



RESEARCH ARTICLE

# Impact of long-term climate change on *Moluccella bucharica* (B. Fedtsch.) Ryding population decline in Uzbekistan

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## Abstract

The article provides a comprehensive analysis of long-term climate change trends in the distribution of the endemic population of *Moluccella bucharica* (B. Fedtsch.) Ryding in southern Uzbekistan. Based on the analysis of daily data of 2 meteorological sources (NASA POWER and Boysun (M-II)), reliable long-term trends in changes in the amounts of atmospheric precipitation and air temperatures (average, average minimum, absolute minimum, average maximum and absolute maximum) for different periods (1982–2020) of the year (year, half-year, season) have been established, which are actively manifested in the dynamics of the *M. bucharica* population. The results of this study serve to substantiate and explain that the conditions that lead to the *M. bucharica* crisis - changes in the reproductive phase and damage to seeds by insects - are the result of the effects of climate change. We found that the amplitude of the change of sediments is 59.8%, the amplitude of the change of the average temperature of the air is 19.3–53.76%, the amplitude of the change of the average maximum temperature of the air is 9.75–47.54%, the average minimum temperature of the air is 29–59%. These coefficients of change indicate that the climate of the region where the species grows has changed and is changing towards a sharp aridization.

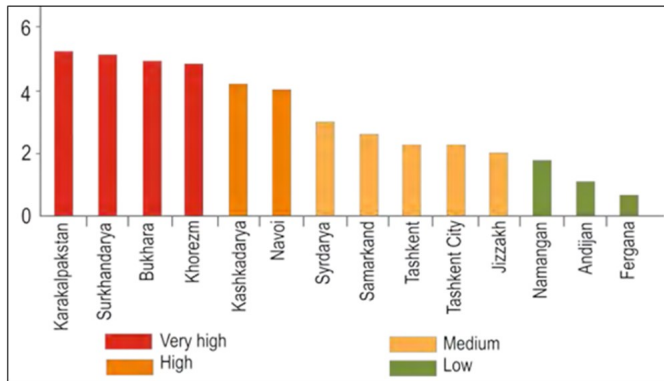
## Keywords

endemic species, coefficient of change, trend, precipitation, air temperature

## Introduction

Biodiversity is generally accepted to be decreasing at an unprecedented rate (1–4). Among the many reasons for this, climate change is often regarded as one of the most significant drivers as it influences the growth and reproduction of species, thereby determining the natural distribution of species (4–8). The Intergovernmental Panel on Climate Change (IPCC) estimated that the average global temperature, which has increased by 0.85 °C during the 20<sup>th</sup> century, will continue to increase by at least 0.3–1.7 °C and at most by 2.6–4.8 °C by 2100 (9). This increase in temperature is often considered to negatively affect ecosystems through habitat fragmentation, increases in disease outbreak frequencies, and increases in the extinction rate of endangered species (10, 11), although some studies have also found positive impacts on some species (12). Therefore, to clarify the specific effects of climate change on species and mitigate the possible negative effects of climate change on ecosystems and biodiversity, it is important to identify the distribution of species under current climatic conditions and expected future climate change (13, 14).

In the Third National Communication (15), the administrative provinces of Uzbekistan have been classified by their sensitivity to climate change based on climatic variables analysis using statistical methods (Fig. 1). Accordingly, the Surkhandarya region (southern Uzbekistan) is the second most vulnerable to climate change (16). Such effects can be especially evident in plant crises growing in this area (17).

