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Brief description: We are using the data sets of NDVI, surface air temperature, rainfall and soil moisture to analyze the correlation between Uzbekistan's ecology environment and locust habitants.

Introduction

SDGs 2 and what is SDGs 2

Our team aims to advance SGDs second goal: Zero Hunger. The primary objective of SDG 2 is to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture worldwide by the year 2030. Within the key aspects of SDGs 2 such as "Increase Agricultural Productivity", "Address Trade Restrictions" and more…Our project is focusing on food security.

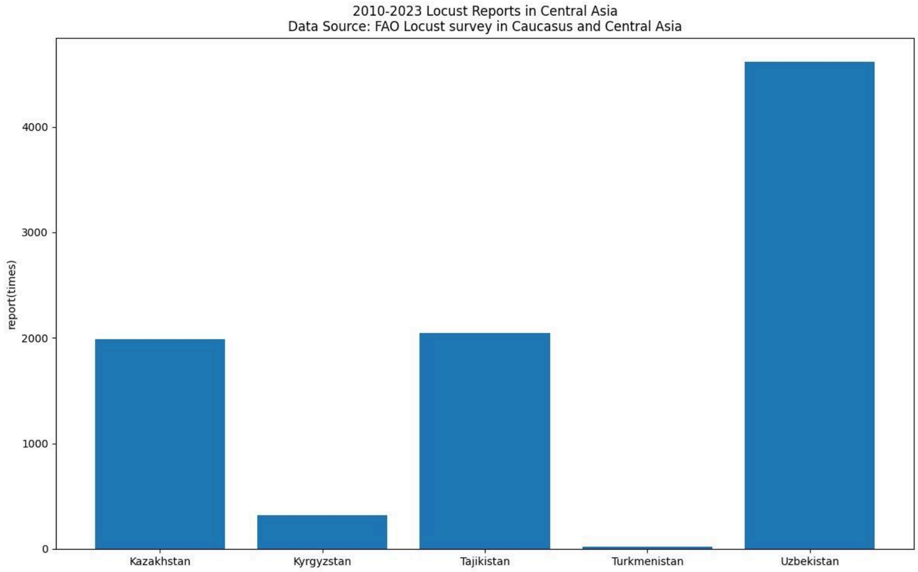
Food Security and what caused food insecurity

In recent years, food insecurity has been rising to a high record. It is caused by factors such as conflict, climate shocks and COVID-19. According to The World Bank in July 2023, over 258 million people worldwide could be suffering from acute food insecurity. One issue that derives food insecurity is the locust crisis.

Locust crisis and how locusts cause food insecurity

Locusts are herbivorous insects with a wide range of feeding habits. They prefer crops from the Poaceae family, such as corn, rice, and wheat. It inhabits harsh environments such as deserts and typically exhibit a solitary phase in their normal state. However, there is a tendency for them to form swarms (gregarious phase) in specific regions or during the rainy season, and they have migratory habits.

Our research topic



The international attention to locust plague is more focused on areas of the Horn of Africa, the Middle East, and South Asia. Due to global warming, our team expects countries in temperate Central Asia would face locust plagues more commonly. Drawn from statistics, Uzbekistan stands out as the nation with the highest number of locust reports in Central Asia. Moreover, Uzbekistan 25% - 39.9% of the total population of their country is considered to be experiencing food insecurity from 2020 to 2022, according to FAO (Food and Agriculture Organization of the United States). Consequently, our team thinks Uzbekistan is a country worth paying attention to on the matter of hunger Problems. This motivated us to investigate the current situation of Uzbekistan's locust issue, the positive correlation between their ecology environment and locust habitation. From primary research, vegetation, temperature, rainfall are the ecological variables used to forecast locusts.

Materials

Datasets we used

1. NASA AppEEARS
- Terra MODIS Vegetation Indices (NDVI & EVI) , MOD13A3.061, 1000m, Monthly, _1km_monthly_NDVI
2. NASA Giovanni
- Rain precipitation rate (GLDAS_NOAH025_M v2.1), 0.25, monthly

- Soil Moisture content (10-40cm)(GLDAS_NOAH025_M v2.1), 0.25, monthly
- Root Zone Soil Moisture (GLDAS_NOAH025_M v2.1), 0.25, monthly

Kimberly Slinski, Daniel Sarmiento (NASA/GSFC/HSL) (2023), FLDAS2 Noah-MP GDAS Land Surface Model L4 Central Asia Daily 0.01 x 0.01 degree, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: Jan 25th, 2024, 10.5067/C4IOYF41EEZB

Tools we used

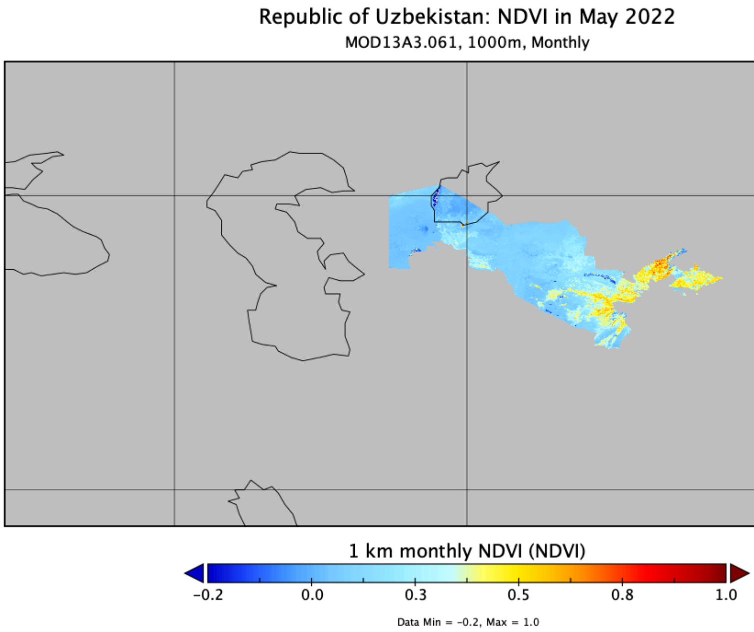
1. Panoply
2. Giovanni
3. AppEEARS
4. Python

Methodology and Visualization Interpretation

NDVI variable

What is NDVI

NDVI stands for Normalised Difference Vegetation Index. It is often used in satellite image observations and landscape ecology research. The calculation formula of NDVI is based on the process of capturing the difference in the reflection of green light and infrared light after plants absorb visible light (photosynthesis). It calculates the difference between the amounts of red light and infrared radiation reflected by objects. A higher NDVI value indicates that the local vegetation is in good health, with abundant chlorophyll and active photosynthesis. Conversely, a lower NDVI value suggests that there is little to no healthy vegetation in the area.

