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Impact of Climate Change on Rare Species in Arid Environments

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ABSTRACT: Human development has drastically increased the chances of climate change by burning fossil fuels, including oil, gas and coal, causing disturbances to humans, plants, and animals. Changing climate dynamics has impacted many plants, which are the primary source of life on Earth. Egypt is one of the countries where the temperatures have risen in the past decades due to climate change. In this country, many plants are vulnerable to climate change especially rare plant species. One of the most common tools for determining plant species' biological and conservation activity is the IUCN (International Union for Conservation of Nature) Red list. In this study, two plant species, evaluated *Micromeria serbaliana* and *Veronica kaiseri*, which are identified as critically endangered species. After evaluation, it was seen that *Micromeria serbaliana* falls under the category of B1ab (iii) + 2ab (iii) and is termed an endangered species (EN). The same problem applies to *Veronica kaiseri*, another targeted species which is Endangered (EN) under categories B1ab (iii) +2ab (iii). Both species are declining and have severely fragmented distributions.

Keywords: *Micromeria serbaliana*; Endangered species; *Veronica kaiseri*.

تأثير التغيرات المناخية على النباتات الأكثر ندرة في البيئات الجافة

حمادة السيد علي

الملخص: حيث أن التغيرات المناخية تناقش الأنماط المترولوجية طويلة المدى. إلى جانب الطبيعة فإن زيادة التنمية البشرية تؤثر بشكل كبير من فرص تغيرالمناخ عن طريق حرق الوقود الأحفوري، بما في ذلك النفط والغاز والفحم. أدى ذلك إلى إضطراب بين البشر والنباتات والحيوانات. لقد أثرت قابلية التأثر أو ديناميكيات المناخ المتغيرة على النباتات التي تمثل المصدر الأساسي للحياة على الأرض. مصر هي إحدى الدول التي ارتفعت فيها درجات الحرارة في العقود الماضية بسبب تغير المناخ. تتأثر النباتات في هذا البلد بضعف هذا التغير الديناميكي للمناخ، وخاصة الأنواع النباتية النادرة. تعد القائمة الحمراء للاتحاد الدولي لحفظ الطبيعة (IUCN) إحدى أكثر الأدوات أهمية ووفرة لتحديد النشاط البيولوجي وأنشطة الحفظ للأنواع النباتية. لذلك فقد قامت الدراسة بتقييم تأثير التغيرات المناخية على نوعين من الأنواع الأكثر ندرة والمهددة بالانقراض فى مصر، وهما *Micromeria serbaliana* و *Veronica kaiseri*. بعد التقييم، لوحظ أن *Micromeria serbaliana* يندرج تحت فئة (iii) B1ab (iii) + 2ab ويطلق عليه نوع من الأنواع المهددة بالانقراض (EN). ينطبق نفس الموقف على الأنواع المستهدفة الأخرى وهي *Veronica kaiseri*، والتي تم تصنيفها على أنها مهددة بالانقراض (EN) ضمن الفئات (iii) B1ab (iii) + 2ab. كلا النوعين يتناقصان بشدة فى أماكنهما الأصلية بمصر ويجب الحفاظ عليهما فى أسرع وقت.

الكلمات المفتاحية: النباتات المهددة بالإنقراض؛ مصر ؛ البيئات الجافة.

1. Introduction

In the twenty-first century, climate change is the biggest challenge for human society. Many studies have concluded that climate change is real and the dynamics of the physical world are changing considerably [1]. Climate change is not new, but it has recently received more attention. Every country has been affected by this change. Many cases worldwide have been reported on climate vulnerability, including melting glaciers, increasing temperature, volcanic eruptions, and burning forests [2]. Biodiversity is the most affected by this vulnerability of climate. The global temperature has increased by 0.6ºC and is predicted to rise quickly [3]. Continuously increasing temperatures will affect biodiversity and ecosystems.