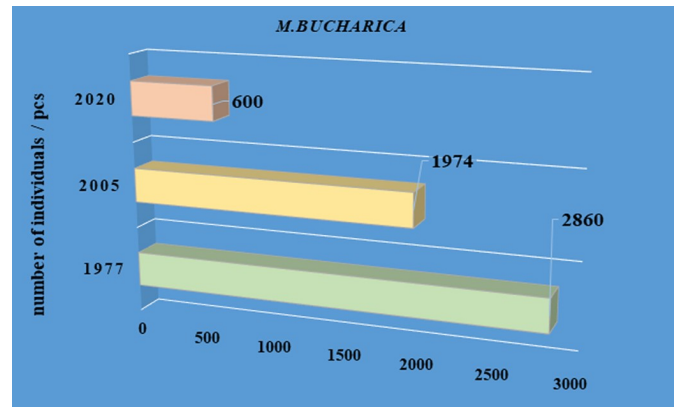


**Fig. 1.** Ranking of Uzbekistan's territory by the degree of vulnerability to climate change.

*Moluccella bucharica* (B. Fedtsch.) Ryding is a threatened and endangered species growing in the Surkhandarya region of Uzbekistan. Through the analysis of perennial climate change and the variability of the properties of their components, the impact of climate change on the relict *M. bucharica* population was studied. *M. bucharica* is an endemic species listed in the Red Book of Uzbekistan (18) and corresponds to the CR B1ab (i,ii,iii,iv,v) + 2ab (i,ii,iii,iv,v) category of the IUCN Red list (19), the population area is limited on the mountain foothills of the southwestern Pamir-Alay (Surkhandarya), with a narrow altitudinal range between 1142 and 1450 m a.s.l. *M. bucharica* is distributed in two locations (foothills Mountain Area): the gypsum soils around the Shurob – Derbend, and Gurkhozhi villages are favourable areas for species growth. Its extent of occurrence (EOO) area is estimated to be 8 km<sup>2</sup> (19). The existing subpopulations of *M. bucharica* grow in very small, isolated gypsum soils in the foothills. The number of total individuals of all three subpopulations in 1977 was 2860 (20), after 28 years (in 2005), the number of individuals decreased to 1974 (21). In 2006, 2007, 2008, 2018 the subpopulations were monitored, the number of tufts is not counted (22), today only two subpopulations of the species had been preserved (the third subpopulation near Sairob has completely disappeared), where the number of individuals is no more than 600 (on Derbend-Shurab subpopulation –400 and Gurkhozhi subpopulation –200 individuals). During the last 40 years, it has been observed that these subpopulations have been subject to large changes in the total number of individuals, cover and density (Fig. 2).

## Materials and Methods

For a general comparative assessment of the nature of climatic changes in the study area, we established linear



**Fig. 2.** The decrease in the number of individuals in the *M. bucharica* population.

trends and their significance in the long-term dynamics of atmospheric precipitation and temperature for the different periods based on long-term meteorological data from NASA POWER (“a”), 1980–2020, and the meteorological station Boysun (M-II) (“b”), 1989–2019. NASA data are only relevant for the coordinates of the area in which the species is being studied (Transect: bottom-left latitude 38.2065°N; bottom-left longitude 66.9553°E; upper-right latitude 38.2079°N; upper-right longitude 66.9600°E) (23). The Boysun meteorological station (latitude 38.189351°N longitude 67.177062°E) is located 20 km from the localization of *M. bucharica* population. The total amount of atmospheric precipitation and the average air temperature were analyzed.

The amount of atmospheric precipitation for different periods (month, season, half-year, year) was calculated based on summing up their daily amount. Average air temperatures for a month, a year, a season, and half a year were calculated based on the values of the average daily temperature by averaging the data for the analyzed periods. The absolute minimum and maximum air temperatures for different periods were also established based on daily indicators. The annual cycle was divided into warm (March–September) and cold (November–February) half-years. In addition, for all meteorological stations, data were also analyzed by seasons: spring (March–May), summer (June–August), autumn (September–November), winter (December–February) in a long-term aspect. For each of the obtained long-term data series (annual, semi-annual, seasonal), graphs of their long-term dynamics were built, and the correlation coefficients were calculated between the actual data and their linear trends (for precipitation or air temperatures: average, maximum and minimum). Only reliable trends were analyzed, i.e. those, with the significance of the correlation coefficients ranged from 90–99.9% (24).

To adequately assess the magnitude of the long-term dynamics of air temperature (as well as precipitation), the relative coefficient of change was calculated, which is calculated as the ratio of the modulus of change in trend values of temperature (or precipitation) over a long-term period to the modulus of the amplitude of fluctuations of the actual (measured) values of this parameter in the long-term aspect (25). The graphs were created using MS Excel.