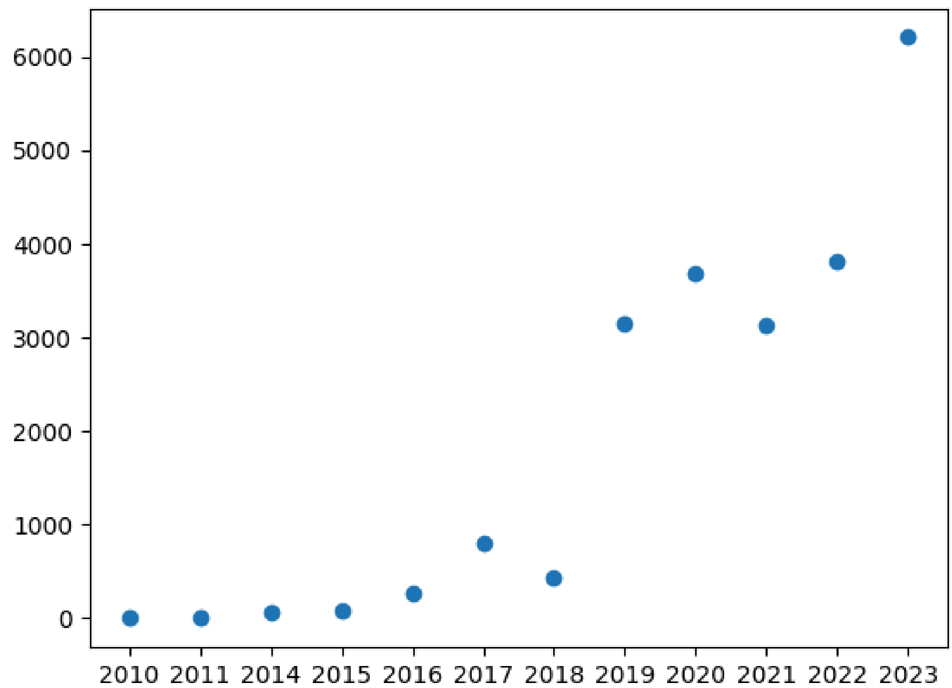


The figure above illustrates that in Uzbekistan in May of the year 2022, the vegetation in the western region of Urgench and the eastern regions of Andijan and Fergana appears more abundant compared to other areas across the country.

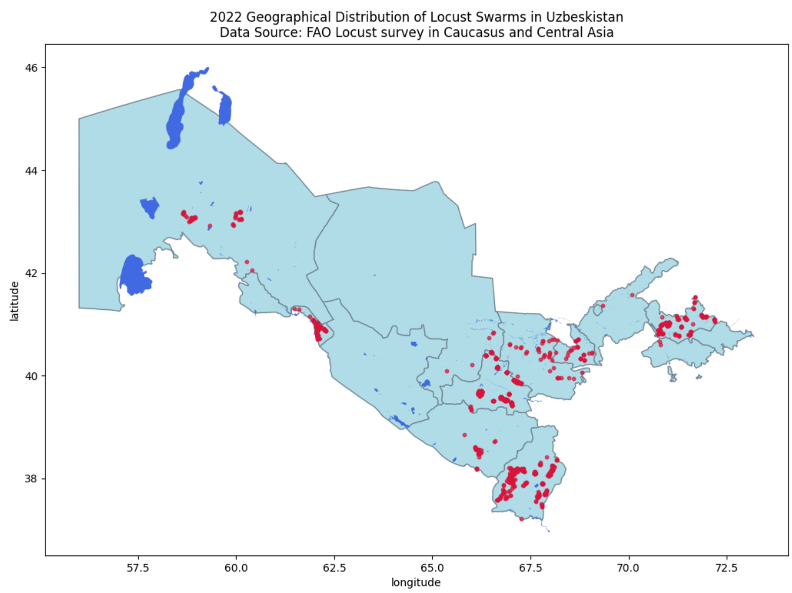
Relationship between NDVI and locust issue

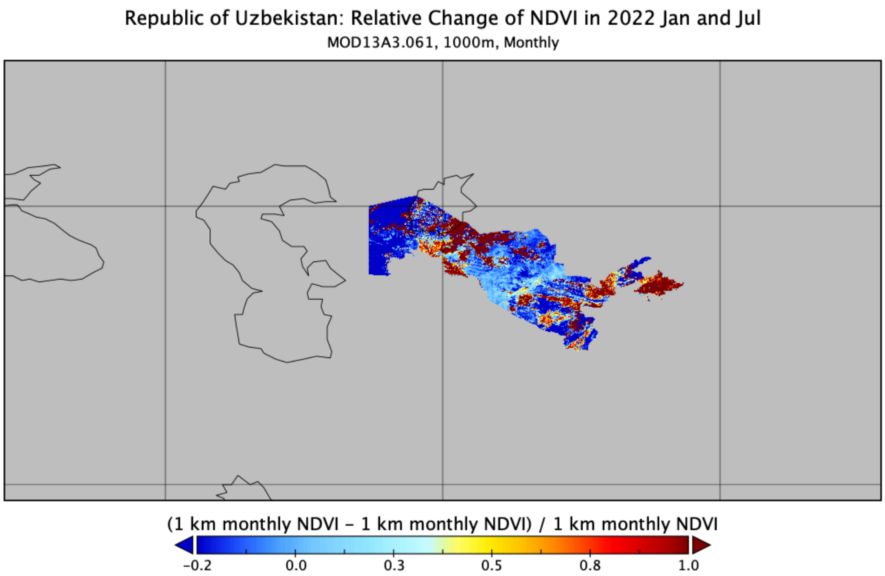
According to the research paper titled "Dynamic Forecast of Desert Locust Presence Using Machine Learning with a Multivariate Time Lag Sliding Window Technique," desert locusts deposit their eggs under the surface of the soil. Upon hatching, the locusts rely on vegetation, including grasses, shrubs, and crops, as a source of food and habitat. Previous studies have indicated that an increase in the Normalized Difference Vegetation Index (NDVI) in a particular region is associated with the emergence of locust swarms in that area.

Data Visualization interpretation and insights



According to the statistics, it has been noted that Uzbekistan experienced significant locust infestations in the years 2018 and 2022. Therefore, we have chosen to compare the NDVI data from these two years.

