Temperature prediction model for Ankara. Global warming as a result of climate change - on example of Ankara (capital of Turkey). The city with the significant temperature increase in years 2000-2013 (data extended till the end of 2020).

Presenter: Agnieszka Kamińska
PJATK, Big Data Engineering, 01/29/2024

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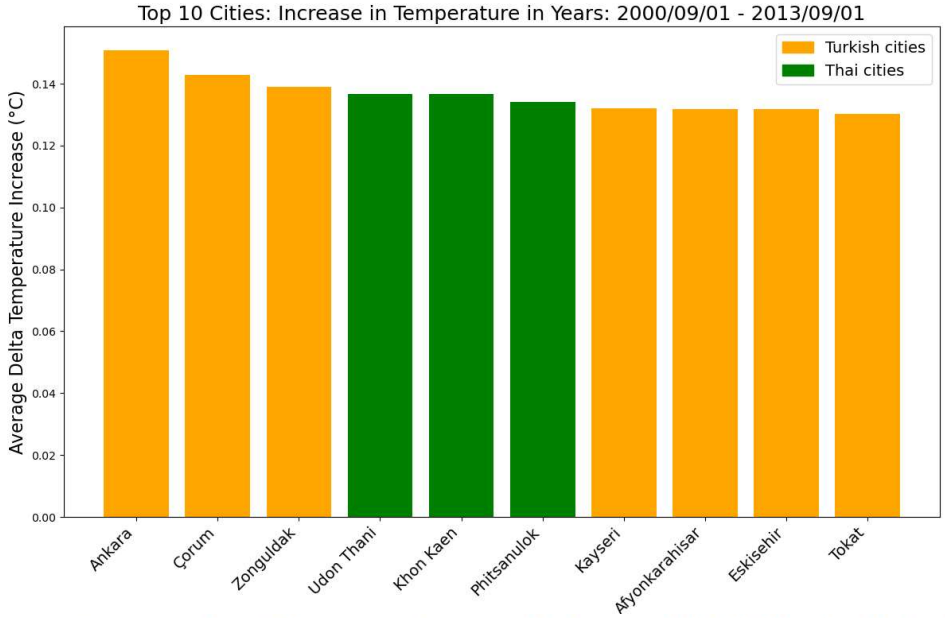
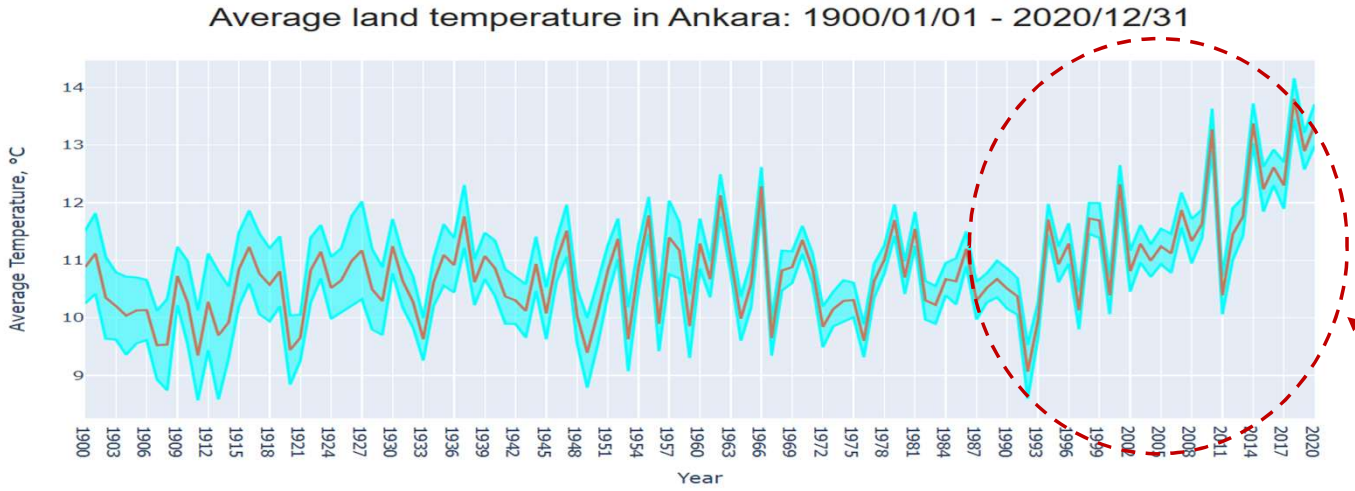
1. Scientific/business problem statement

Based on **GlobalLandTemperaturesByCity.csv** data originally generated **@Berkeley Earth**. One city with significant temperature increase in 2000 -2020 : Ankara, was chosen for future investigation and temperature model built.



Country	City	Delta_Temperature
Turkey	Ankara	0.150878
Turkey	Çorum	0.142962
Turkey	Zonguldak	0.139058
Thailand	Udon Thani	0.136756
Thailand	Khon Kaen	0.136756
Thailand	Phitsanulok	0.134173
Turkey	Kayseri	0.132058
Turkey	Afyonkarahisar	0.131917
Turkey	Eskisehir	0.131917
Turkey	Tokat	0.130282



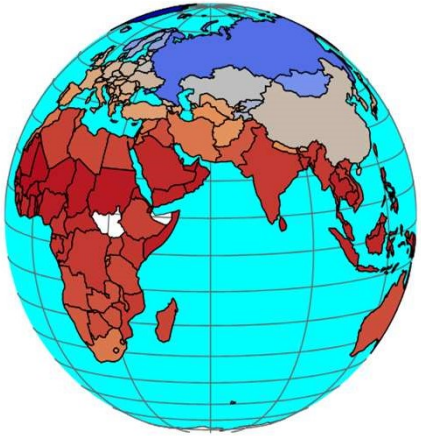
Over years we can observe significant increase in average land temperature in Ankara : From 10.9 °C in 1900 till 13.3 °C at the end of 2020.

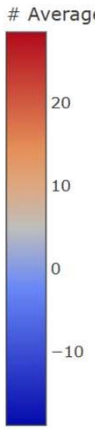
Most significant temperature increment can be observed in Ankara after approx. 1990

1. Scientific/business problem statement

Average Temperature in years:

1755 -1950

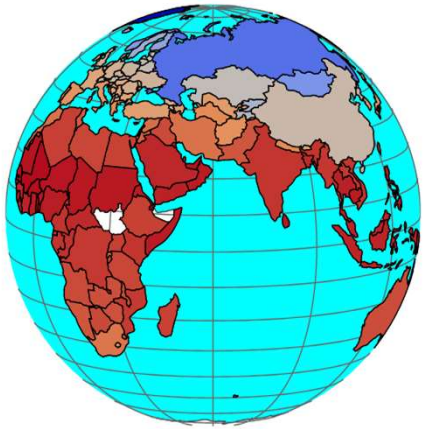


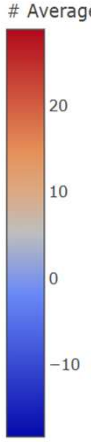


Turkey: 11.445°C

+ 0.531°C

1950 - 2000

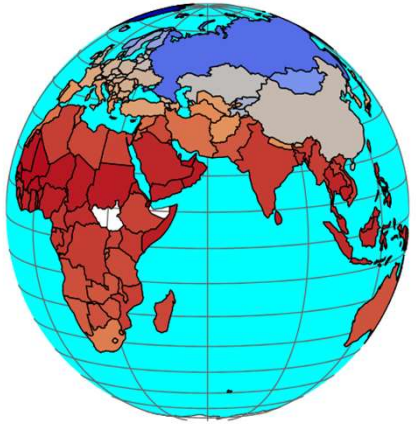


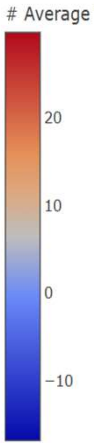


Turkey: 11.976°C

+ 0.759°C

2000 - 2013





Turkey: 12.735°C

Average temperature in Turkey increased by 0.759°C only in 13 years through 2000-2013!

