Forecasting Greenhouse gases emission from global agricultural land

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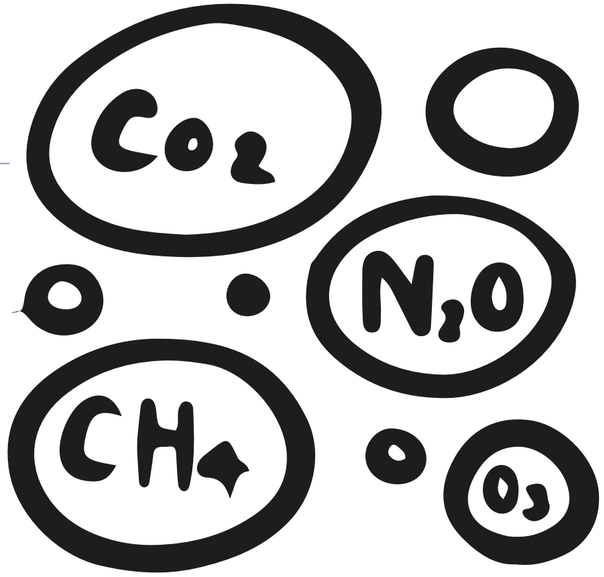
Greenhouse gases



Greenhouse gases (**also known as GHGs**) are gases in the earth's atmosphere that trap heat. During the day, the sun shines through the atmosphere, warming the earth's surface. At night the earth's surface cools, releasing heat back into the air. But some of the heat is trapped by the greenhouse gases in the atmosphere.

Greenhouse gases

The gases act like the glass walls of a greenhouse – hence the name, greenhouse gases. Without this greenhouse effect, temperatures would drop to as low as -18˚C (-0.4˚F); too cold to sustain life on earth.

Problem

Greenhouse gas emissions are a critical environmental issue due to their profound impact on the Earth's climate system.

1. Climate Change and Global Warming
2. Rising Sea Levels
3. Impact on Ecosystems and Biodiversity
4. Human Health
5. Economic Consequences

Problem

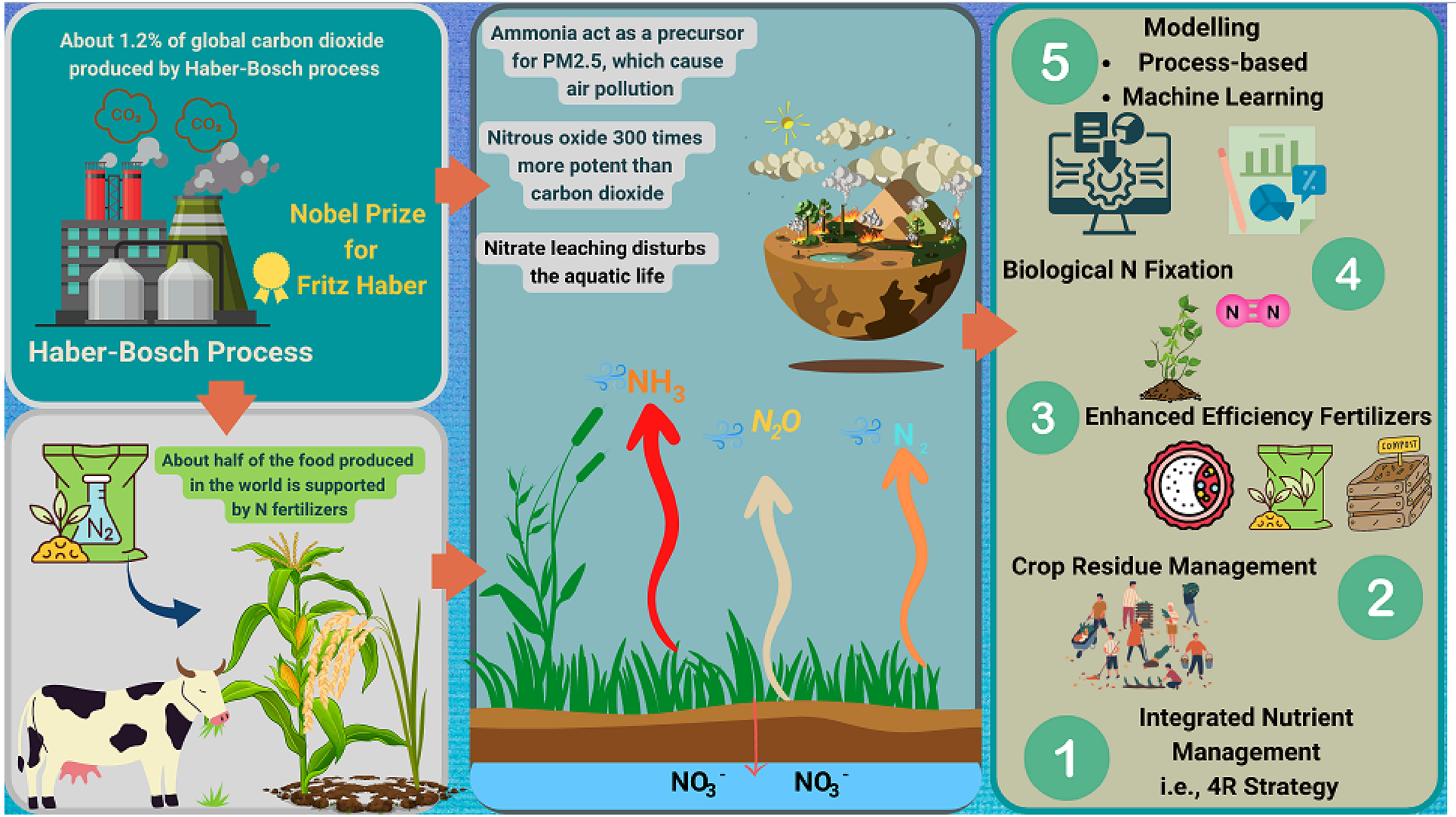
GHGs emission forecast from agricultural soils on a small scale is a big issue these days.