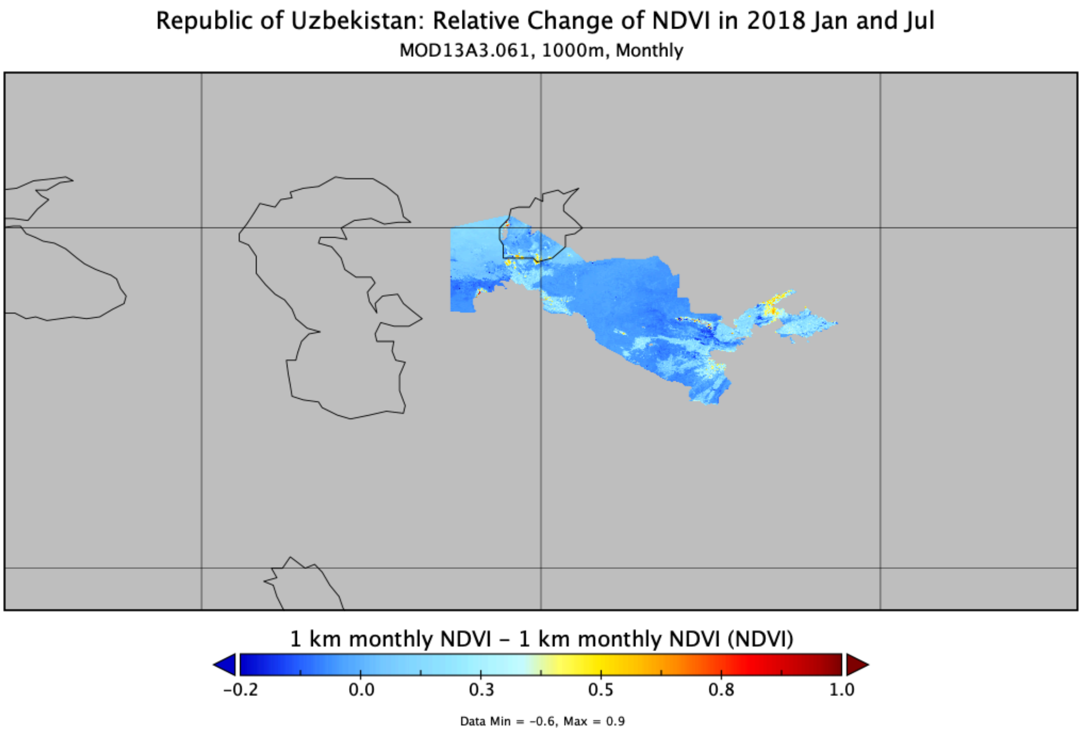




The two images above represent the distribution of locust infestations in Uzbekistan in 2022 and the NDVI Relative Change of January and July 2022, respectively. The calculation of NDVI Relative Change is:

$$\frac{NDVI_{JUL2022} - NDVI_{JAN2022}}{NDVI_{JAN2022}}$$

The two images above indicate a correlation between areas in Uzbekistan where NDVI values increased in mid-2022 and regions affected by locust infestations during the same year.



The image above indicates that the NDVI Relative Change in January and July 2018 is not as significant as in 2022. The observation that the NDVI Relative Change in January and July 2018 is not as significant as in 2022 aligns with the fact that Uzbekistan had virtually no locust infestation records in 2018.

Temperature variable

For the surface air temperature, we make the hypothesis that global warming, abnormally hot weather and temperature anomalies contribute to the significance of the locust problem in Uzbekistan. As the locust problem stands as the major threat to the cereal crops and cotton in Uzbekistan, we consider that one consequence of climate change and rising temperatures for Uzbekistan is the worsening condition of its food security.

Both FAO's Locusts in the Caucasus and Central Asia project website and FAO's Hand-in-Hand Geospatial Platform are resourceful, however, we found them not that satisfiable. For example, from the "Locust survey in Caucasus and Central Asia" dataset, we got to know the time-space distribution of locust swarms, however, 21,669 locust reports have 15,136 pieces that aren't able to provide us with information of air temperature.[1]

Thanks to NASA's FLDAS project and the project's Central Asia modeling system that provides us with daily surface air temperature data with 0.01° spatial resolution, which enabled us to acquire from Giovanni and use Panoply to draw sophisticated and insightful anomaly maps.

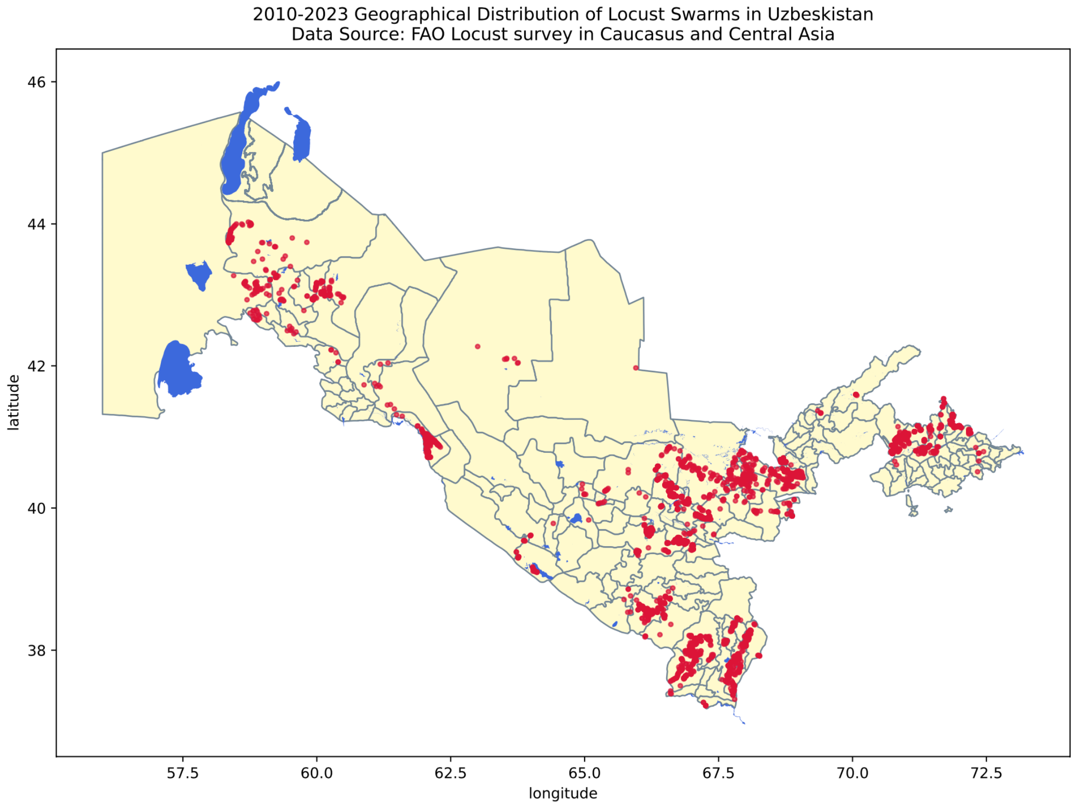
Our temperature anomaly maps are derived from comparing the average temperature of each month to that of the years 2018 and 2022, regarding year 2004 to 2023 as baseline. There are several insights we gained from the maps.