## Results and Discussion

The southern part of Central Asia (Surkhandarya), where *M. bucharica* is distributed, corresponds to a sharp continental (26) climate zone. On the mountain foothills, where it grows, the average annual temperature is in the range of 11.76–13.95 °C, with an average annual rainfall of 198.26 mm (1982–2020). In the hottest summer months, the average maximum temperature is 21.1 °C, and the soil temperature rises to 72 °C (summer 2017), while in the coldest winter months, the average minimum temperature is 6.21 °C and the soil temperature can drop to -25 °C (winter 2008, 2014).

“a” obtains meteorological data by analyzing space images from different years and based on data from the World Meteorological Organization. The “b” receives meteorological data through special measuring and tracking equipment. We preferred to use data from both sources during our study. Based on meteorological data “a” and “b”, it was revealed that in recent years in the distribution of atmospheric precipitation and average monthly air temperature, certain trends were noted depending on meteorological stations (Table 1). A positive trend  $r=0,37$  (“a”), was

revealed in the long-term distribution of annual precipitation (Fig. 3). The main reasons for the decrease in the trend indicator are associated with three observation points, indicating a very dry period (1986, 2000, 2001) with annual total precipitation of only 87.5–98.91 mm. However, at the same time, an increase in the amount of precipitation was observed on average at 83.5 mm for the period 1982–2020. The amplitude of precipitation changes ( $K_{\text{chang}}$ ) is more than 59.8%. Data from the “b” also showed that the trend ( $r=0,02$ ) of perennial precipitation is negative (albeit very low), and the trend was found to be unreliable according to Dimitriev's (2009) table "Minimum size of the correlation series" (Fig. 3). The amount and timing of precipitation events is strong driver of environmental processes. (27, 28). Although the effects of drought on plants have been extensively studied (29, 30), the effects of altered timing of precipitation on plants remain largely unknown (31, 32).

For average air temperatures (mean long-term) at all analyzed sources (“a”, “b”), only positive trends were revealed ( $r=0,21$ ,  $r=0,61$ ) (Fig. 4). At the same time, the interval of long-term mean temperatures shows 11.76–14.06 °C (1982–2020) and 12.3–15 °C (1989–2018). The increase in average

**Table 1.** Climatic data of Nasa Power in 1982–2020 (Boysun, Surkhandarya)

Years	Air temperature, t °C			Total precipitation, mm
	average	maximum	minimum	
1982	12,33	18,76	6,88	139,75
1983	13,36	20,06	7,71	126,39
1984	11,94	18,55	6,21	195,11
1985	13,2	19,92	7,5	160,51
1986	13,03	19,81	7,29	98,91
1987	13,46	20,19	7,72	153,52
1988	14,06	20,85	8,29	154,68
1989	12,56	19,22	6,89	136,01
1990	13,51	20,05	7,92	197,99
1991	12,61	18,94	7,23	239,27
1992	12,09	18,45	6,64	249,2
1993	11,96	18,44	6,44	291,93
1994	12,43	19,06	6,74	253,53
1995	12,84	19,67	7,1	200,83
1996	12,07	18,86	6,32	166,6
1997	12,65	19,31	6,91	299,46
1998	12,94	19,45	7,28	231,62
1999	13,15	20,04	7,38	181,53
2000	13,54	20,59	7,62	89,7
2001	13,98	21,1	8,02	87,5
2002	13,57	20,36	7,83	210,19
2003	12,78	19,16	7,37	223,85
2004	13,53	20,12	7,9	248,39
2005	12,82	19,36	7,31	172,77
2006	13,93	20,67	8,24	199,04
2007	13,54	20,3	7,93	194,85
2008	13,18	19,85	7,58	129,16
2009	13,06	19,47	7,64	234,69

2010	13,95	20,47	8,61	166,67
2011	13,1	19,57	7,59	197,24
2012	12,36	18,69	7,08	199,82
2013	13,62	20,22	8,04	177,87
2014	12,92	19,46	7,49	150,03
2015	13,07	19,43	7,53	262,42
2016	13,95	20,52	8,4	260,71
2017	13,26	19,93	7,68	251,72
2018	13,57	20,26	8,01	162,48
2019	13,11	19,49	7,76	279,04
2020	11,76	18,14	6,49	357,13