1. Methane Emissions from Livestock
2. Nitrous Oxide Emissions from Fertilizers
3. Deforestation for Agricultural Expansion
4. Rice Paddy Methane Emissions
5. Carbon Dioxide Emissions from Soil Management

Solutions to reduce GHGs emissions from Agriculture

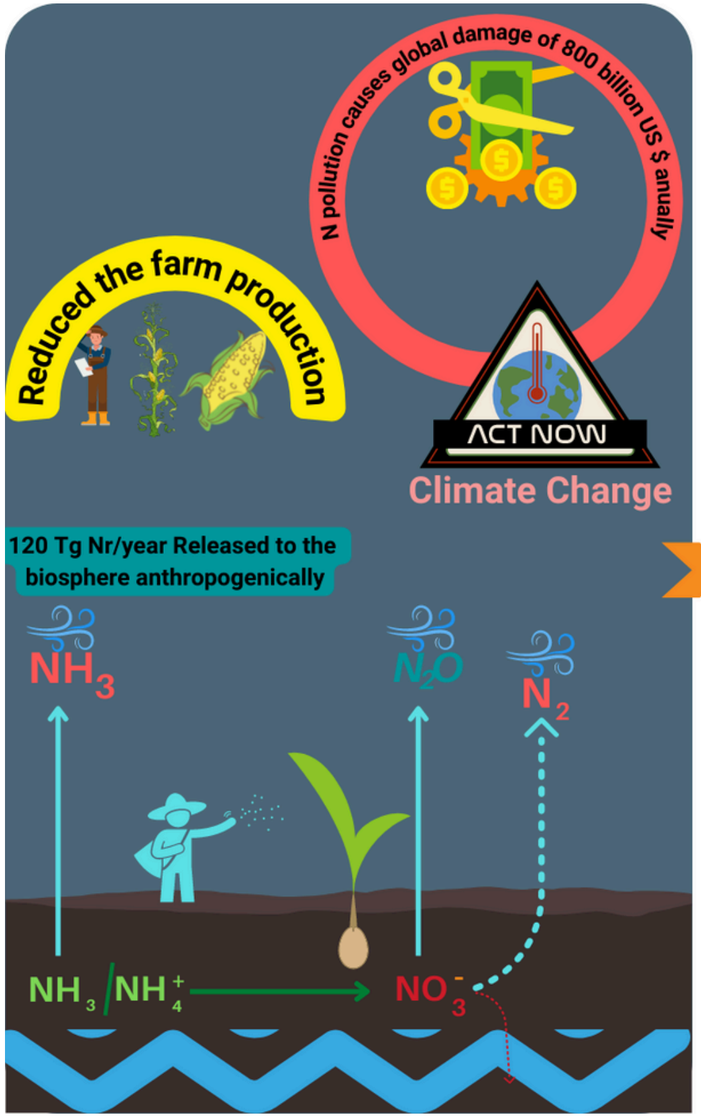
Category	Solutions	Roles of Forecasting GHG Emissions
Livestock Management	- **Diet Optimization:** Adjusting livestock diets to reduce methane emissions - **Manure Management:** Capturing methane from manure	- **Policy and Decision Making:** Inform policies and regulations - **Resource Allocation:** Target mitigation efforts effectively
Fertilizer Use	- **Precision Agriculture:** Efficient fertilizer application - **Nitrification Inhibitors:** Slowing ammonia to nitrate conversion	- **Monitoring and Reporting:** Track progress towards climate goals - **Adapting to Climate Change:** Implement resilient agricultural practices
Agroforestry and Reforestation	- **Agroforestry:** Integrating trees into farming systems - **Reforestation:** Planting trees on degraded agricultural land	- **Resource Allocation:** Better resource management - **Research and Development:** Drive advancements in emission reduction technologies
Rice Production	- **Alternate Wetting and Drying (AWD):** Reducing methane in rice paddies - **Improved Rice Varieties:** Low methane-producing rice	- **Policy and Decision Making:** Develop informed agricultural policies - **Monitoring and Reporting:** Ensure transparent reporting
Soil Management	- **No-Till and Reduced-Till Farming:** Maintain soil structure - **Cover Cropping:** Improve soil health and carbon sequestration	- **Adapting to Climate Change:** Prepare for climate impacts - **Research and Development:** Identify areas for scientific advancements

