CLUSTERING OF EUROPEAN COUNTRIES BASED ON THEIR AVERAGE TEMPERATURE AND HUMIDITY TO FIND THE BEST CONDITIONS OF SUSTAINABLE PLANTING BY USING PYTHON

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ABSTRACT

Analysis of climatic conditions for growing agricultural crops in most European countries, taking into account humidity and temperature values for 1975-2024. The analysis is based on open climate databases from the Copernicus E-OBS website [1]. Vector maps of the Earth's surface from the Natural Earth website [2] were used to preserve the exact borders of European countries. In order to distribute the data into similar climatic zones, the K-Means clustering method was applied in the Python (PyCharm) programming environment, which allowed eight clusters to be identified. During data processing, Python libraries such as xarray, pandas, geopandas, numpy, tqdm, os, sklearn. cluster, matplotlib. pyplot, and zipfile were used, which made it possible to efficiently process large amounts of data. The arithmetic mean formula was used to calculate the average yearly values of temperature and humidity. A quantitative assessment of average temperature and humidity over the last 50 years shows that the average temperature increase across Europe of approximately 1.9 oC while humidity in some regions has decreased by 8.6%. The results demonstrate clear climate zones in Europe, which reflect important factors in agricultural production and clearly show climate change and global warming. The data obtained can be the basis for further research aimed at forecasting climate changes, developing strategic decisions for agricultural development, and creating relevant applications with elements of artificial intelligence.

Index Terms— climate change, agriculture, temperature, humidity, Python, planting, sustainability.

1.0 INTRODUCTION

Climate change is one of the most pressing issues of today, directly affecting natural ecosystems and human life. Agriculture is one of the most climate-dependent industries. It is notably dependent on temperature and humidity, as these are crucial factors in plant growing. An analysis of long-term indicators for European countries spanning approximately 50 years shows that these indicators have changed profoundly [1]. In 1975, only one country, Portugal, was among the warmest countries, whereas today there are seven such countries: Albania, Spain, Greece, Italy, Croatia, San Marino and Portugal. These changes have complex consequences, including rising sea levels due to melting polar ice caps, changes in human health and, of course, changes in agriculture [5].

1.1 Local Context and Personal Experience

The European continent has extraordinary climatic diversity, as it is located in three climatic zones - from subarctic in the north to temperate and subtropical in the south [4]. This creates a wide range of conditions for the development of rural industry. Ukraine is a prime example of the environmental consequences of anthropogenic climate change [6]. One of the most visible examples of this impact and the destruction of the Kakhovka Reservoir, which has significantly affected changes in humidity and temperature levels. These changes resulted in a massive influx of locusts, which caused significant damage to crops. This example demonstrates that anthropogenic impact, together with natural changes in the ecosystem, directly affects the agro-industrial sector [3].

1.2 Object and Purpose of The Research

The purpose of this research was to demonstrate in practice the use of Python to change the temperature and humidity over the last 50 years and to assess their impact on the development of agriculture. The research has both theoretical and practical significance.

- Theoretically, it creates a basis for further wider research into environmental changes in European countries.
- In practical terms, the results of the research can be used for agricultural production planning, climate change prediction, and the creation of artificial intelligence capable of solving agricultural issues.

2.0 METODOLOGY

2.1 Description of the Research Area

The study covers most European countries and aims to analyze the climatic conditions that affect the environment. The goal of the study was to demonstrate, using Python, the changes in temperature and humidity between 1975 and 2024 and to assess their impact on the development of agriculture.

Maps from the Natural Earth website [2] were used to more clearly identify country borders. Climate data was obtained from the Copernicus E-OBS website [1], which contains high-resolution daily temperature and humidity observations.

2.2 Research Technology

The Python programming language was used in the PyCharm development framework to process, analyze and visualize data, using the following libraries:

- Xarray, pandas, numpy, tqdm, os, zipfile – for processing, analyzing and organizing data;
- Geopandas - for comparing climate data with country boundaries;
- Sklearn.cluster - for clustering countries;
- Matplotlib.pyplot - for visualizing the results.

Due to the large amount of data, the processing was carried out separately for two-time blocks: 1975 to 1999 and 2000 to 2024, after which the results were combined into a single summary Excel file. For each country, the average monthly and average yearly values of temperature and humidity were calculated and used for clustering. Table 1 shows a few examples of temperature on the other hand Table 2 shows a few examples of humidity.

Table 1: Example of temperature list

Country	1	2	3	4	5	6	7	8	9	10	11	12	Year
FR	5.9	5.1	4.6	8.6	11.6	15.4	18.7	19.4	15.4	9.6	6.0	2.0	1975
UA	-0.3	-3.0	3.3	11.0	17.6	20.7	20.7	19.6	16.6	7.6	-0.2	-1.8	1975
BY	-0.4	-2.6	2.2	7.7	16.1	16.9	18.5	17.5	14.4	6.1	-1.2	-1.5	1975
LT	0.4	-1.1	2.5	5.8	13.9	15.1	18.1	17.6	14.6	7.0	0.1	0.2	1975

Table 2 Example of humidity list

Country	1	2	3	4	5	6	7	8	9	10	11	12	Year
FR	85	78	83	78	78	75	72	75	83	83	87	87	1975
UA	85	81	80	78	76	78	75	77	76	82	83	86	1975
BY	87	82	81	79	70	76	73	77	76	82	83	86	1975
LT	87	83	80	79	68	71	70	74	72	82	85	86	1975

2.3 Key Parameters

Average of the temperature calculation was done by the following equation

$$T_{mean} = \frac{1}{12}\sum_{i=1}^{12}\left(T_{month_i}\right)$$

where Tmonth i is ith month's temperature average and Tmean is the overall average of temperature in oC.