1. Scientific/business problem statement

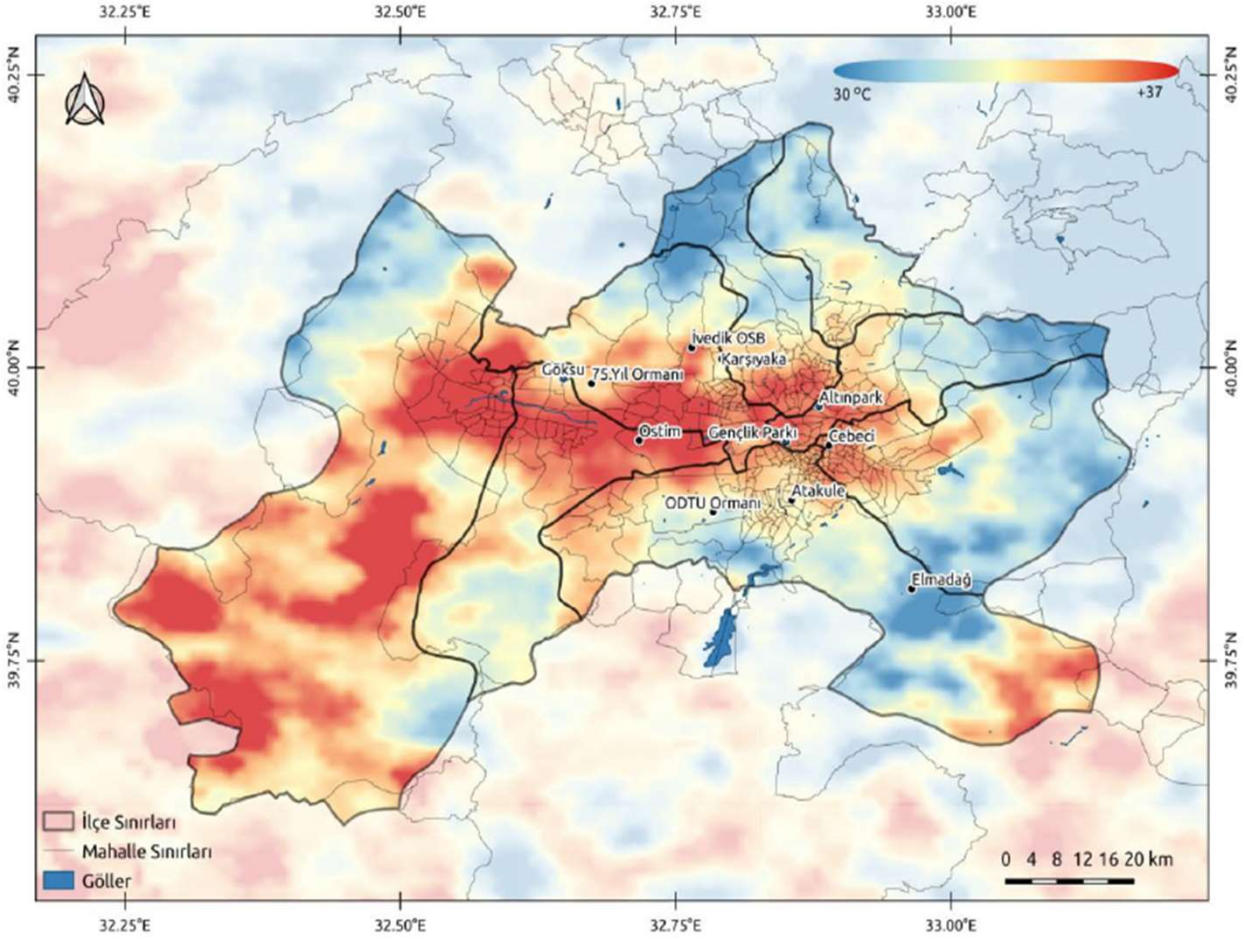
Ankara - Ankara is 874 m above sea level. In general, continental climate is observed in Ankara. In addition to the steppe climate, which is the climate of Central Anatolia, temperate and rainy climate characteristics are observed from the Black Sea climate characteristics in the northern regions. In winter, there is much more rainfall than in summer. According to Köppen-Geiger, the climate is Csa (**Hot Summer Mediterranean Climate**).

Climate change problem statement:

- **Change in greenhouse gas emissions**, **population growth**, **economic growth**, **increase in energy consumption, food (agricultural) demand**, and **technological development** are treated as the main factors causing temperature increment.

1. Scientific/business problem statement

Urban heat island observed in June in Ankara for the years 2019 and 2020.



The surface temperature maps produced based on the data of 2019 and 2020 show the sub-regions of the city that can be considered as risky in terms of heat waves and urban heat island effect.

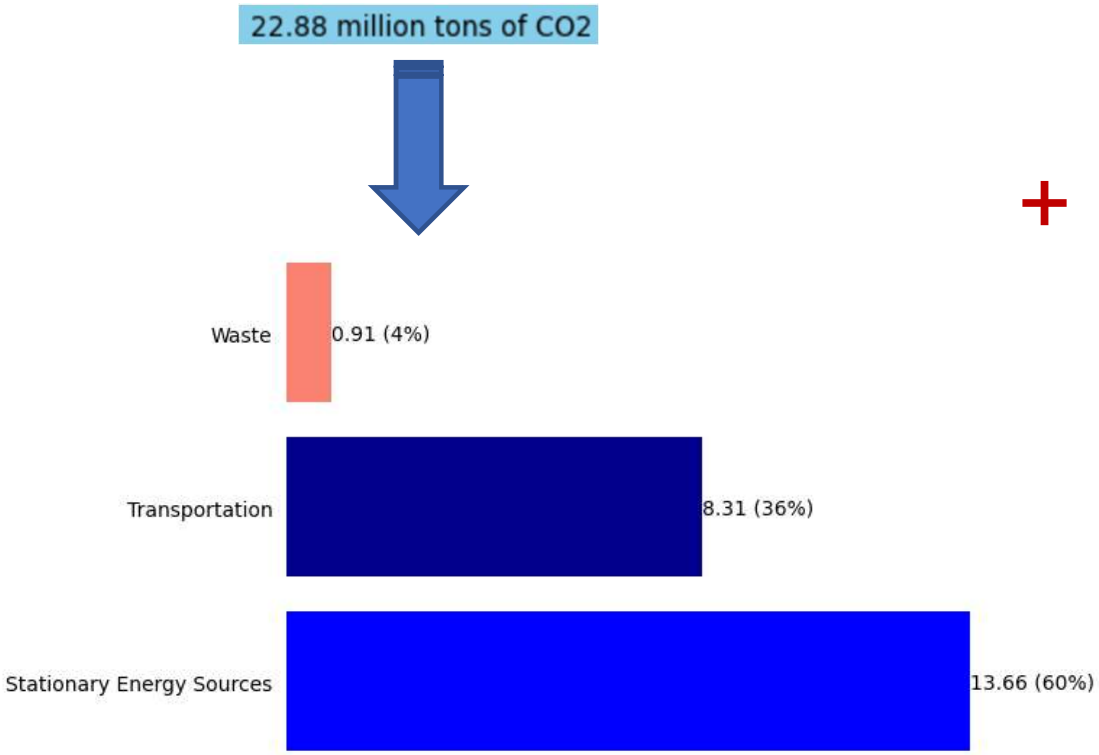
When the surface temperature maps of the city of Ankara are examined, it is seen that the coolest areas are urban forests and large open-green areas, while the hottest areas are dense urban areas, hard and impermeable floors and large production areas.

@ Information based on **ANKARA CLIMATE CHANGE ACTION PLAN Report**

2. Ankara – climate change : main factors @ANKARA CLIMATE CHANGE ACTION PLAN Report

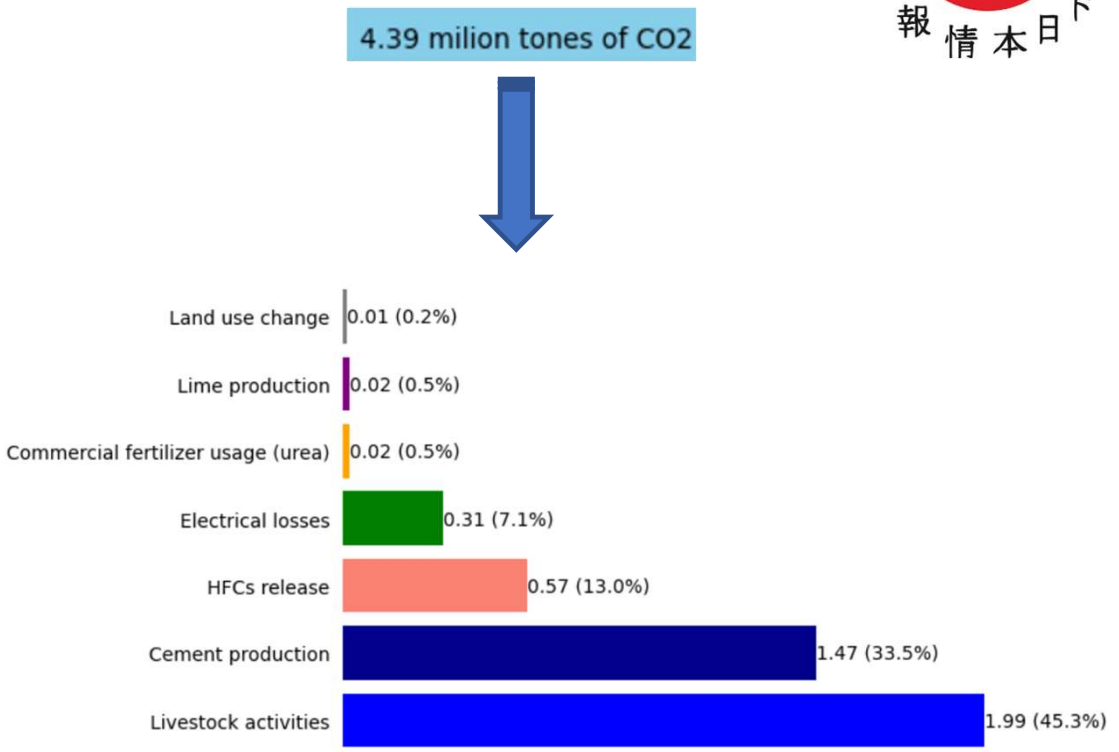
CO2 emissions in 2019

Categories of the GPC standard (GPC Basic)