Over the past few hundred years, Egypt's climate has changed dramatically due to its location on earth [2]. Most cities are vulnerable to climate change, including Cairo and the population near the Nile River. Flooding, a decrease in rainfall, and drought have impacted the people in the country [4]. Along with this, plant species are also affected by these climate conditions. Most rainfall happens in the winter season. The Mediterranean and high altitudes of mountains in southern Sinai influence the climate. South Sinai is categorized by a wide range of differences in air temperature. The tropical influence is considerable laterally in the Gulf of Aqaba and the Gulf of Suez [5].

Abdel-Fattah, *et al.* [5] also stated that South Sinai has a range of mountains, including Mousa's Mountain and Catherine Mountain. Mousa's mountain is considered one of the holiest historical mountains and a respectful place in Southern Sinai, Egypt. It is located on the eastern side of Catherine Mountain, and due to its high elevation, Catherine Mountain is considered to have the mildest climate in Southern Sinai and Egypt. Summers are long, arid, and hot, whereas winters are dry and chilly in the areas of Catherine Mountain. It was reported by Kaky and Gilbert [6] that the factors which are influenced by the warming are photosynthesis, and the rate of plant respiration. For instance, carbon emission can increase the photosynthesis mechanism even in warm and dry conditions.

Usually, plants can optimize photosynthesis process at a specific level of temperature. When soil temperature increases, it maximizes the deterioration and decreases the sources of plant mineralization and availability [7]. Plant distribution and spread can be dictated by the soil property, availability of resources, and nutrients availability. Typical plants' responses can be positive or negative depending on the different conditions and variable atmosphere.

Cai [8] supported the argument of Heneidy, *et al.* [9] that fragmentation, disturbance, loss of biodiversity, and habitat destruction are affected by climate vulnerability. Mountain vegetation can suffer as the climate gets warmer and drier. On the other side, higher temperatures lead to higher biodiversity. Due to the environment's vulnerability, some ecologists have noticed that with increasing temperature, the number of Nematodes increases in polyculture plots, whereas their number decline in monoculture plots [10]. Heavy flooding destroys communities and plant species because many species that live in flooded areas have been dislocated. Additionally, its lifespan is decreasing, so preserving those species is very important.

The main objective of this study was to evaluate effects of ongoing climate change on two critically endangered rare species found in Egypt, *Micromeria serbaliana* and *Veronica kaiseri,* and to assess the physicochemical variation in the habitat and between each other.

2. Materials and methods

2.1. Study Area

The study was performed in South Sinai, Egypt. In Egypt, South Sinai has a latitude of 29.3102° N and a longitude of 34.1532° E (Figure. 1A). Precipitation in the study area is characterized by its scantiness, seasonality, and inconsistency [11]. It occurs mainly in winter from October to April, the mean annual precipitation in the study area is 15 mm. The monthly mean temperature varies between 6.8º C in January and 26.1º C in August [10]. The relative humidity is higher in winter than in summer; it attains a minimum average of 32% in May and 62% in February [12].

2.2. Data Collection Process

The data was gained from the "IUCN Red List" for threatened species. The list identifies threats to known plant species [13]. The "IUCN Red List" is divided into many categories according to the severity of climate change. As the name implies, the most affected and at-risk species fall under the categories of endangered, critically endangered, and extinct. The other remaining categories i.e., vulnerable, near threatened, least concerned, and extinct in the wild, have less impact and severity of climate change on them. The categories like data deficient and not evaluated are considered because some species do not have enough information on them [14].

Based on distinct categories, the species collected from the IUCN Red List are classified under the above-mentioned nine groups. These nine groups are shown in Table 1.

The data collection was conducted from July to August 2022. Species selection was based upon the literature review. Literature showed the availability of endangered species in this area of Egypt. *Micromeria serbaliana* and *Veronica kaiseri* were mainly found near and on mountain ranges rather than in other regions. *Veronica kaiseri* was observed at a lower area on the mountain because they are usually found in wet places. In contrast, in patch form, *Micromeria serbaliana* was found in mid and top regions.