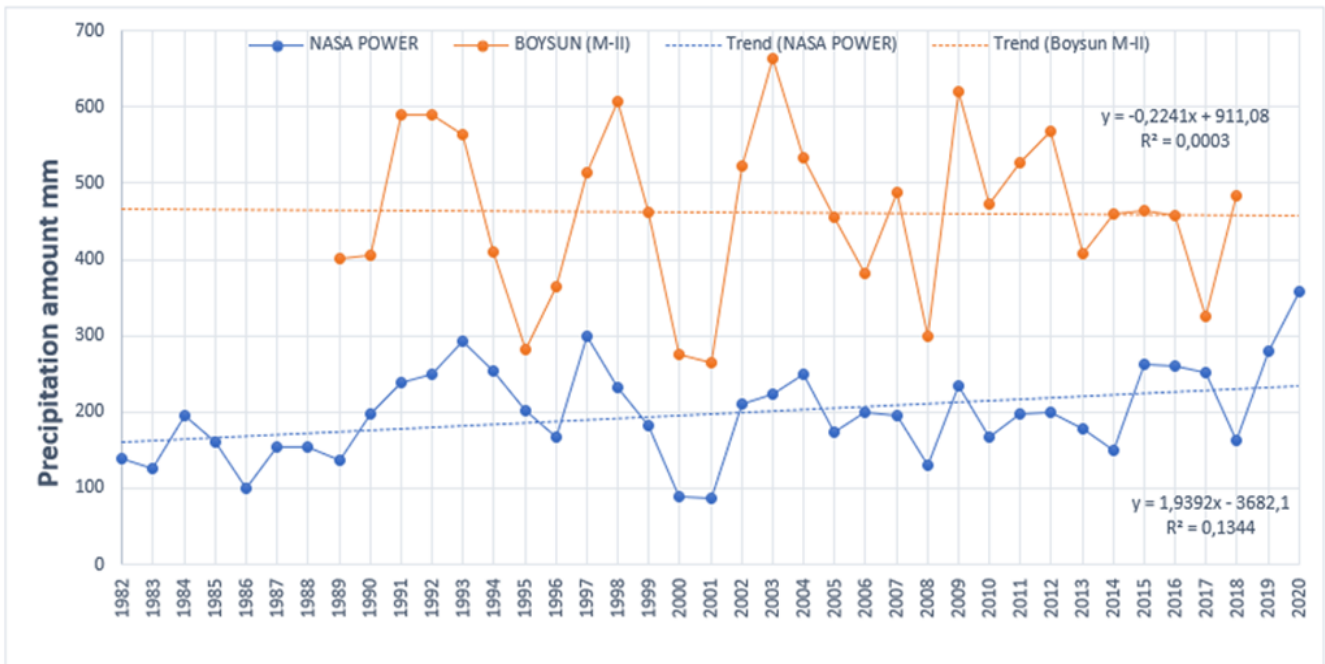


Fig. 3. The trend of perennial atmospheric precipitation in the localization of *M. bucharica*.