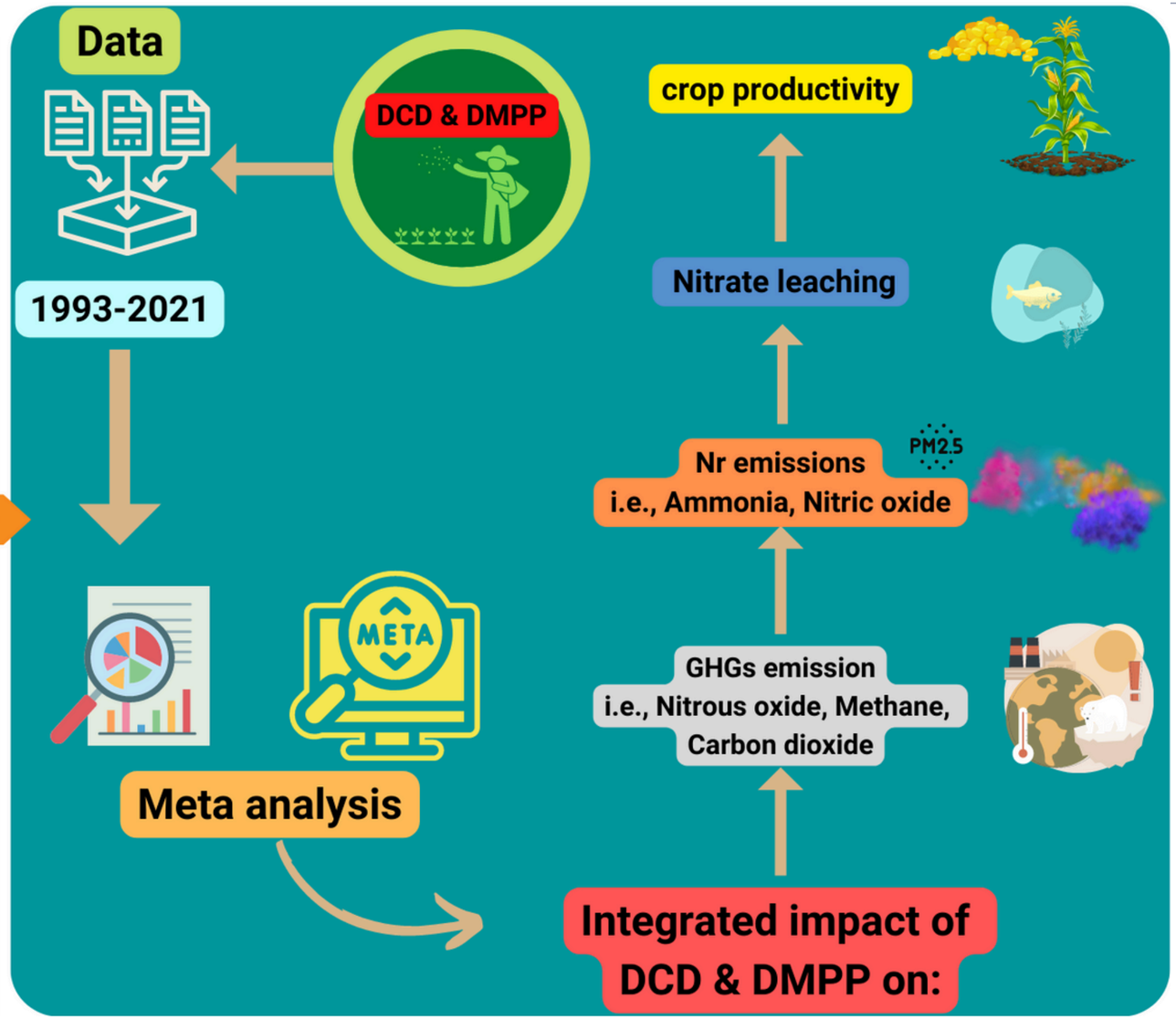
Agricultural Emissions from N-fertilizers