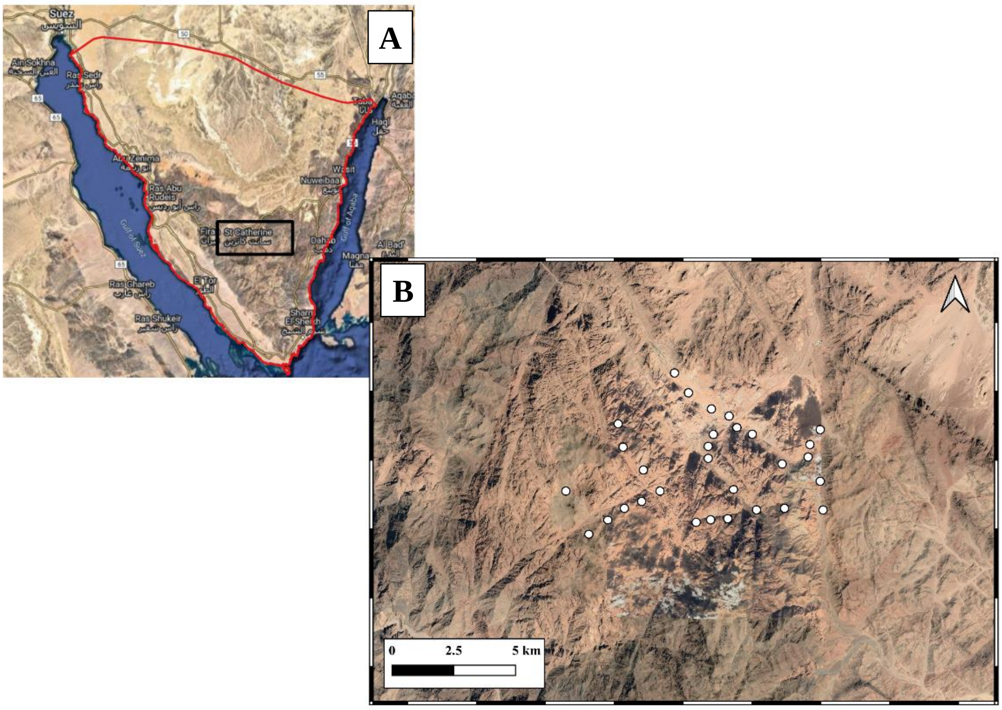

Figure 1. Location map for the study area showing A. South Sinai and B. Sampling sites within the Saint Catherine area.

Table 1. Description of categories according to IUCN.

Categories	The Description based on IUCN
Vulnerable	meets one of the 5 red list criteria and is thus considered to be a high
Near Threatened	close to being at high risk of extinction in the near future
Endangered	very high risk of extinction in the wild meets any of criteria A to E for Endangered.
Critically endangered	in a particular and extremely critical state
Extinct	beyond reasonable doubt that the species is no longer extant
Extinct in wild	survives only in captivity, cultivation, and/or outside the native range, as presumed after exhaustive surveys
Least concerned	unlikely to become extinct in the near future
Data Deficient	Not enough information
Not Evaluated	Not enough information

According to the literature review, 30 plots were investigated (Figure, 1B), in which vegetation data were collected using the quadrate method of a 20 m^2 size. For geographical and ecological determination, IUCN protocols were followed. Soil was collected at 20 cm depth from each plot using a soil probe. GPS and GeoCAT were used for geographical location. Collected soil samples were further analyzed for soil pH, which were measured using pH meter following Chapman [15] method, soil electric conductivity (EC) and total dissolved salts (TDS) were measured using Wheatstone bridge (TDS and EC meter) as described by Wilde, Voigt [16] in µS/cm and ppm respectively, the soil organic matter content was determined by loss on ignition method in percentage following Sparks, Page [17], the water content of the soil samples was determined according to Richards [18] in percentage, soil potassium (K) in ppm and Mg (meq/L) were measured using method developed by Mehlich [19], and finally soil SO_4 (meq/L) was measured following Westermann [20].