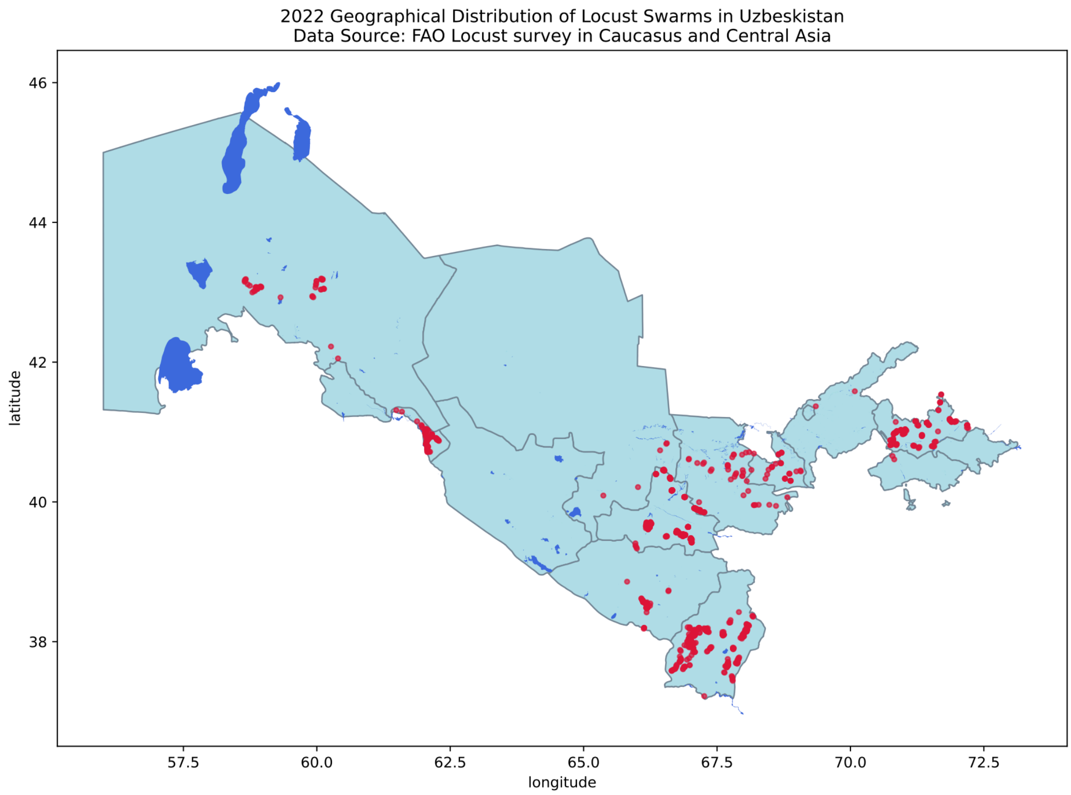
First, it is obvious that for most of the months, both in the year 2018 and 2022, the temperature anomalies are observable, and most of them are positive.

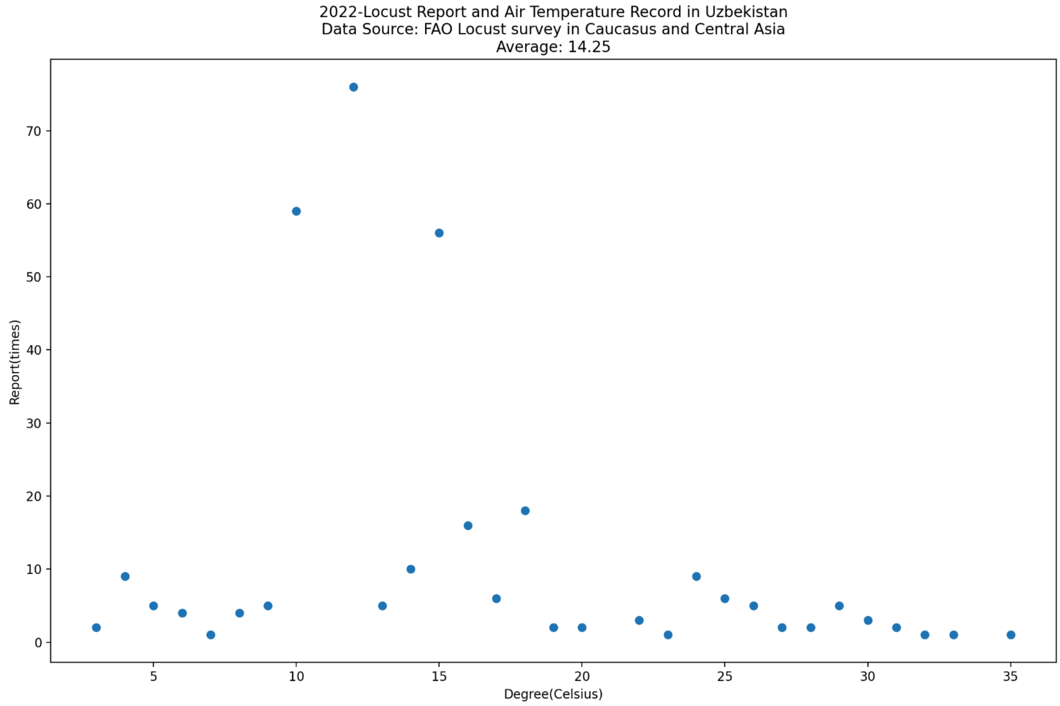
Second, the temperature anomalies accompanied by the geographical distribution of Uzbekistan's locust report (from FAO data), we can see that the areas with rising temperatures generally correspond to the locust spots in clusters on the distribution map.