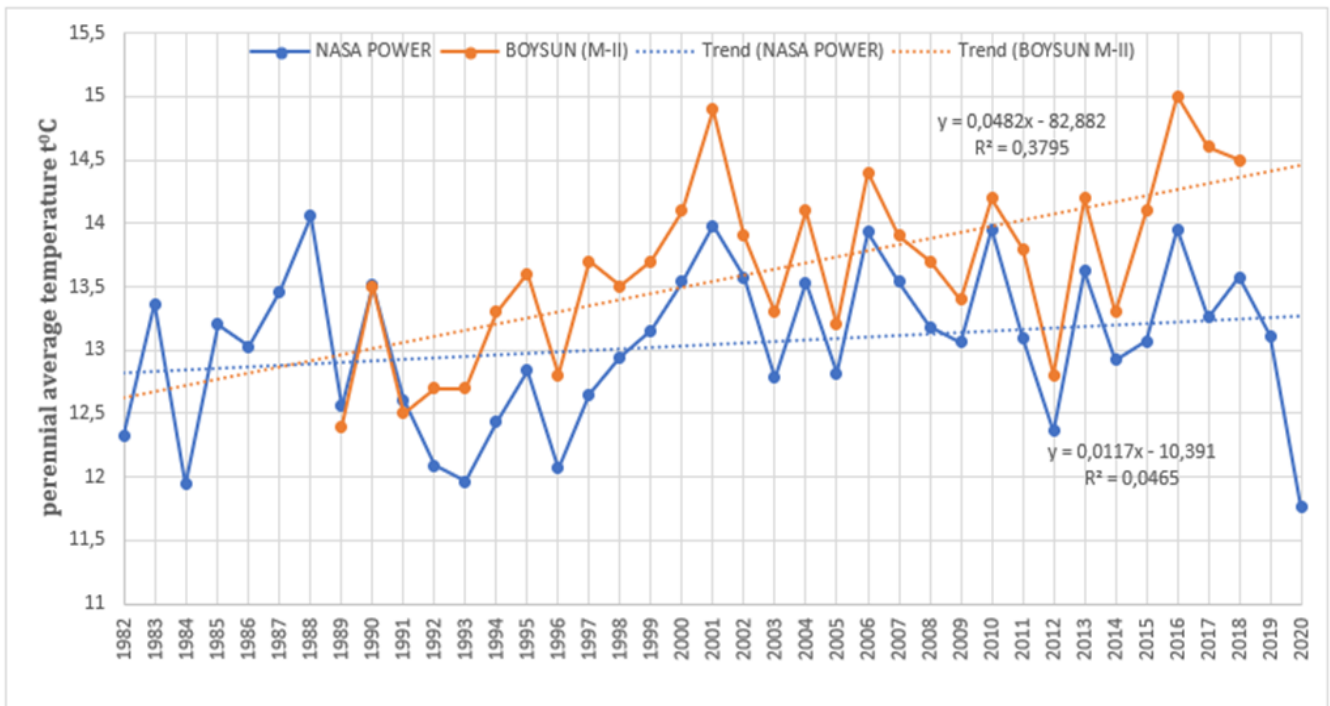


Fig. 4. The trend of perennial average air temperature in the localization of *M. bucharica*.

annual temperatures over a long-term period averages 2.3–6.7 °C (compared to the first year studied). The prevailing and only tendency in the long-term distribution of the average annual air temperature is a stable increase, which reliably occurs due to air warming, both in the cold and in the warm half of the year. At the same time, in cold periods of the year, temperatures increase with a slightly greater amplitude (especially January-February) than in warm ones. The range of changes ( $K_{\text{chang}}$ ) of the average air temperature is 19.3–53.76%.

For average maximum air temperatures (long-term), significant increases in values reach from 1.83 °C (“a”) to 9.1 °C (“b”) ( $r=0.12$ ,  $r=0.55$ ) (Fig. 5). In their long-term dynamics by semesters and seasons of the year, only positive trends are noted, characteristic mainly for the warm half of the year, which are formed, due to the summer season, partly, of the autumn seasons of the year. The amplitude of changes ( $K_{\text{chang}}$ ) of the average maximum air temperature is from 9.75% (“a”) to 47.54% (“b”).

For the average minimum air temperatures, the main trend in the long-term dynamics is also their increase, characteristic of the cold half-year and winter, against the background of weaker changes in the warm half-year, as well as in autumn and spring. The magnitude of changes in values lies in the range from 2 °C “a” to 3.84 °C “b” ( $r=0,356$ ,  $r=0,73$ ) (Fig. 6). At the same time, in the cold half of the year, the changes were more significant than in the warm one. The amplitude of changes ( $K_{\text{chang}}$ ) of the absolute minimum air temperature is from 29% “a” to 59.1% “b”.