+

Categories non included by GPC



Within the scope of the main categories of the GPC standard (GPC Basic), **the greenhouse gas emissions caused in Ankara Province in 2019 have been calculated as approximately 22.88 million tons**. According to the results of the 2019 Address Based Population Registration System (ABPRS) by TURKSTAT, the population of Ankara is 5,639,076 people. Therefore, emissions per capita were calculated as 4.05 tons. This value is calculated as 6.1 tons per person in Turkey. **When livestock, cement process emissions, electricity losses, refrigerant gases, chemical fertilizers and land use, which are not included in the GPC main category, are included, the total emissions are approximately 27.3 million tons.**

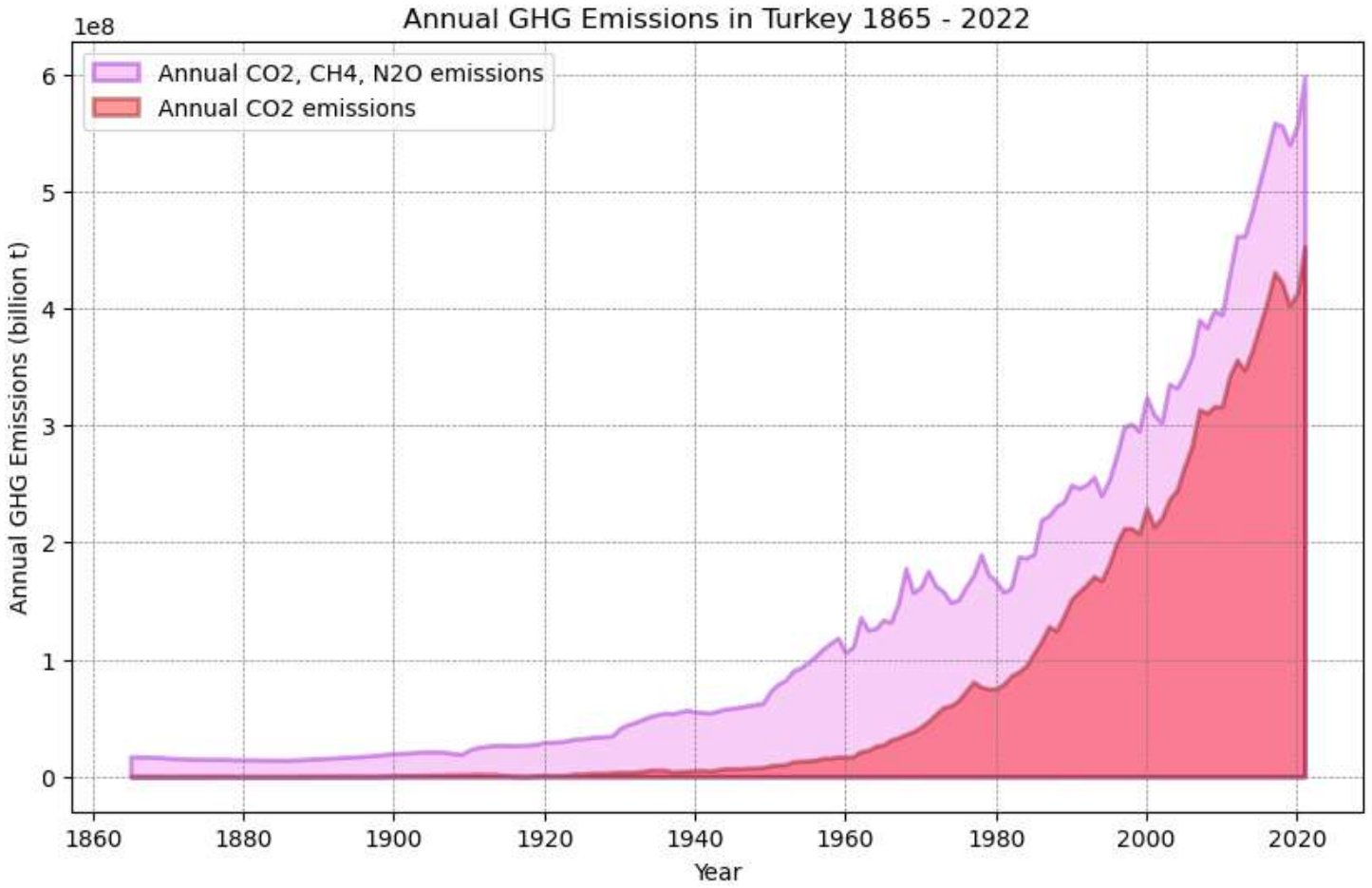
3. Turkey – climate change : main factors

Data from @**Berkeley Earth** shows that the problem with temperature increase as the final result of climate change applies not only to Ankara**, but also to the whole of Turkey,** let's investigate possible factors causing temperature increment: **@Our Worl in Data**

- Greenhouse gases emission,
- CO2 Emissions by sector,
- Energy production sources,
- Deforestation,
- Agricultural land area,
- Beef and buffalo meat production.

3. Turkey – climate change : main factors

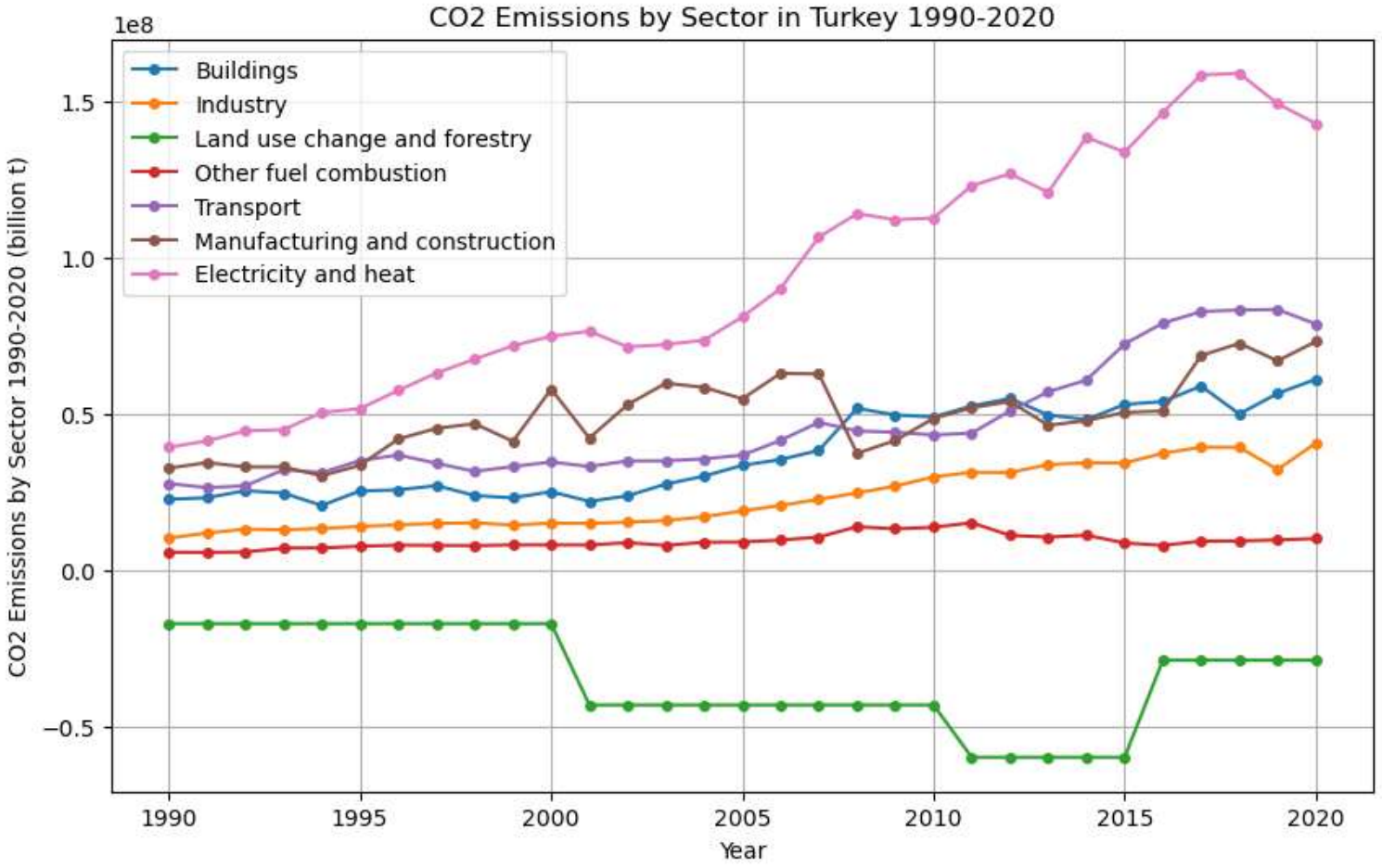
Greenhouse gases emission



Significant increment in greenhouse gases emission can be observed after 1950 due to country development.