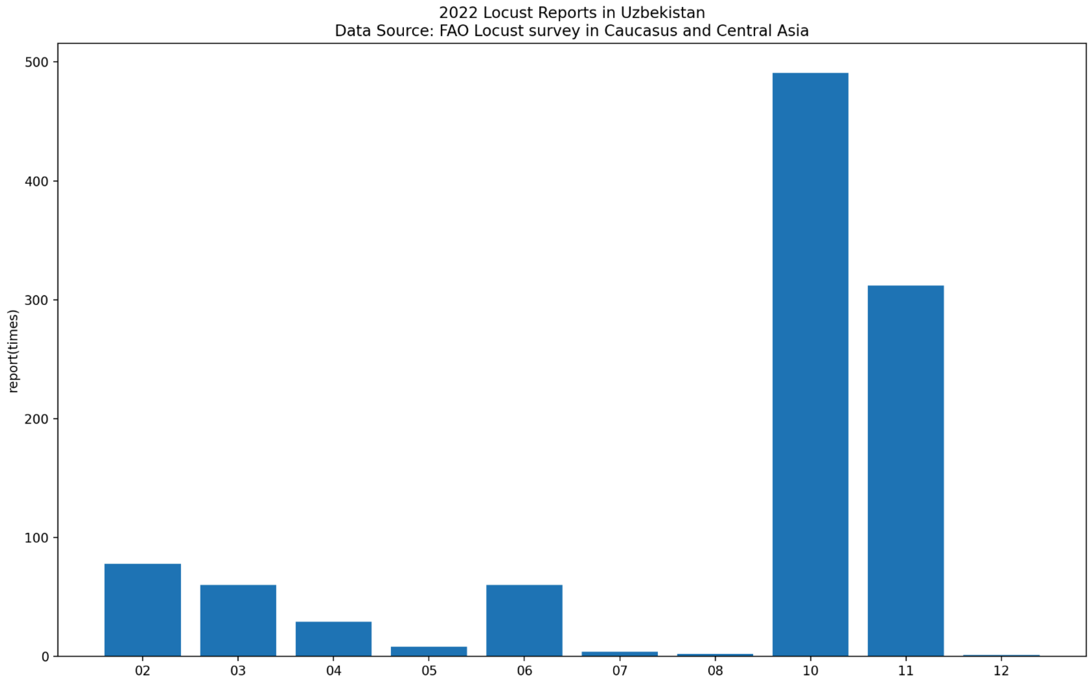
Third, according to FAO data, the average temperature recorded by locust reports was 14.25 degrees Celsius in the year 2022, and the reports were highly concentrated in months such as October, November, February, and June. Subsequently, we turned to NASA air temperature data for the aforementioned months and compared the temperature anomaly maps from 2018 to 2022. We found that the distinctive colors on the maps make it evident that the temperatures in the months of 2022 were generally not only warmer than those in 2018 but also higher than the baseline average.

[1] https://data.apps.fao.org/?lang=en&share=f-b91b8800-8b10-40ff-bbd4-5f9d910508c2

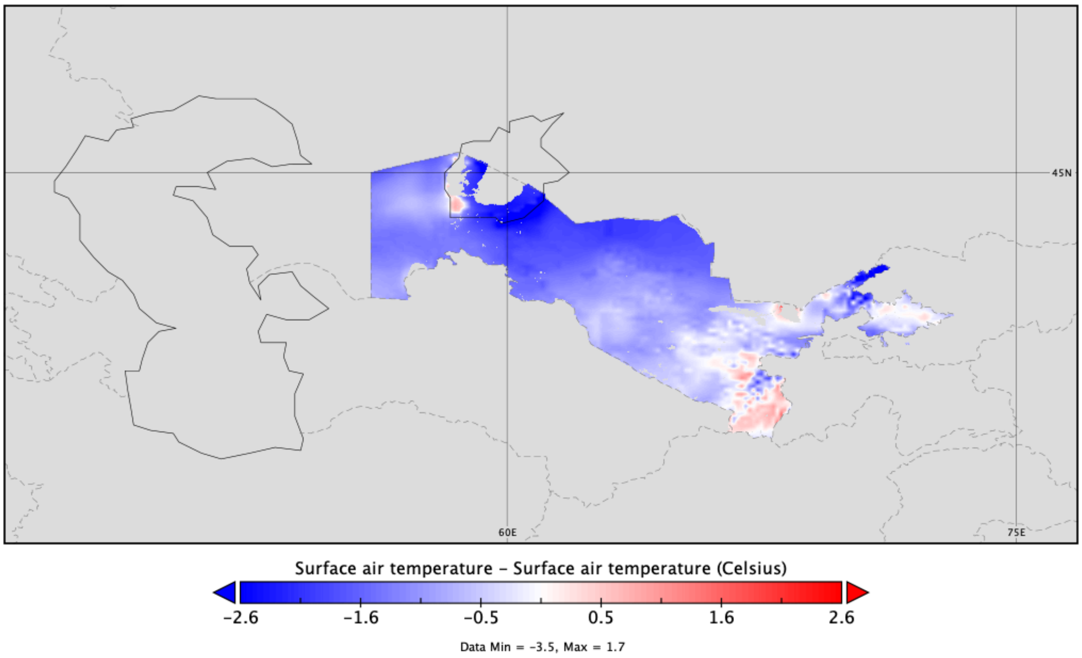

2010-2023 Geographical Distribution of Locust Swarms in Uzbeskistan
Data Source: FAO Locust survey in Caucasus and Central Asia
46
44
42
40
38
latitude
57.5
60.0
62.5
65.0
67.5
70.0
72.5
longitude


2022 Geographical Distribution of Locust Swarms in Uzbeskistan
Data Source: FAO Locust survey in Caucasus and Central Asia
46
44
42
40
38
latitude
57.5
60.0
62.5
65.0
67.5
70.0
72.5
longitude

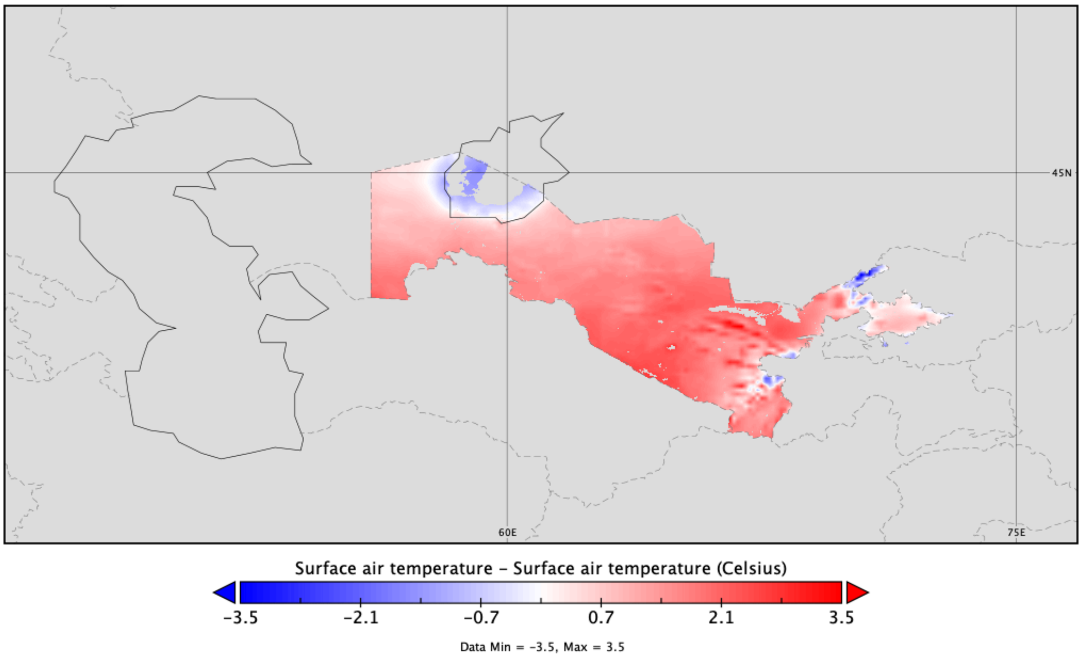

2022-Locust Report and Air Temperature Record in Uzbekistan
Data Source: FAO Locust survey in Caucasus and Central Asia
Average: 14.25
Report(times)
Degree(Celsius)