The phenology of *M. bucharica* flowering lasts from July to August (33). Our field studies for 2019–2021 showed that the flowering biology of the species begins much earlier, that is, it lasts from May to the first ten days of July. According to a comparative analysis, over the past 50 years, the flowering of the plant has accelerated by two months. Due to the intensive process of aridization taking place in the territory, this species has an accelerated flowering phase. The potential yield of *M. bucharica* seeds was 347-

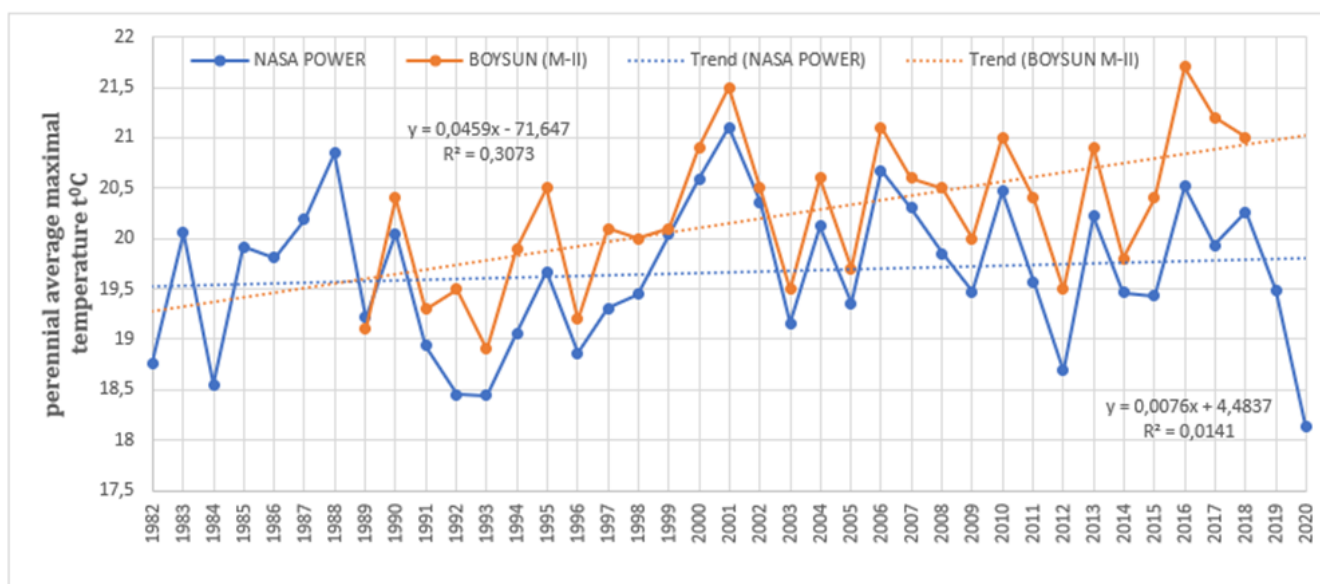


Fig. 5. The perennial trend of average maximum temperatures for sources “a” and “b”.