3. Turkey – climate change : main factors

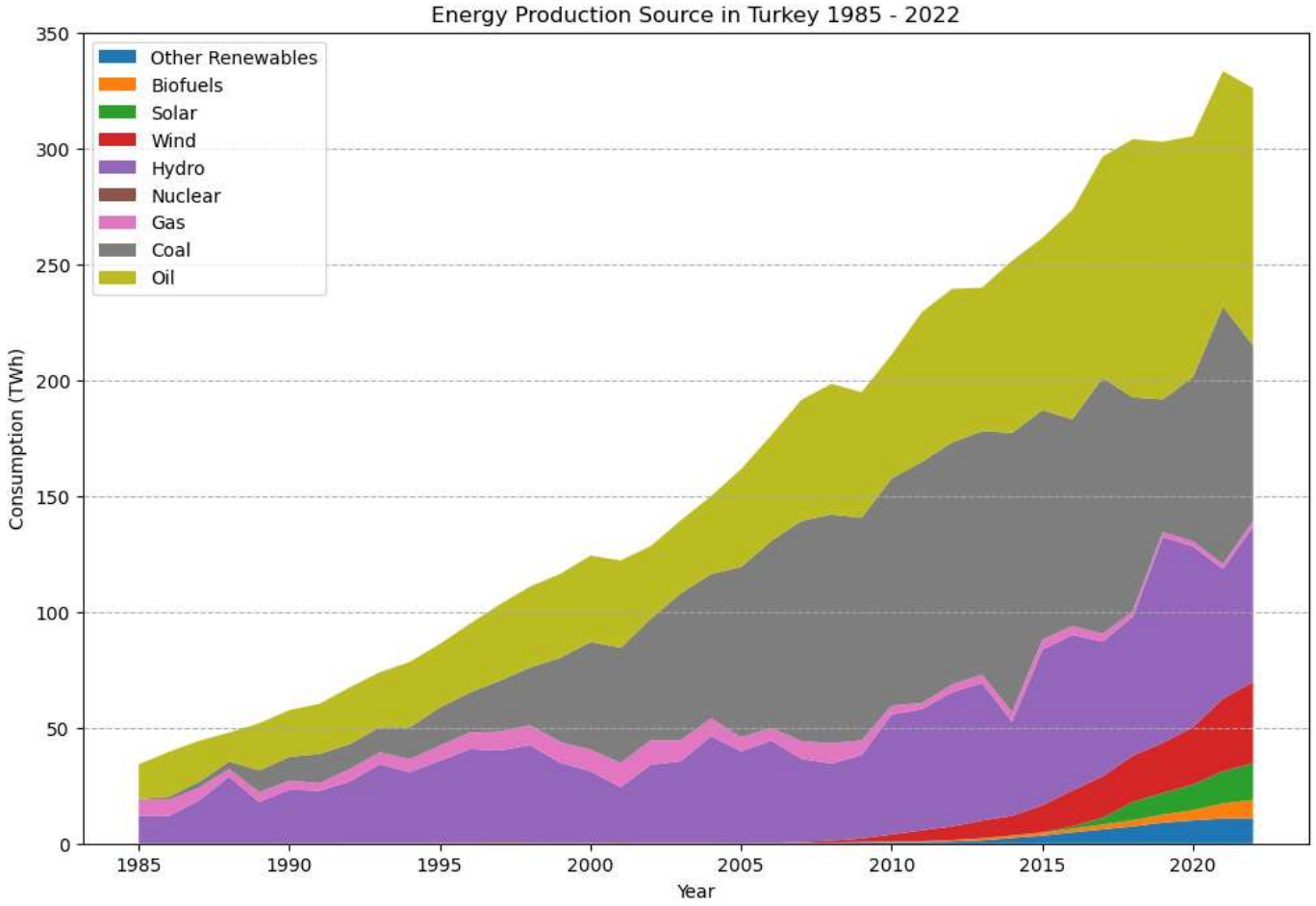
CO2 Emissions by sector



Main sector responsible for the highest CO2 emission is Electricity and Heat (~ 3 times higher than Transport).

3. Turkey – climate change : main factors

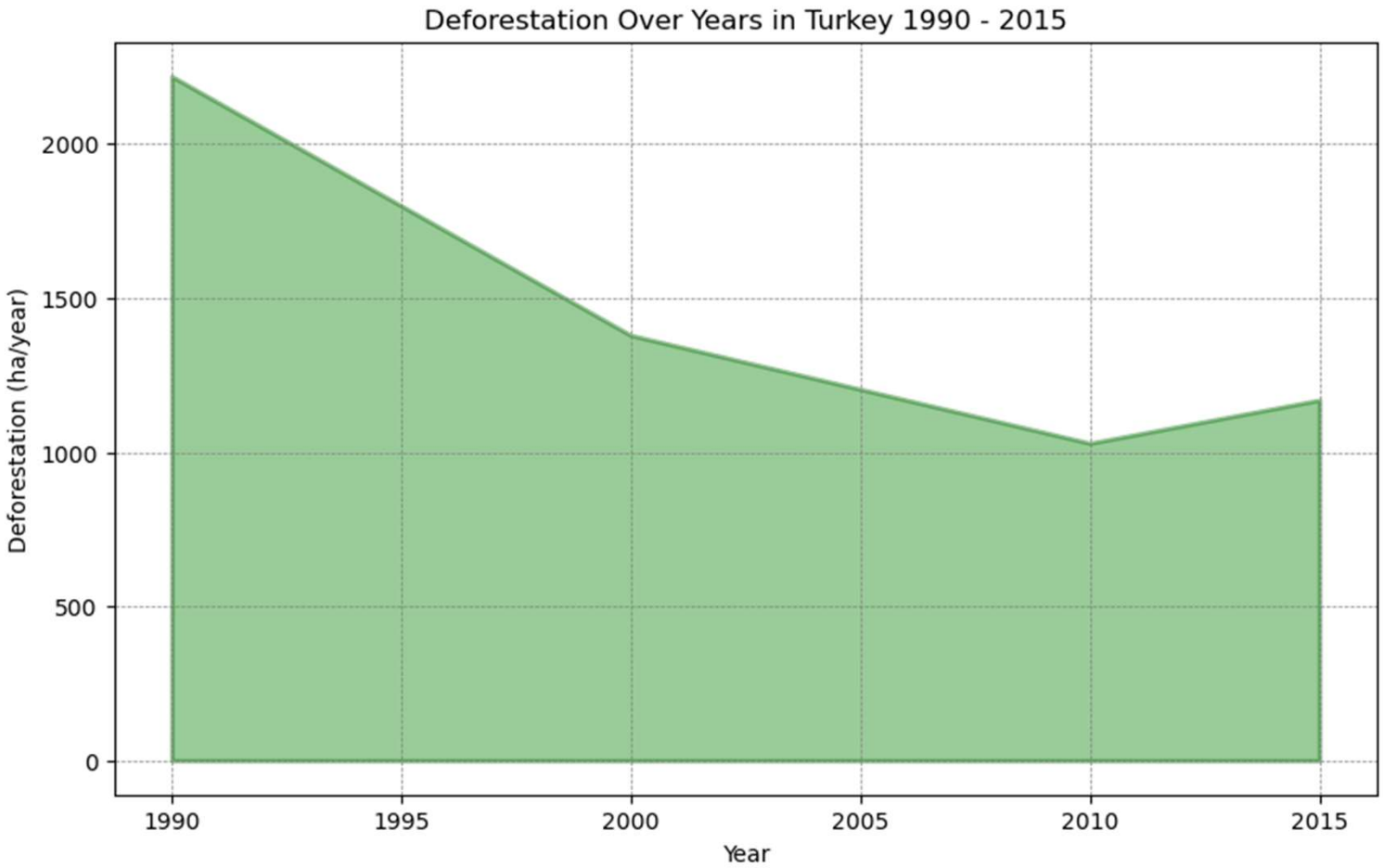
Energy production source



Energy production in Turkey is based on two main sources: Oil and Coal. Gas and Hydro constitute 1/3 part of oil used. Oil and Coal used during energy production stand for the significant pollution and emission of greenhouse gases.