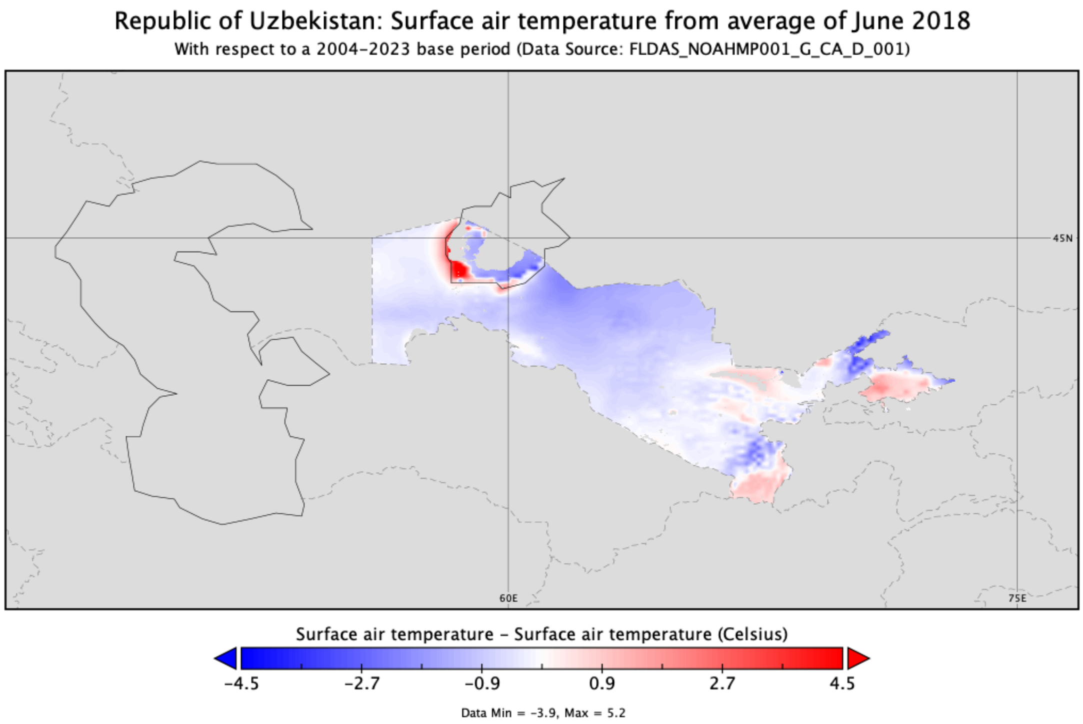

2022 Locust Reports in Uzbekistan
Data Source: FAO Locust survey in Caucasus and Central Asia
report(times)
02
03
04
05
06
07
08
10
11
12

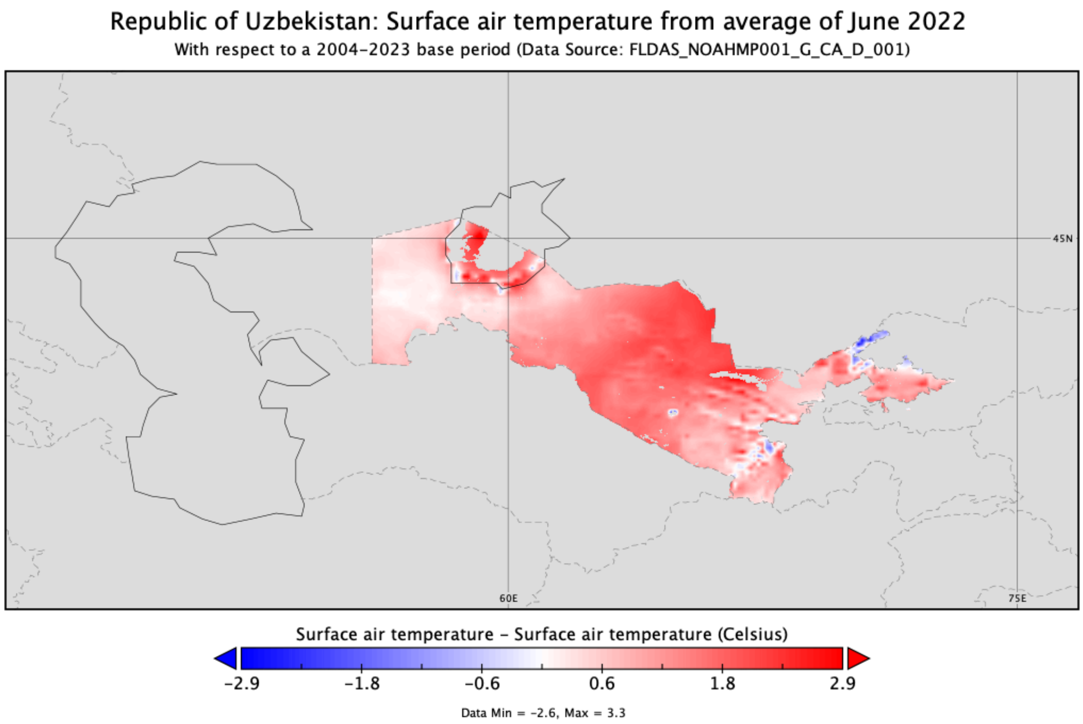
Republic of Uzbekistan: Surface air temperature from average of Nov 2018
With respect to a 2004-2023 base period (Data Source: FLDAS_NOAHMP001_G_CA_D_001)



Republic of Uzbekistan: Surface air temperature from average of Nov 2022
With respect to a 2004-2023 base period (Data Source: FLDAS_NOAHMP001_G_CA_D_001)