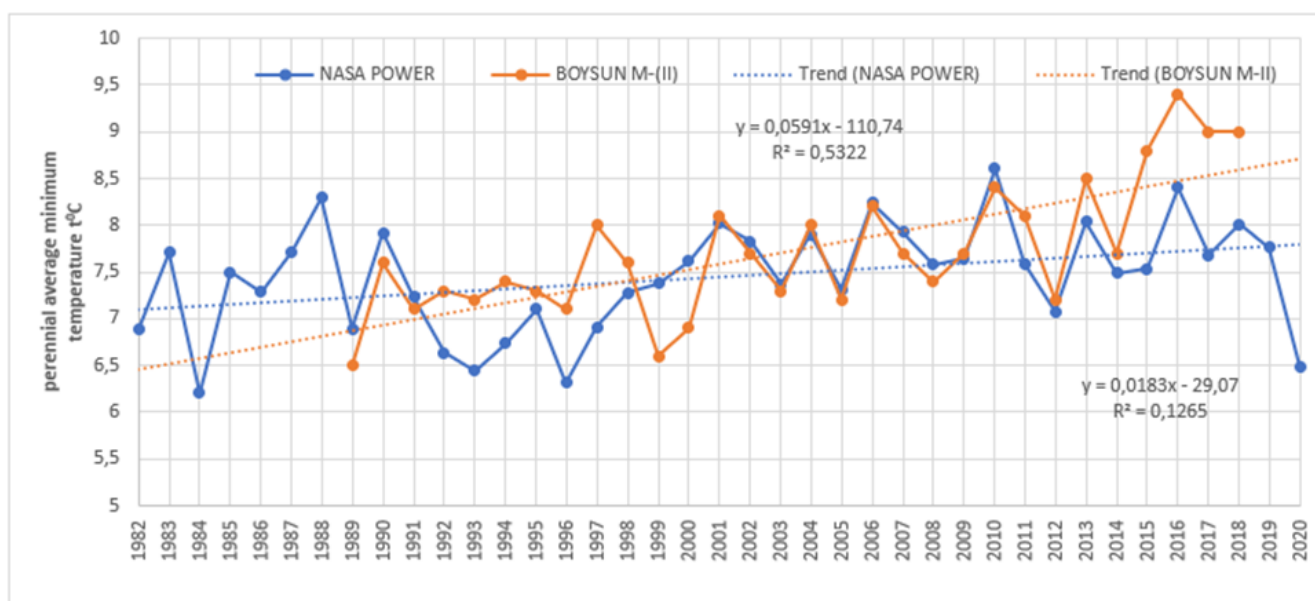


Fig. 6. The perennial trend of average minimum temperatures Darbend-Shurob location.



503 per bush in 2019–2021, while the actual yield of seeds during these years was 44–45 per bush, that is, in one season, 89 % of the seeds of one bush fall to the ground in a state of complete unusability. Thus, it is not difficult to understand that the greatest impact of climate change is felt in the reproductive phase of the plant.

Morphologically studied 100 seeds of more than 30 herbarium specimens of *M. bucharica* stored in the TASH Herbarium. It used seeds from herbariums collected between 1930 and 1971. The results showed that in the first half of the 20<sup>th</sup> century, insect damage to the harvested seeds was 19.7%. Today, insect damage to seeds is 81–90 % per 100 seeds (34). As a result, seed damage has increased by at least 78 % in the 21<sup>st</sup> century. The study confirms that against the backdrop of climate change, the number of insect pests in the area is increasing from year to year, resulting in increased seed damage.

Increased aridization in spring and summer due to climate change contributes to the active process of plant transformation. The temperature in Uzbekistan rises by an average of 0.27 °C every ten years. Analysis of data from sources NASA POWER and Boysun M-II (1982–2020), also showed that the perennial average, average maximum, average minimum, the absolute maximum–minimum temperature was significantly higher over the past 39 years and the process continues. Although the increased annual precipitation trend is associated with cold half-year, precipitation during the warm half-year (May–October) remains almost zero in the semi-arid region where *M. bucharica* grows. In the hot half of the year, the moisture deficit increased to 28%, and the overall humidity level continued to fall. The *M. bucharica* population area was significantly dry in 2000–2001. In just two years, in total 177.2 mm of atmospheric precipitation fell. The studied data for 39 years show that the average annual temperature in the same years was higher than in other years (14.9–21.5 °C). These two very inconvenient years could have the most negative impact on the transformation of the study species population.

## Conclusion

One of the main reasons for the transformation of the *M. bucharica* population is the change in the abiotic components of the ecosystem. Through statistical analysis of perennial climate data, we found that the amplitude of change was high in the northwestern part of the Surkhandarya region. At the same time, the amplitude of the change of sediments is 59.8%, the amplitude of the change of the average temperature of the air is 19.3–53.76%, the amplitude of the change of the average maximum temperature of the air is 9.75–47.54%, the average minimum temperature of the air is 29–59% was found. This change affects the population of the studied species in different ways. The reproductive phase in plants might be particularly vulnerable to the effects of global warming (35). This is close to the truth, because in our field studies for several years, we practically did not see young individuals of *M. bucharica*. At a time when global warming is negatively affecting to the flowering phase, global climate change is positively (36) affecting

the growth and distribution of pests. This can be confirmed by an increase in the pest infestation of *M. bucharica* seeds. Damaged seeds completely lose their ability to grow. We recognize that the analysis of long-term climate change is one of the main drivers of the crisis of the studied species, among other factors.

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## Authors contributions

The work was a part of PhD thesis work of first author, which was supervised by second and third authors. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None.

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