Tufail et al. 2024 https://doi.org/10.1080/00380768.2024.2361068

Agricultural Emissions





Tufail et al. 2023 https://doi.org/10.1007/s11356-023-26318-5

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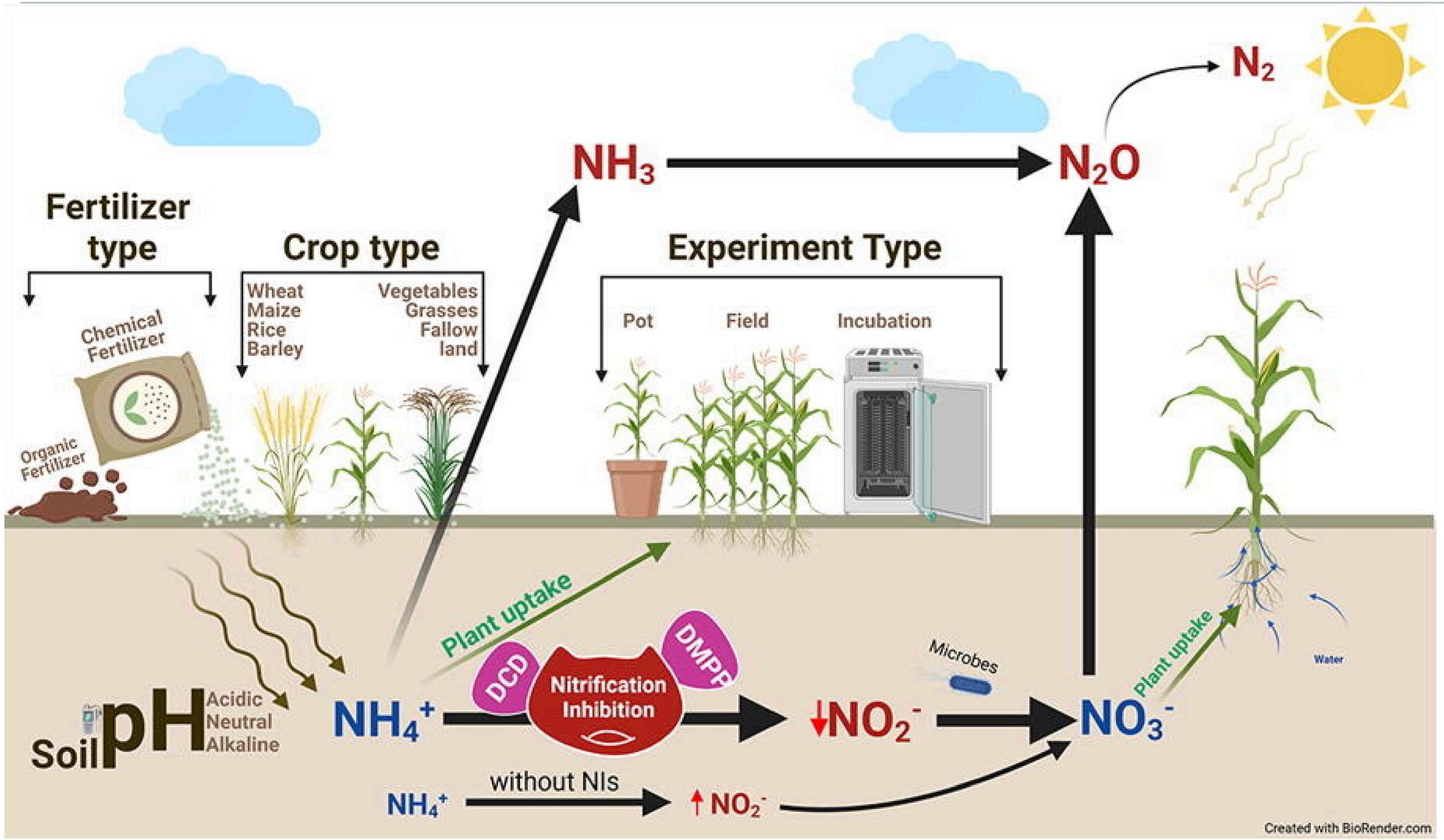