On the other hand, the average of the humidity calculation was done by the following equation

$$H_{mean} = \frac{1}{12}\sum_{i=1}^{12}\left(H_{month_i}\right)$$

where Hmonth i is ith month's humidity average and Hmean is the overall average of humidity in %.

The following figure 1 shows the python code for calculation of average of temperature and humidity.

```
month_cols = [col for col in temp_df.columns if "Month" in col]
temp_df["mean_temp_year"] = temp_df[month_cols].mean(axis=1)
hum_df["mean_hum_year"] = hum_df[month_cols].mean(axis=1)
```

Figure 1: Python code to perform calculations

3.0 RESULT

3.1 Data Visualization

The full time period from 1975 to 2024 was considered to show the dynamics of temperature and humidity changes in each year. Tmean and Hmean were used to group countries with similar values using the K-Means method, which created 8 clusters. The resulting clusters for temperature, figure 3, and humidity, figure 4, are shown in the form of graphs as follows:

Figure 3: Clusters of countries for average temperature in oC
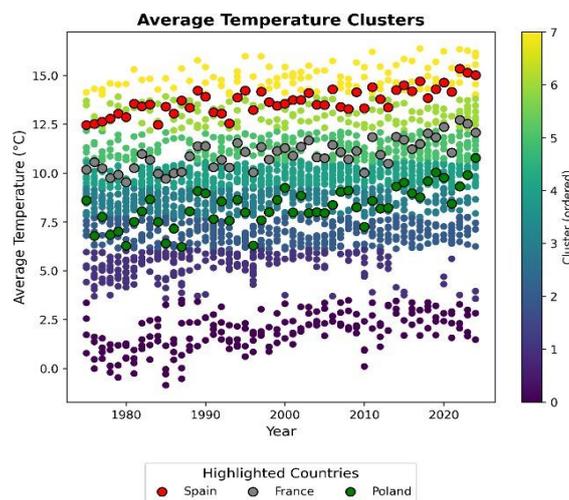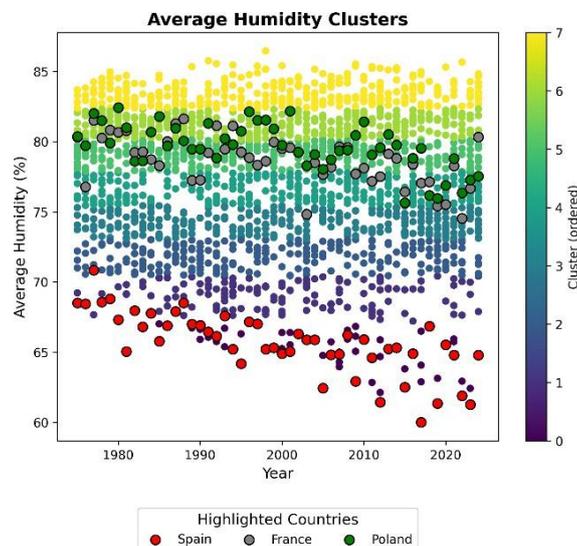

Figure 4: Clusters of countries for average humidity in %

For both figures, figure 3 and figure 4, X-axis represents the years of observation and Y-axis represents Tmean for figure 3 and Hmean for figure 4 on the left and distribution into clusters from 0 to 7 on the right.

The colour of the point corresponds to the cluster number. This representation made it possible to track how countries are gradually moving from 'colder' to 'warmer' clusters, which is a clear indicator of global warming.

The changes in the environment over the last 50 years can be easily calculated by checking the difference between temperature/humidity average in 2024 and temperature/humidity average in 1975.

For a more illustrative demonstration, Spain, France, and Poland were highlighted in red, gray, and green, respectively, to clearly show the trends in these specific countries.

4.0 CONCLUSION

Analysis of climate data from 1975 to 2024 revealed a steady trend towards an increase in average annual temperatures in most European countries. The graphs clearly show how countries have changed in clusters, moving from 'cool' to 'warmer'. This indicates a systematic increase in temperature on the continent.

At the same time, observing changes in humidity, which is also one of the important factors in the agricultural sector were observed.

A quantitative assessment of average temperature and humidity over the last 50 years shows that the average temperature increase across Europe of approximately 1.9 oC and decrease in humidity in some regions of up to 8.6%.

The results obtained demonstrate the direct impact of climate change on the agricultural industry. Rising temperatures are expanding the growing area for heat-loving crops. At the same time, humidity is decreasing, which may lead to a decrease in the production of other plants. Therefore, irrigation systems need to be used. Finally, the Python-based approach developed has made it possible to clearly confirm climate trends over the last 50 years and lay the groundwork for further research.

4.1 Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

4.2 Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

4.3 Data Availability Statement

The data that support the findings of this study are openly available form the Copernicus E-OBS dataset at https://surfobs.climate.copernicus.eu/dataaccess/access_eobs_months.php (accessed on 04/11/2025).

REFERENCES

Copernicus E-OBS data access months, https://surfobs.climate.copernicus.eu/dataaccess/access_eobs_months. php, Accessed on 04/11/2025.

Natural Earth, 2009, https://www.naturalearthdata.com/downloads/10m-cultural-vectors/10m-admin-0-countries/, Accessed on 04/11/2025.

AGROWEEK, https://lnk.ua/y4zjond4j, Accessed on 09/11/2025.

Climate Box, https://lnk.ua/LVbP1j04y, Accessed on 09/11/2025.

European Commission, https://lnk.ua/aV7o0n0V1, Accessed on 09/11/2025.

Global Witness, https://lnk.ua/9erXmzqNp, Accessed on 09/11/2025.