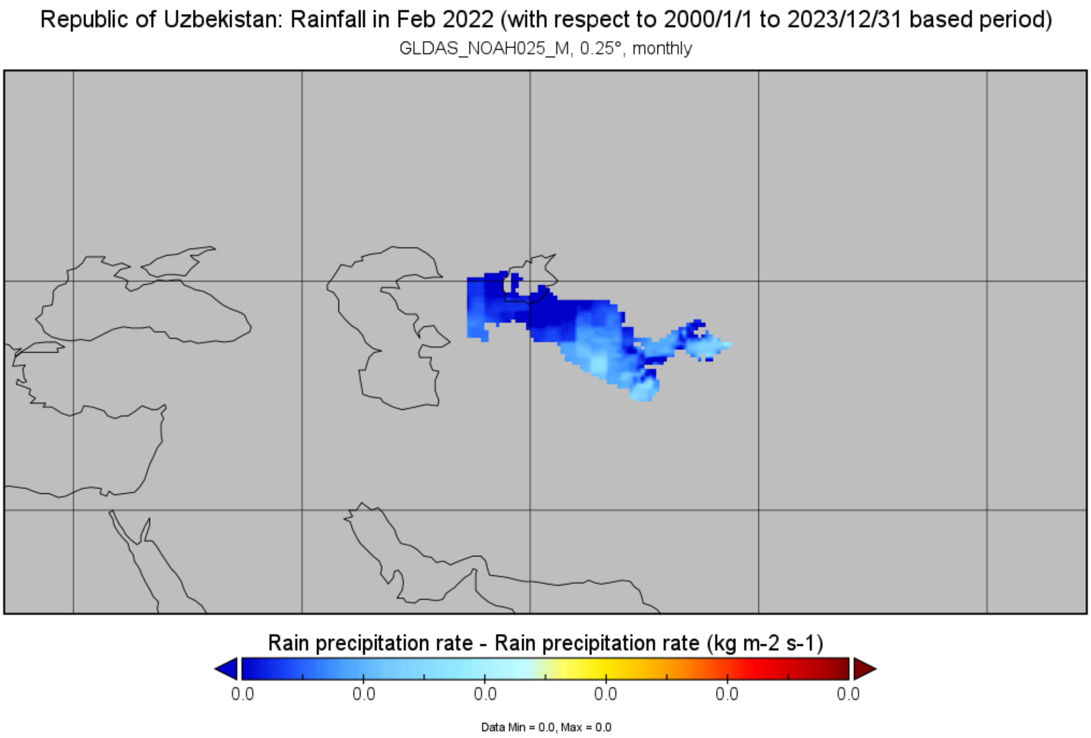



Republic of Uzbekistan: Surface air temperature from average of June 2018
With respect to a 2004-2023 base period (Data Source: FLDAS_NOAHMP001_G_CA_D_001)
45N
60E
75E
Surface air temperature - Surface air temperature (Celsius)
-4.5
-2.7
-0.9
0.9
2.7
4.5
Data Min = -3.9, Max = 5.2

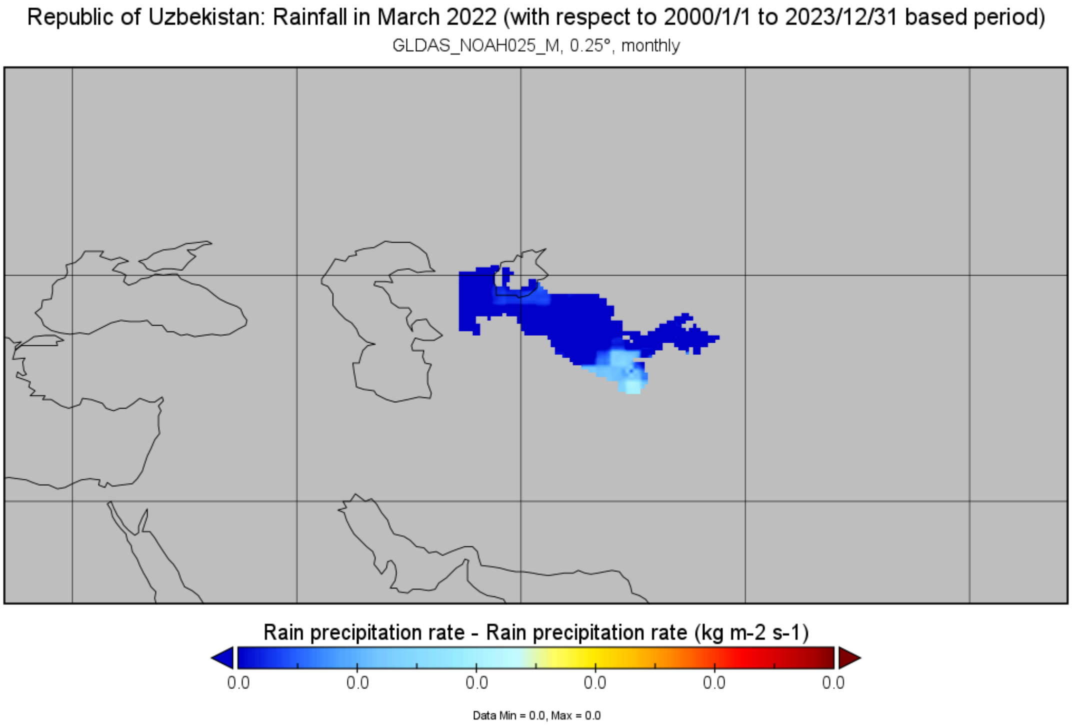

Republic of Uzbekistan: Surface air temperature from average of June 2022
With respect to a 2004-2023 base period (Data Source: FLDAS_NOAHMP001_G_CA_D_001)
45N
60E
75E
Surface air temperature - Surface air temperature (Celsius)
-2.9
-1.8
-0.6
0.6
1.8
2.9
Data Min = -2.6, Max = 3.3

Rainfall and Soil moisture variable

As papers our team studied, it tells that the phenomenon of a particularly dry month preceding heavy rainfall in the subsequent month is observed before the locust infestations. Therefore, we expect to observe the same result in rainfall in 2022.
The images below depict the rainfall patterns for the years 2018, 2022, as well as the cumulative rainfall from 2000 to 2023, segmented across 12 months.