Tufail et al. 2022 https://doi.org/10.1016/j.fuel.2022.124725

Objectives

1. **Data Analysis and Trends Identification:**
    - **Objective:** To analyze historical data on GHG emissions from agricultural lands provided by FAOstats to identify key trends, patterns, and factors influencing these emissions over the past decades. This analysis will serve as the foundation for understanding the current state of emissions and the drivers behind them.

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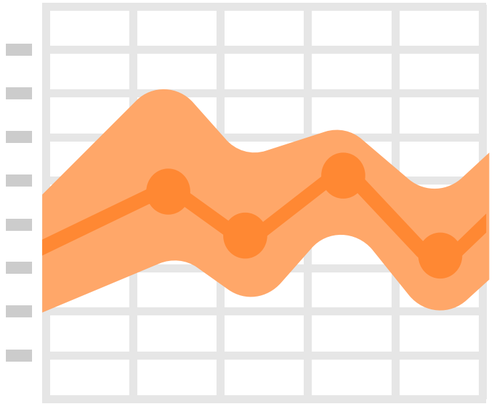
2. **Time Series Model Development and Forecasting:**
    - **Objective:** To develop and implement a robust time series model that accurately predicts future GHG emissions from agricultural lands over the next 10 years. The model will be validated and tested to ensure its reliability and will incorporate variables identified as significant in the trend analysis.



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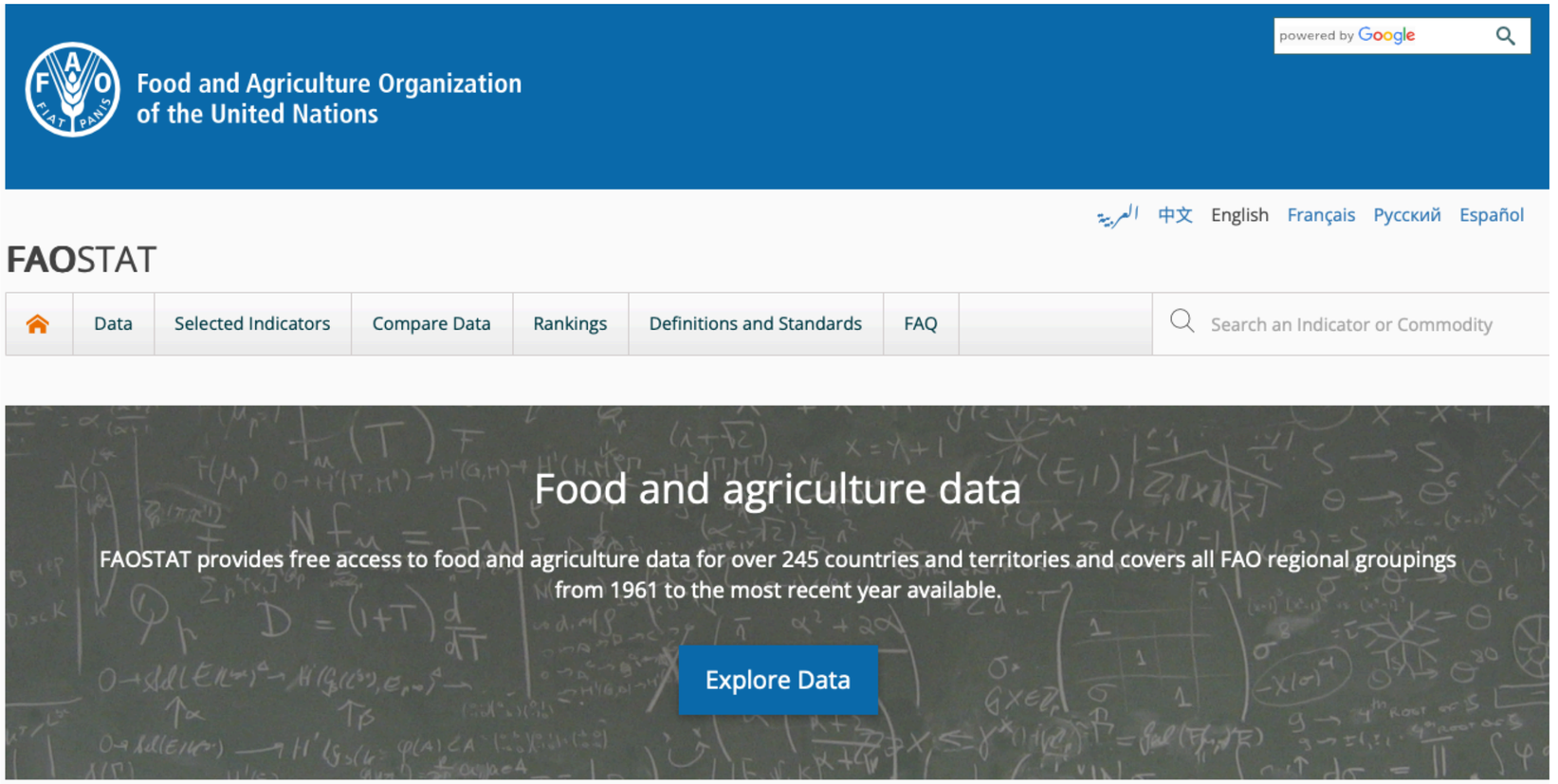
Data Acquisition