2.3. Data Analysis

Differences between the vegetation and the physico-chemical parameters of the two studied species were analyzed using Tukey's multiple comparison test in R [21]. The IUCN Red List data were collected through a literature review.

3. Results

Based on data extracted from the IUCN Red list, nine groups of plant species from Egypt that are endangered owing to climatic changes and, thus, are decreasing and becoming rare were reported. After searching for the rare plant species over the IUCN's category for the Plantae Kingdom, the ones belonging to Egypt are sorted out and depicted in Table 2.

Table 2. Threatened Egyptian Plant Species Listed Under IUCN Red List.

Scientific name	Assessment Year	Category	Criteria
Phlomis aurea	2015	Endangered	B1ab (iii, v) + 2ab (iii, v)
Euphorbia obovata	2015	Endangered	B1ab (iii, v) + 2ab (iii, v)
Silene leucophylla	2020	Endangered	B1ab (i, ii, iii) + 2ab (i, ii, iii)
Bufonia multiceps	2015	Endangered	B1ab (i, ii, iii, v) + 2ab (i, ii, iii, v); C2a (i)
Anarrhinum pubescens	2015	Endangered	B1ab (i, ii, iii, iv, v) + 2ab (i, ii, iii, iv, v); C2a (i)
Medemia argun	2019	Vulnerable	B2ab (iii)
Cyperus papyrus	2008	Vulnerable	B2ab (v)
Stipa tenacissima	2015	Vulnerable	A4acd
Rosa arabica	2015	Critically Endangered	B1ab (i, ii, iii, iv, v); C2a (i)
Primula boveana	2014	Critically Endangered	B1ab (i, ii, iii, iv, v) + 2ab (i, ii, iii, iv, v)
Juncus maroccanus	2013	Critically Endangered	B1ab (iii) + 2ab (iii); D
Veronica kaiseri	2020	Critically Endangered	B1ab (i, ii, iii, iv)
Nymphaea lotus	2007	Critically Endangered	B1ab (i, ii, iv) c (ii, iv) + 2ab (i, ii, iv) c (ii, iv)
Silene oreosinaica	2020	Critically Endangered	B1ab (ii, iii) + 2ab (ii, iii)
Micromeria serbaliana	2020	Critically Endangered	B1ab (ii, iii)
Marsilea strigosa	2007	Endangered	B2ab (ii, iii, iv, v)
Marsilea minuta	2007	Endangered	B2ab (ii, iii, iv, v)
Dracaena ombet	1998	Endangered	A1cd
Silene schimperiana	2020	Endangered	B1ab (ii, iii) + 2ab (ii, iii)

Table 2 depicts plant species that are declining or becoming rare. Two species, namely *Micromeria serbaliana* and *Veronica kaiseri*, are identified as critically endangered species, and are evaluated in this study.

3.1. *Micromeria serbaliana*

One of the most promising plants of the Lamiaceae family is the *Micromeria serbaliana*. This plant has remarkable antimicrobial and anti-inflammatory features that is used efficiently for medical purpose such as "against heart disease, headache, wound skin, infections, colds, as an antispasmodic, and as a stimulant [22]. In Egypt, *Micromeria* is represented by five species, namely *M. serbaliana*, *M. sinaica*, *M. imbricata*, *M. nervosa*, and *M. myrtifolia*" [23].

3.2. *Veronica kaiseri*

The genus of *Veronica*, comprises over 500 species. The species have the adaptability to grow in different climates and different habitats like water land or the elevated mountainous level. Eleven other species of *Veronica* have been identified in the region of Egypt [24].

The current research only targets two species, i.e., *Micromeria serbaliana* and *Veronica kaiseri*, so the focus was only on these species. After evaluation, it was seen that *Micromeria serbaliana* falls under the category of B1ab (iii) + 2ab (iii) and is termed an Endangered (EN) species. The same situation is for another targeted species, *Veronica kaiseri*, which falls under categories B1ab (iii) +2ab (iii) and is qualified as Endangered (EN). Both species are declining and severely fragmented in their fields.

Some primary threats of the targeted species based on the IUCN list are displayed in Table 3.