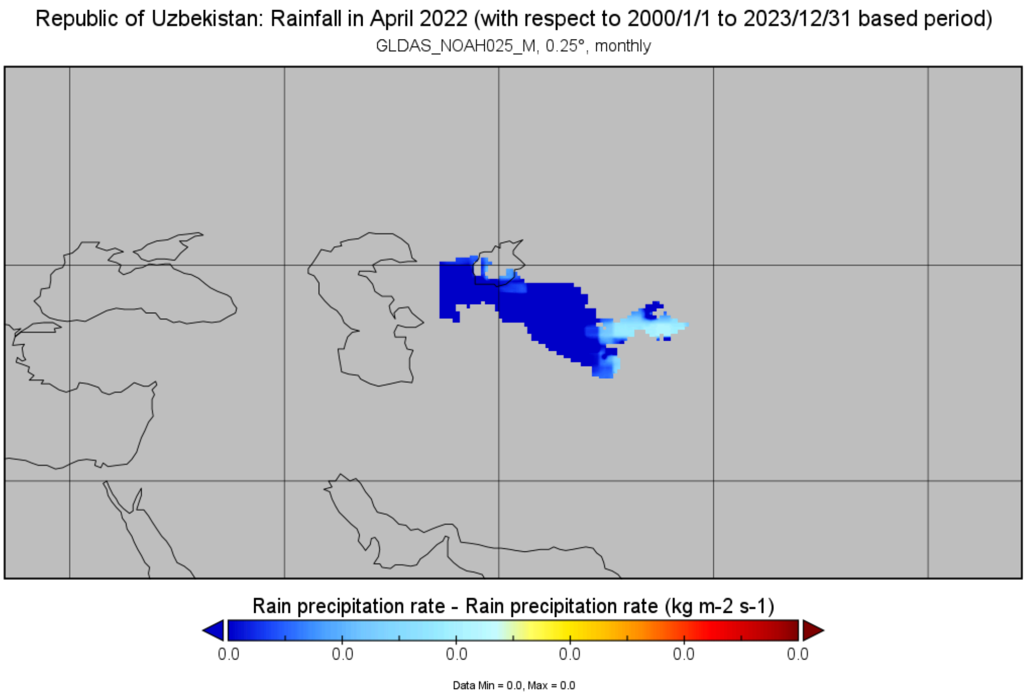


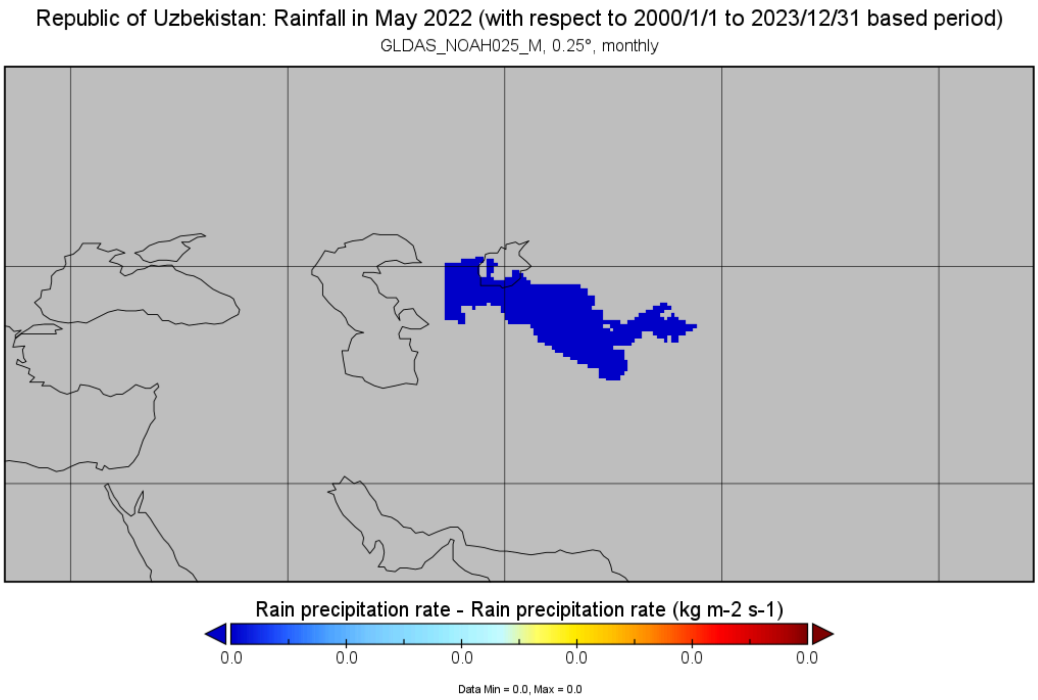
From the image, rainfall in February was much lower than the past 20-year rainfall average for all eastern regions.



However, except Surxondaryo Region, all other eastern regions got enough rainfall in March, which is the highest rainfall month of the year at all times. Therefore, the phenomenon of a particularly dry month preceding heavy rainfall in the subsequent month is observed.

From the images below, we can observe the same result in April and May as rainfall in February and March in 2022.





In terms of soil moisture, it is closely correlated to rainfall. Since around 15cm underground is where locusts spawn, our team focuses soil moisture on 10-40cm underground data.[2] In 2022, the mean rainfall from January to May exceeded the 20-year historical average, resulting in the 10-40cm underground layers becoming conducive for the growth of locust eggs.

[2] https://www.fao.org/fao-stories/article/en/c/1397831/

To conclude, due to climate extremes, we believe that locust infestations are more likely to occur.

Data Insights and our advice

We predict that locust issues in the Uzbekistan region will occur more frequently due to climate change, potentially leading to more extreme food security concerns.

From FAO data, it is astonishing for us to see that the food insecurity in Uzbekistan has been a worsening problem in recent years despite the advance in agricultural productivity, this food insecurity places more than 25% of the Uzbekistan population under threat of hunger.[3]

Currently, the allocation of resources for locust disaster prevention worldwide is based on severity rankings derived from AI and large model algorithms, with limited attention paid to Central Asia and Uzbekistan. However, Uzbekistan could benefit from increased attention and resource allocation for locust-related issues.

We are aware that weeds, such as reed grass, are a good fit for locust oviposition and serve as the locust's food plant.[4] We advise actions to enhance the prediction of locust outbreaks in Uzbekistan by the prediction model including rainfall phenomenon and strengthen measures for locust control by clearing weeds from abandoned farmland.

Reference

1. https://www.fao.org/locusts-cca/bioecology/en/
2. https://www.sciencedirect.com/science/article/abs/pii/S0301479716306508
3. https://sdgs.un.org/zh/goals/goal2
4. https://www.worldbank.org/en/news/factsheet/2020/04/27/the-locust-crisis-the-world-banks-response
5. https://www.fao.org/locust-watch/en
6. https://www.fao.org/ag/locusts/common/ecg/190/en/1996_EPPO_Cressman_Forecasting.pdf

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[3] <iframesrc="https://data.worldbank.org/share/widget?indicators=SN.ITK.SVFI.ZS&locations=UZ" width='450' height='300' frameBorder='0' scrolling="no" ></iframe>

[4] Fabian Löw, François Waldner, Alexandre Latchininsky, Chandrashekhar Biradar, Maximilian Bolkart, René R. Colditz, "Timely monitoring of Asian Migratory locust habitats in the Amudarya delta, Uzbekistan using time series of satellite remote sensing vegetation index", *Journal of Environmental Management*, V. 183, Part 3 (2016) ISSN 0301-4797, pp. 562-575. https://doi.org/10.1016/j.jenvman.2016.09.001. https://www.sciencedirect.com/science/article/pii/S0301479716306508