3. Turkey – climate change : main factors

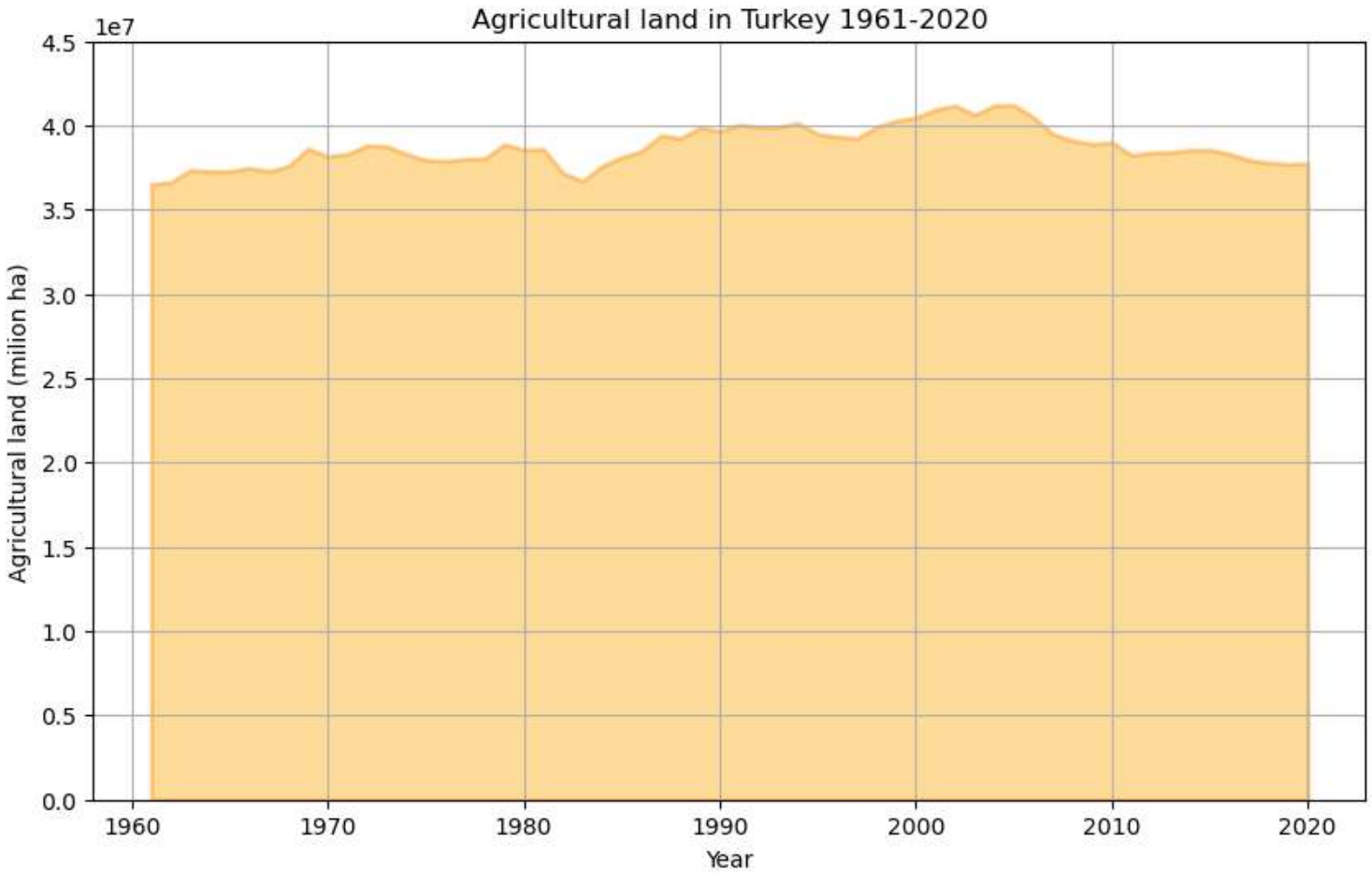
Deforestation



We can observe that the area covered by the forest in 2015 is half of the area covered in 1990!

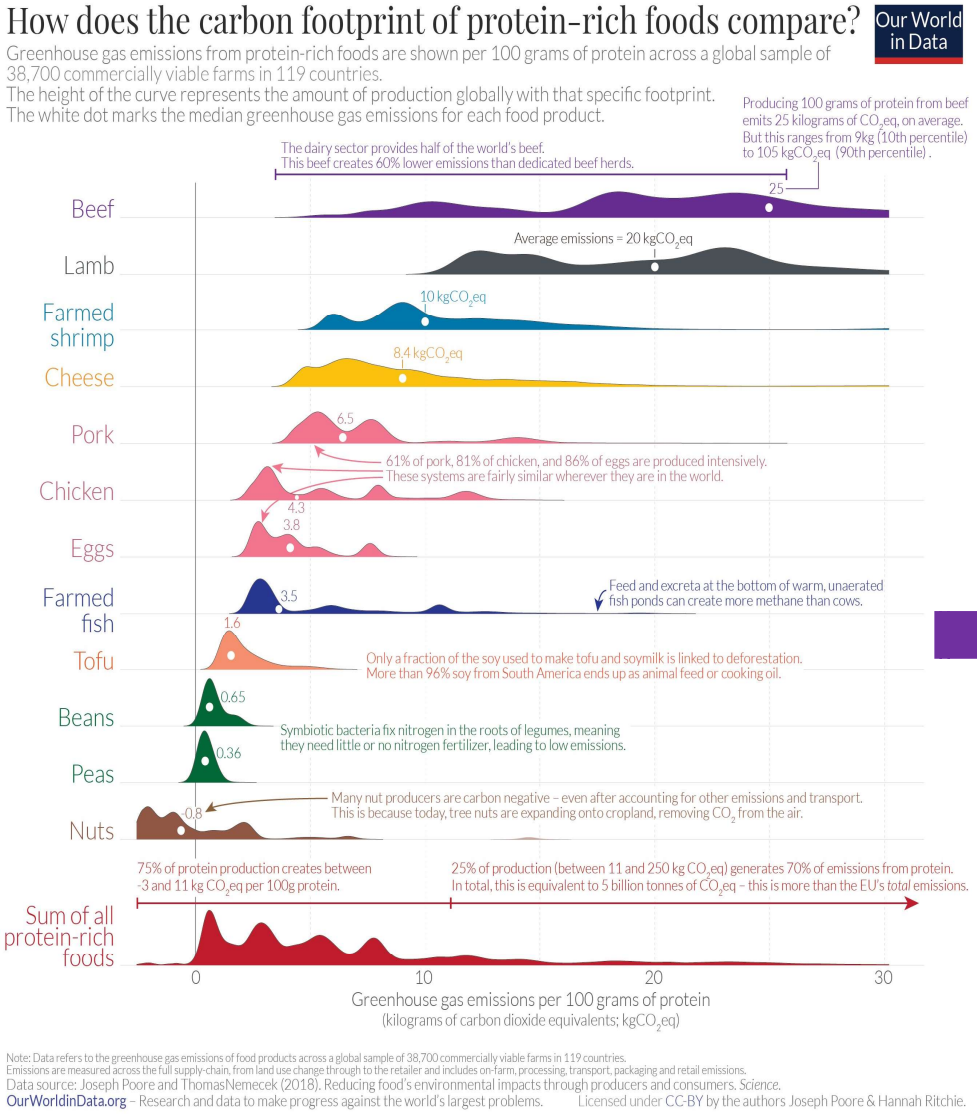
3. Turkey – climate change : main factors