Table 3. Threats of target species based on the IUCN list.

Threats	Severity
Farming activities	Moderate can cause fluctuation
Disturbances occur by humans	Moderate can cause fluctuation
Climate change (e.g., drought)	Very severe, rapidly increasing
Natural disasters	Rare, slowly increasing

The results indicated that both targeted species are under drought stress. Grazing impact on *M. serbaliana* species can arise from grazing domestic animals. Both targeted species are disturbed through numerous human activities, which includes grazing of animals, collection for medicinal or fuel purposes, and this mis-management of their occurrence.

The results showed a high diversity of *M. serbaliana* than *V. kaiseri* frequency species, while the high total no. of species was observed in *V. kaiseri* (Figure 2).

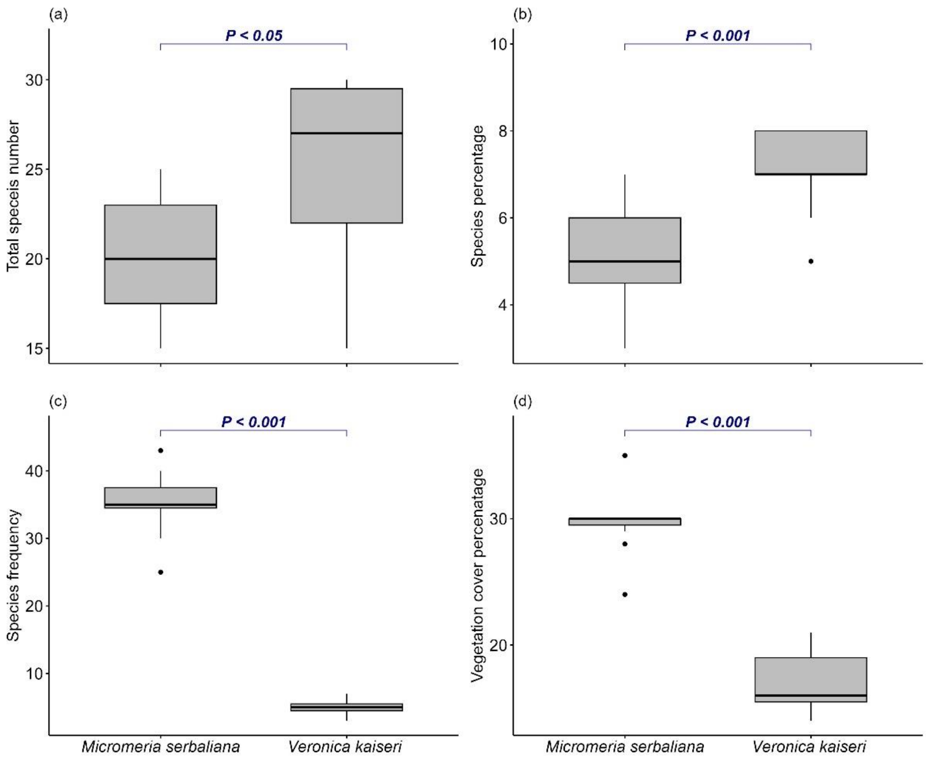

Figure 2. Comparison between the different vegetation parameters of *Micromeria serbaliana* and *Veronica kaiseri* species. Numbers are *P* values of the statistical significant differences between *Micromeria serbaliana* and *Veronica kaiseri* based on pairwise comparisons using Tukey's multiple comparison test (ns: non-significant differences).

The mean maximum value for physicochemical factors in abundant *M. serbaliana* species locations were 1350 ppm Total dissolved solids (TDS), 7.99 (pH), 50.5 meq/L (Mg), 52.9 ppm (potassium), 150 meq/L (sulphate), while 2%, 690 µS/cm and 16.99% water content, soil EC and organic matter were observed respectively. In comparison, the minimum values were 40 ppm (TDS), 6.85 (pH), 0.49 meq/L (Mg), 11 ppm (potassium), 5 meq/L (sulphate) and 0.5%, 20 µS/cm and 0.39% water content, soil EC and organic matter were observed, respectively (Figure 3).

