising areas have high priority for future field excavations.

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ABSTRACT

The Iranian Plateau is an important geographical unit located in a key potential region for the Pleistocene population dispersals across Eurasia. Despite its important location and a long history of archaeological investigations, the Epipaleolithic sites distribution pattern and connectivity remained less explored compared to the Middle and Upper Paleolithic periods. In this study we used ecological niche modelling (Generalized Linear Models, Generalized Additive Models, Generalized Boosting Models, Maximum Entropy Modelling and Random Forest), together with corridor mapping methods, to reconstruct the Epipaleolithic settlements and their connectivity in the Zagros Mountains. We showed that the central parts and the western slopes of the Zagros Mountains were the most suitable areas for Epipaleolithic settlement during the Last Glacial Maximum (LGM). Topographic complexity was the most important variable in shaping Epipaleolithic settlement distribution with a positive association. The niche model and corridors maps developed for the Epipaleolithic humans show areas potentially suitable for the presence of Epipaleolithic settlements but no site has been discovered in this area so far. Thus, these areas are having high priority for future field excavations.