Agricultural land area

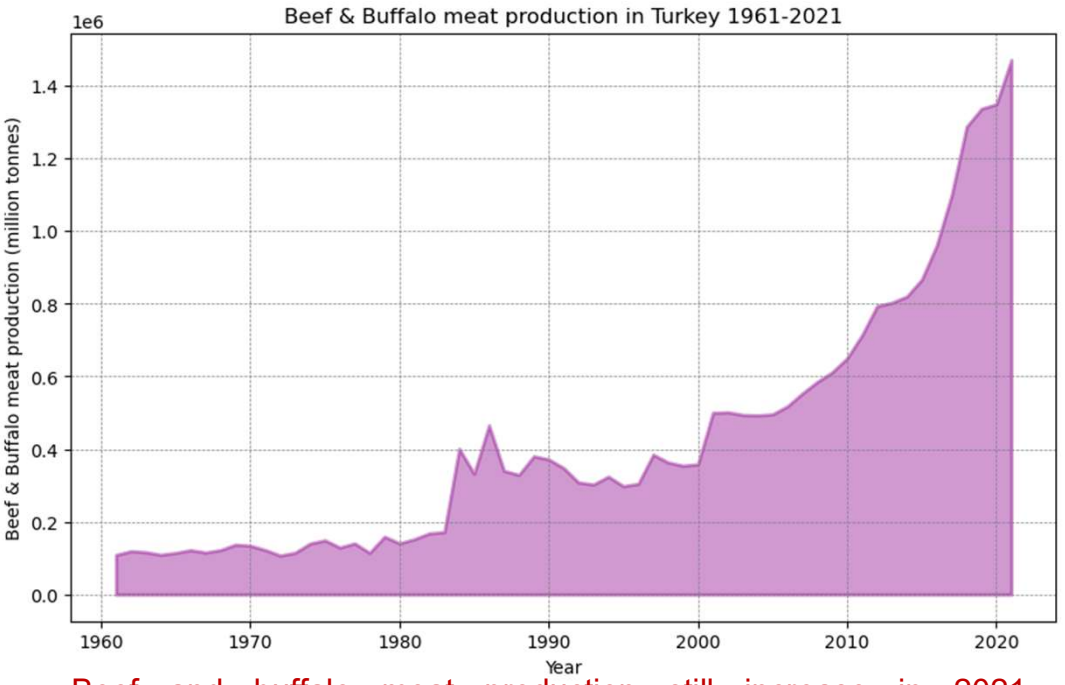


Agricultural land area decreased from the peak of 4.1 million ha in 2006 till 3.8 million ha in 2020.

3. Turkey – climate change : main factors



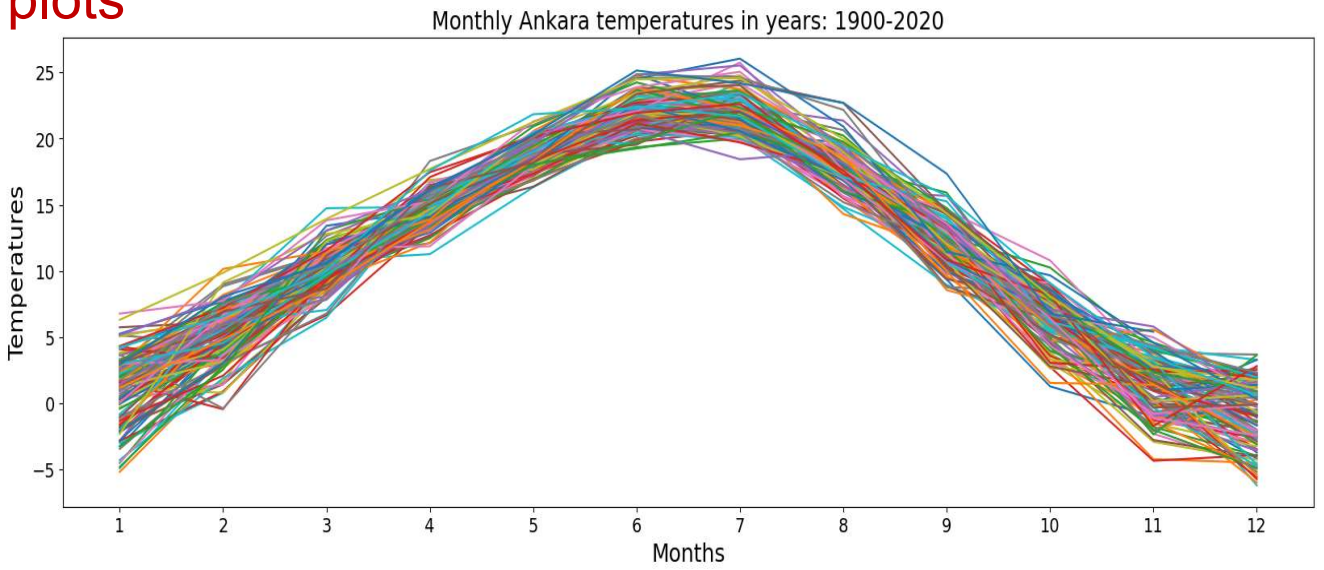
Beef and buffalo meat production



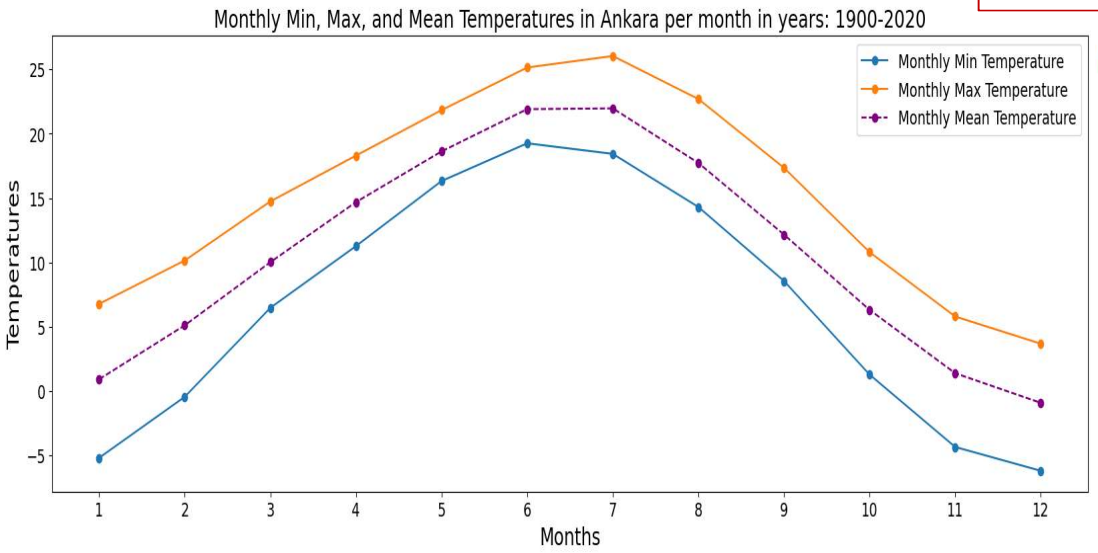
Beef and buffalo meat production still increase in 2021. **Producing 100g of protein from beef emits 25kg of CO2. It's the highest value from all the protein-rich compare.**

4. Ankara's temperature plots

- Monthly temperatures



Based on temperature data recorded monthly in years: 1900-2020, we can observe that **75% of maximum temperature per month occurred in years: 2000-2020**.