The mean maximum value of physico-chemical factors in abundant *Veronica kaiseri* species areas was 402 ppm (TDS), 7.89 (pH) 14 meq/L (Mg), 79.01 ppm (potassium), 79.56 meq/L (sulphate), while 35%, 420 µS/cm, and 7.23% water content, soil EC and organic matter were observed, respectively. While the minimum values were 65 ppm (TDS), 6.85 (pH), 0.5 meq/L (Mg), 24 ppm (potassium), 26.25 meq/L (sulphate) and 0.5%, 45.63 µS/cm and 0.32% water content, soil EC and organic matter were observed, respectively (Figure 3).

4. Discussion

As the environment's vulnerability increases, it is essential to predict the risk of extinction, specifically in wild species. By taking the necessary action concerning these extreme environmental conditions, the Egyptian Biodiversity

Strategy and Action Plan has been updated for 2015-2030 to preserve and manage rare, endemic, and endangered plant species with the international community's help [25].

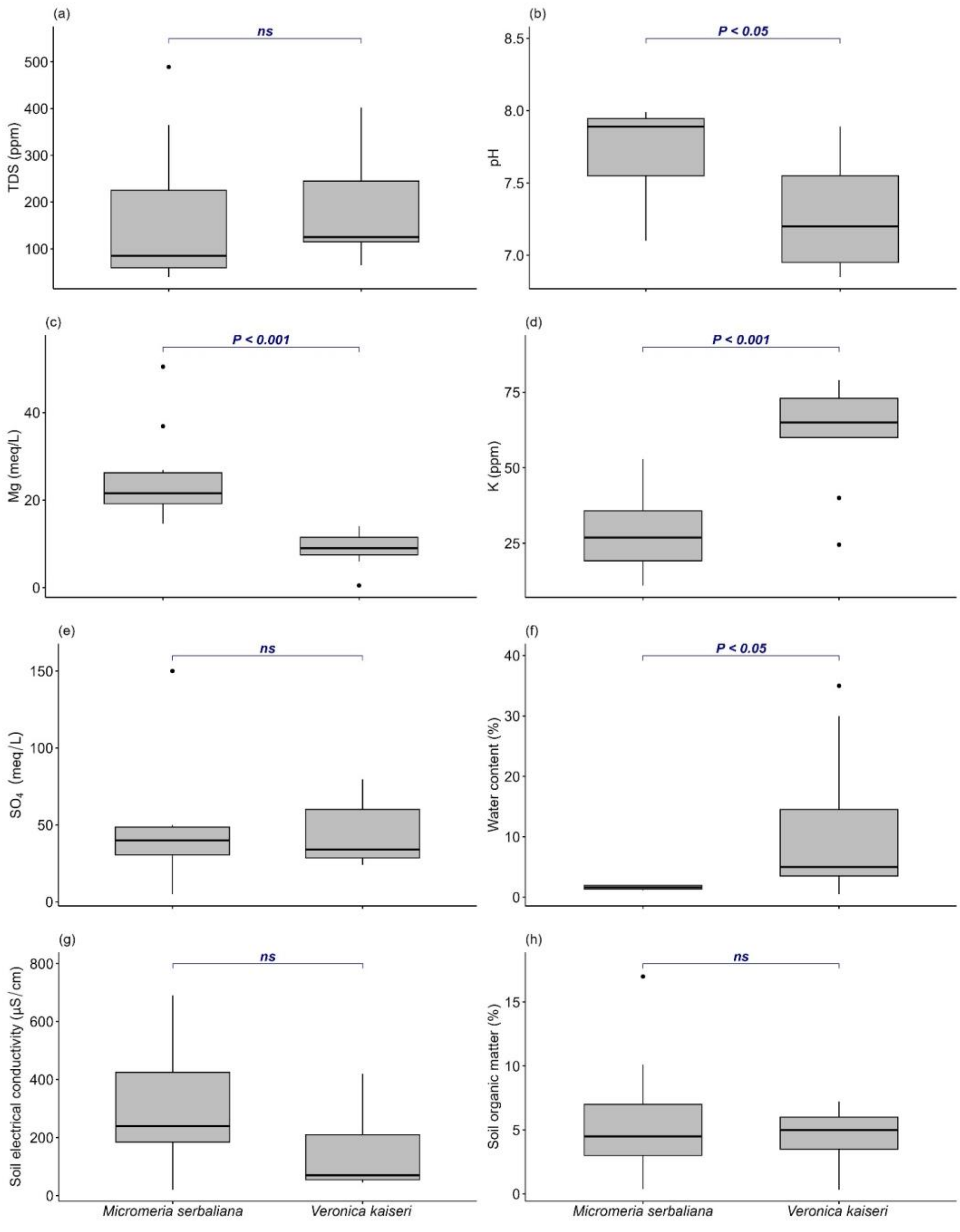

Figure 3. Comparison between the physico-chemical factors in the abundant *Micromeria serbaliana* and *Veronica kaiseri* in the Saint Catherine region's soil. Numbers are *P* values of the statistical significant differences between *Micromeria serbaliana* and *Veronica kaiseri* based on pairwise comparisons using Tukey's multiple comparison test (ns: non-significant differences).

Some researchers, such as Hoveka, *et al.* [26], have offered a number of explanations for the lack of data necessary to safeguard threatened species. He says biases have hindered the data collection processes necessary for effective biodiversity conservation programs in species collection, a lack of funding and research infrastructure, a decrease in the number of taxonomists, the complexity of identifying and describing species, and insufficient training. Therefore, analyzing gaps in the IUCN Red List assessment programs should be a top research priority for any nation that wants to avoid species extinction. As this study and Rodrigues [27] have demonstrated, the distribution, population status, habitats, ecological status, threats, conservation measures, and any other relevant data collected for the IUCN Red List Assessment tool are a significant contribution to filling in gaps in conservation planning programs. The two species that are the focus of this investigation are considered endangered (EN) because they are endemic to a small area and have a severely fragmented population. The quality of their habitat is deteriorating.