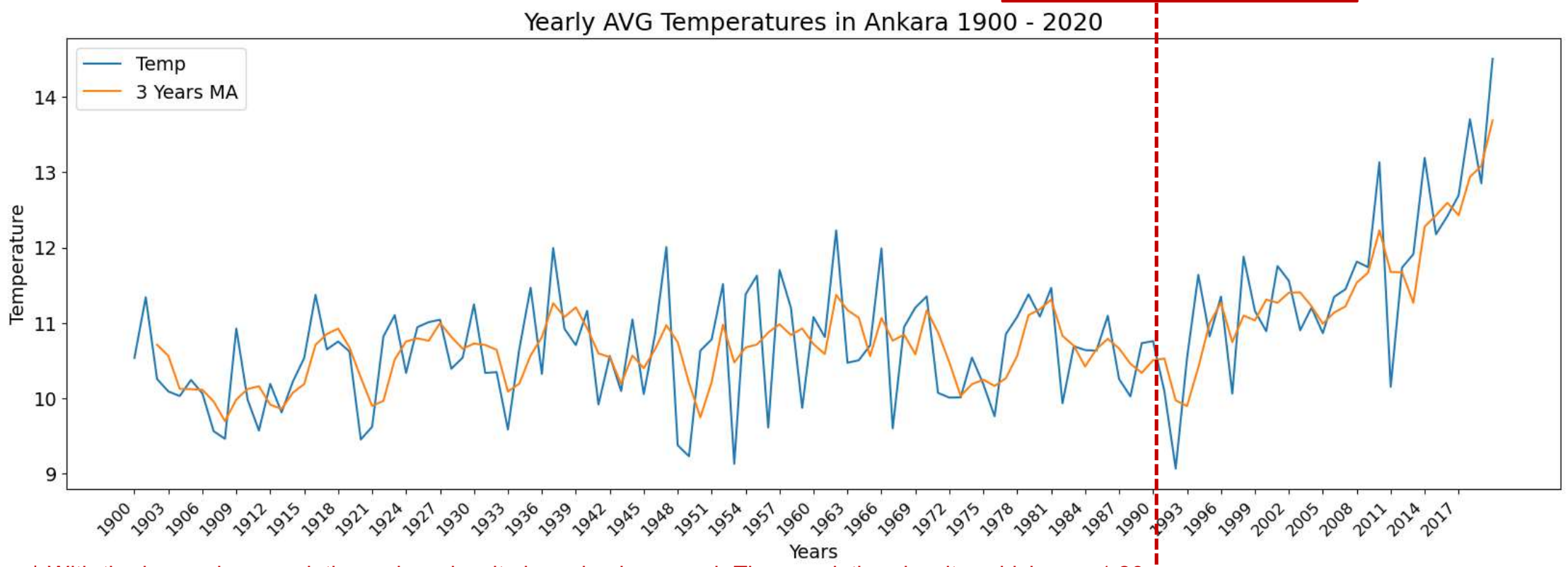


Month	Year_Min	Year_Max	Min_Temperature	Max_Temperature	Temp_Diff(Max-Min)	Mean_Temperature
1	1911	2016	-5.185	6.780	11.965	0.921769
2	1953	2001	-0.443	10.153	10.596	5.114636
3	1949	1989	6.473	14.743	8.270	10.023512
4	1919	2007	11.272	18.305	7.033	14.690149
5	1919	2019	16.329	21.841	5.512	18.631364
6	1982	2020	19.260	25.148	5.888	21.914223
7	1984	2010	18.439	26.044	7.605	21.975521
8	1961	2020	14.309	22.700	8.391	17.731950
9	1951	2020	8.559	17.355	8.796	12.161025
10	1920	1966	1.281	10.798	9.517	6.312066
11	1953	2014	-4.343	5.797	10.140	1.387479
12	1949	1947	-6.195	3.686	9.881	-0.911133

4. Ankara's temperature plots

- Yearly average temperature in years: 1900 – 2020 + 3 -YearAverage

*1990 Significant beginning of population growth and industrial development in Ankara



* With the increasing population, urban density has also increased. The population density, which was 1.26 ha in 1990, became 1.56 ha in 2000 with a 23.80% change. This rate increased by 70.63% in 2018. With the increase in the urban population, the inadequacy of the park areas, which are defined as carbon sinks, in terms of quantity and balanced distribution has emerged.

5. Temperature model settings

I will use the implementation of SARIMA provided by the statsmodels library.

This model has hyperparameters that control the nature of the model performed for the series, trend and seasonality, specifically:

- **order:** A tuple **p, d, and q parameters for the modeling of the trend**.
- **sesonal order:** A tuple of **P, D, Q, and m parameters for the modeling the seasonality trend**:

A parameter for controlling a model of the deterministic trend as one of **'n','c','t','ct' for: 'no trend', 'constant', 'linear', and 'constant with linear trend', respectively.**

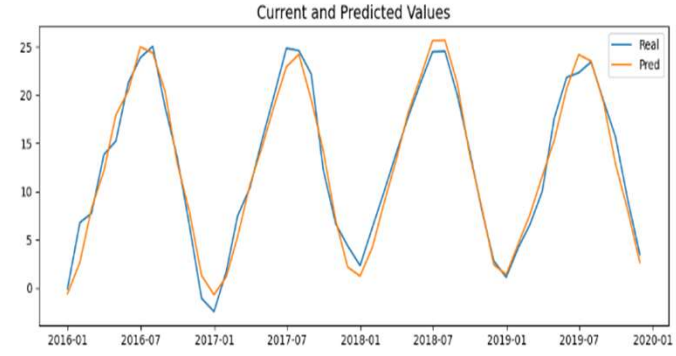
```
# Let's test it in the validation set
val['Pred'] = walk_forward(train['Temp'], val['Temp'], ((1,1,2),(2,1,2,12),'ct'))
```

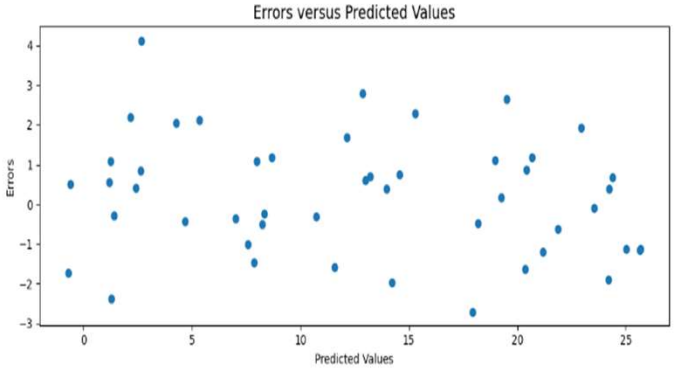
```
# Measuring the error of the prediction
rmse_pred = measure_rmse(val['Temp'], val['Pred'])

print(f"The RMSE of the SARIMA(1,1,2),(2,1,2,12),'ct' model was {round(rmse_pred,4)} celsius degrees")
print(f"It's a decrease of {round((rmse_pred/rmse_base-1)*100,2)}% in the RMSE")
```

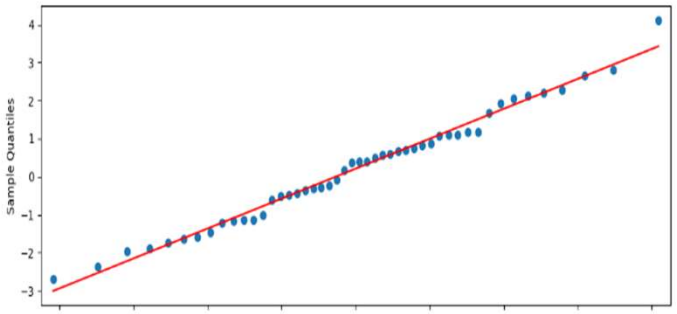
```
The RMSE of the SARIMA(1,1,2),(2,1,2,12),'ct' model was 1.4887 celsius degrees
It's a decrease of -67.66% in the RMSE
```

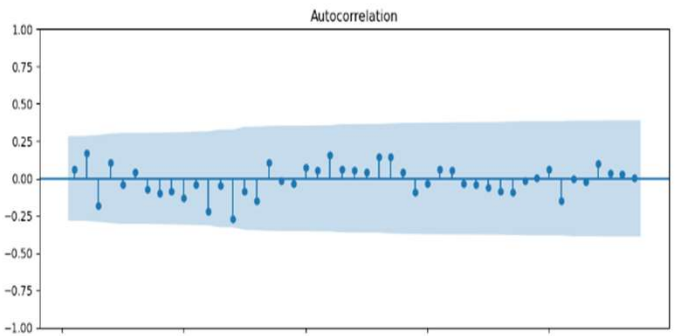
```
# Splitting data in to training validation and test sets.
# After training the model, last 5 years will be used to do the data validation and test,
# being 48 months to do a month by month validation (walk forward) and
# last 12 months to make an extrapolation for the future and compare to the test set:

train = ankara[:-60].copy()  # training set: (12/31/2020 - last 5 years)
val = ankara[-60:-12].copy() # validation set : 48 months
test = ankara[-12:].copy()   # test set : last 12 months
```

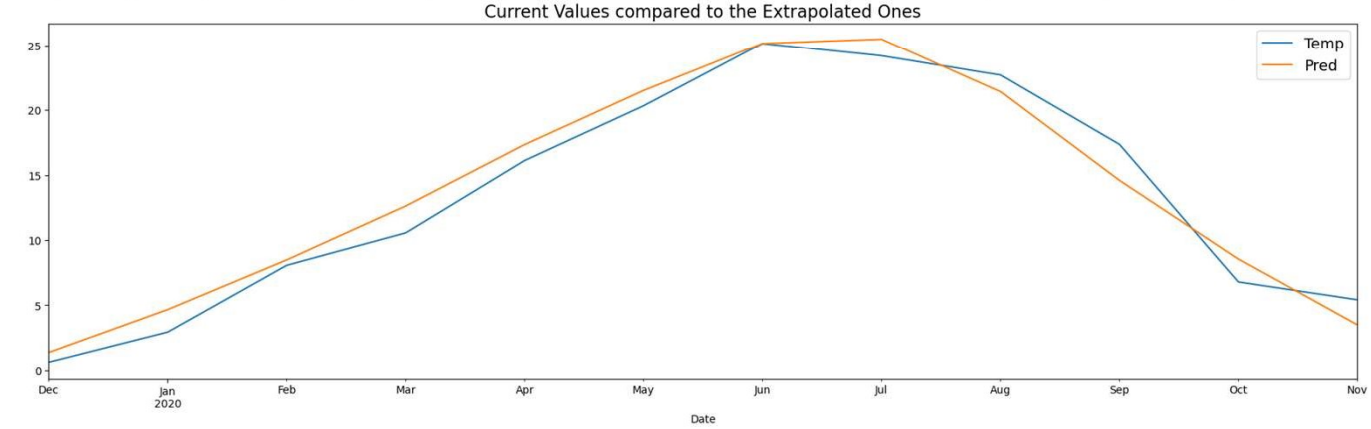
6. Temperature model results and model convergence











Date	Temp	month	year	Pred	Temp_Kelvin	Pred_Kelvin
2019-12-31	0.606	12	2019	1.357487	273.756	274.507487
2020-01-31	2.922	1	2020	4.656290	276.072	277.806290
2020-02-29	8.063	2	2020	8.477330	281.213	281.627330
2020-03-31	10.552	3	2020	12.617443	283.702	285.767443
2020-04-30	16.113	4	2020	17.339491	289.263	290.489491
2020-05-31	20.327	5	2020	21.509296	293.477	294.659296
2020-06-30	25.148	6	2020	25.156807	298.298	298.306807
2020-07-31	24.187	7	2020	25.484348	297.337	298.634348
2020-08-31	22.700	8	2020	21.418079	295.850	294.568079
2020-09-30	17.355	9	2020	14.585668	290.505	287.735668
2020-10-31	6.783	10	2020	8.544031	279.933	281.694031
2020-11-30	5.410	11	2020	3.479051	278.560	276.629051

Date	absolute_err_Kelvin	absolute_err_Kelvin_perc
2019-12-31	0.751487	0.274510
2020-01-31	1.734290	0.628202
2020-02-29	0.414330	0.147337
2020-03-31	2.065443	0.728033
2020-04-30	1.226491	0.424006
2020-05-31	1.182296	0.402858
2020-06-30	0.008807	0.002953
2020-07-31	1.297348	0.436322
2020-08-31	1.281921	0.433301
2020-09-30	2.769332	0.953282
2020-10-31	1.761031	0.629090
2020-11-30	1.930949	0.693190

7. Summary/Conclusions

Ankara is the capital with the highest temperature increase recorded since 2000.

1. Temperature model used SARIMA algorithm for Ankara evaluated in quite good perfomance (absolute error in Kelvins at 0.003% - 0.95%),

2. As my study of the factors influencing the temperature increase in Ankara showed, if it is not implemented in the coming years:
- greenhouse gases emission prevention plan,
- switching to renewable energy sources in energy production, which currently accounts for 27.66% (led by oil, coal and gas: 72.34%),
- afforestation,
- the reduction in beef production,

we will have continous temperature increase effect.
Temperature projections indicate that towards the end of the century, monthly average temperatures in Ankara will increase by 1 to 6°C compared to today (1910-2010 average). The optimistic scenario RCP2.6 indicates a temperature rise of 2°C. The pessimistic scenario, RCP8.5, shows that monthly average temperatures will rise up to 6°C until 2100. All scenarios show a trend towards an increase in temperature,

3. The consequences of rising temperatures will involve changes in flora and fauna, extreme weather phenomena, reduced water content and deterioration of air quality. All these factors will consequently affect the health of people living in Ankara.

8. Data Sources

- Environmental science, data, and analysis of the highest qualityIndependent, non-governmental, and open-source. - Berkeley Earth **(Tempreature source),**
- 10 Best Free Climate & Environment Datasets for ML | Deepchecks (Data sets)
- Search - Our World in Data **(Turkey pollution data),**
- **ANKARA CLIMATE CHANGE ACTION PLAN – pdf Report from 2019** **(Ankara data from 2019),**
- **Kaggle.**

BACK-UP

1. Scientific/business problem statement

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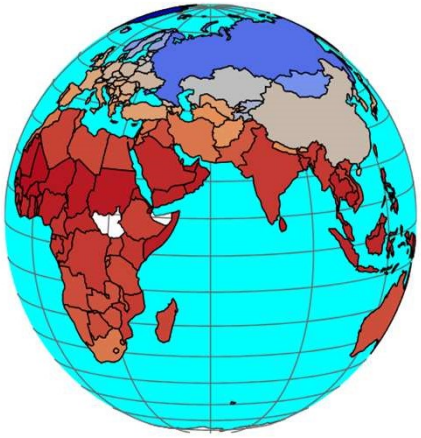

Turkey: 11.445°C

Poland: 7.298°C

+ 0.531°C

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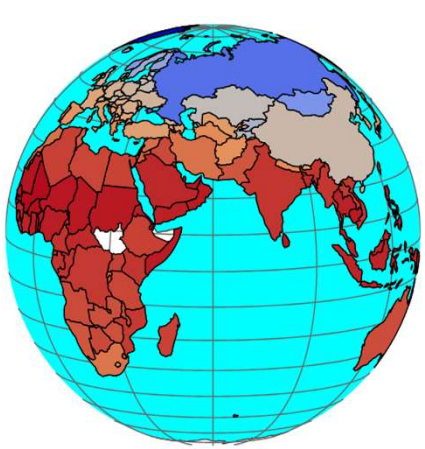

Turkey: 11.976°C

Poland: 7.801°C

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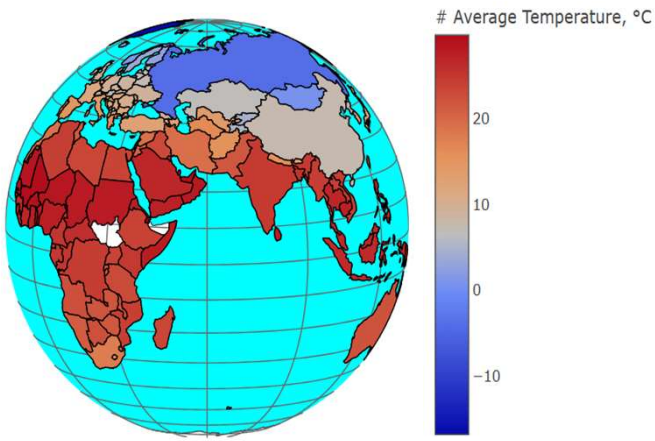
2000 - 2013



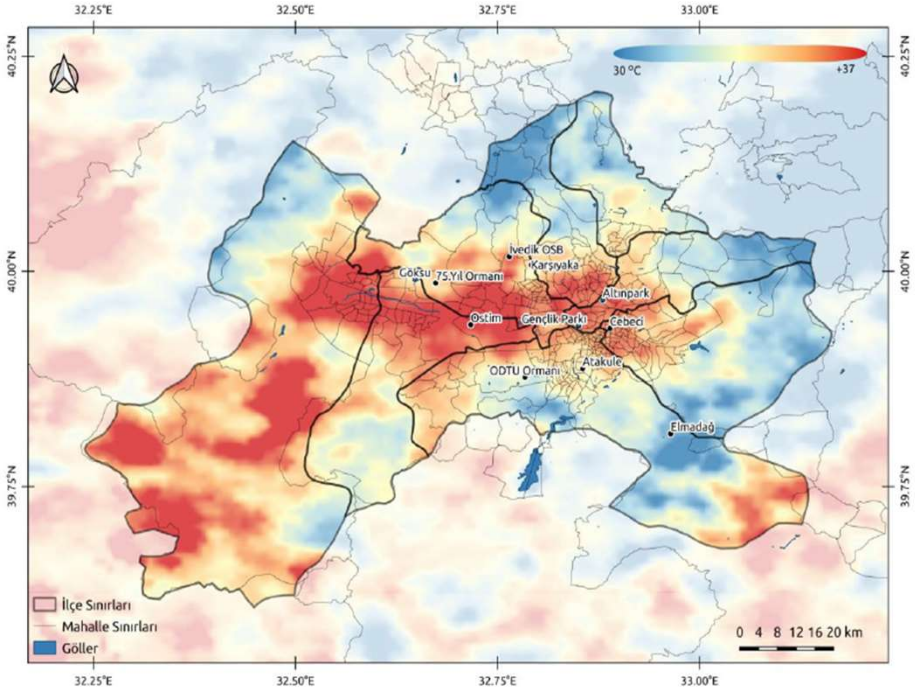
Turkey: 12.735°C

Poland: 8.776°C

Ankara as Urban Heat Island

Urban heat island is defined as the situation where urban centers are warmer than suburban, rural and natural areas as a result of urbanization and land change dynamics. The urban heat island arises due to the scarcity of green areas, the increase in the areas covered by heat retaining materials (eg concrete and asphalt), the congested urban fabric and the inability to ventilate the city, the density of waste heat sources (eg industry, vehicle use and air conditioning systems) in the city, the geographical and microclimatic characteristics of the city. It may vary locally within the city.
As the vegetation density increases, the surface temperature decreases, because it will cause more total evaporation, the energy lost on the vegetated surfaces causes cooling. When the impermeability value increases, the surface temperature increases as the ratio and mass of the covering materials that cause heating and heat preservation increase. **Accordingly, the highest temperature is observed in dense urban residential areas, and the lowest temperature is observed in green areas.**
'Surface Temperature' data is generated by various transformations from the thermal bands of satellite images. In this context, surface temperature (LST) data obtained from MODIS-TERRA satellites were used in the creation of heat maps. Current trends and scenarios regarding climate change indicate that temperatures in Ankara will increase further in the future.

Urban heat island observed in June in Ankara for the years 2019 and 2020.



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