Climate change is one of the significant factors responsible for the vulnerable environment. It has impacted all living organisms, including humans, marine creatures, plants, and animals. Every country is affected by climate change, whether they produce low carbon emissions or high [25]. *Micromeria serbaliana* was found in high abundance at the mid and top of mountain areas, but *Veronica kaiseri* was located in lower mountain regions due to its moist habitat (Figure 1-2). Egypt including the Southern Sinai, at higher altitudes have climates that are vulnerable to change. Already some species have disappeared because of flooding, sand storms, and other natural disasters [28].

The findings in this study are in agreement with those of Kaky and Gilbert [6]. The conclusion is that the standard criteria are used to predict a species' distribution and to determine its extinction risk based on the IUCN Red List assessment. The primary objective of combining information and IUCN Red List assessments is to provide the data required to guide decision-makers in determining conservation priorities [29]. However, some *Micromeria serbaliana* and *Veronica kaiseri* species were observed in the endangered species list.

Sadly, since 1998, neither *Veronica kaiseri* nor *Micromeria serbaliana* has been monitored, so there are no conservation programs for these species. In this study, baseline subpopulations were recorded that can be compared to subsequent population inventories. The findings of the present work are in harmony with [30] and support their idea that targeted management, recovery, and reintroduction activities at the species and population levels must be strengthened in addition to conservation programs for threatened species. The successful conservation of plants, the reduction of pressures placed on plants in the wild, and a better understanding of traditional values and practices will benefit from encouraging participatory approaches involving the local community.

5. Conclusion

Based on these study results, it is highly recommended to keep an eye on population or habitat trends and fluctuations. The current study explains the possible features of the targeted species by evaluating the IUCN red list. It was concluded that these targeted species are endangered as categorized by the IUCN red list. The species are decreasing due to sudden climate changes.

Conflict of interest

The author declares no conflict of interest.

Acknowledgment

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