Data was collected from FAOstats

https://www.fao.org/faostat/en/#home



Data Acquisition

Data

DOMAINS | DOMAINS TABLE

- Production
- Food Security and Nutrition — SDG indicators
- Food Balances
- Trade
- Prices
- Cost and Affordability of a Healthy Diet
- Food and Diet
- Land, Inputs and Sustainability
- Population and Employment
- Investment — SDG indicator
- Macro-Economic Indicators
- Food Value Chain
- Climate Change: Agrifood systems emissions
- Forestry
- SDG Indicators
- World Census of Agriculture
- Discontinued archives and data series

- Climate Change: Agrifood systems emissions
  - Totals and Indicators
  - Farm gate
  - Land use and change
  - Pre and post agricultural production

Data Cleaning

	Domain Code	Domain	Area Code (M49)	Area	Element Code	Element	Item Code	Item	Year Code	Year	Source Code	Source	Unit	Value	Flag	Flag Description	Note
0	GT	Emissions totals	4	Afghanistan	7225	Emissions (CH4)	6995	Emissions on agricultural land	1990	1990	3050	FAO TIER 1	kt	214.4467	E	Estimated value	NaN
1	GT	Emissions totals	4	Afghanistan	7225	Emissions (CH4)	6995	Emissions on agricultural land	1991	1991	3050	FAO TIER 1	kt	224.1393	E	Estimated value	NaN
2	GT	Emissions totals	4	Afghanistan	7225	Emissions (CH4)	6995	Emissions on agricultural land	1992	1992	3050	FAO TIER 1	kt	226.7224	E	Estimated value	NaN
3	GT	Emissions totals	4	Afghanistan	7225	Emissions (CH4)	6995	Emissions on agricultural land	1993	1993	3050	FAO TIER 1	kt	228.5003	E	Estimated value	NaN
4	GT	Emissions totals	4	Afghanistan	7225	Emissions (CH4)	6995	Emissions on agricultural land	1994	1994	3050	FAO TIER 1	kt	236.9822	E	Estimated value	NaN

	Area	Element	Year	Value
0	Afghanistan	Emissions (CH4)	1990	214.4467
1	Afghanistan	Emissions (CH4)	1991	224.1393
2	Afghanistan	Emissions (CH4)	1992	226.7224
3	Afghanistan	Emissions (CH4)	1993	228.5003
4	Afghanistan	Emissions (CH4)	1994	236.9822

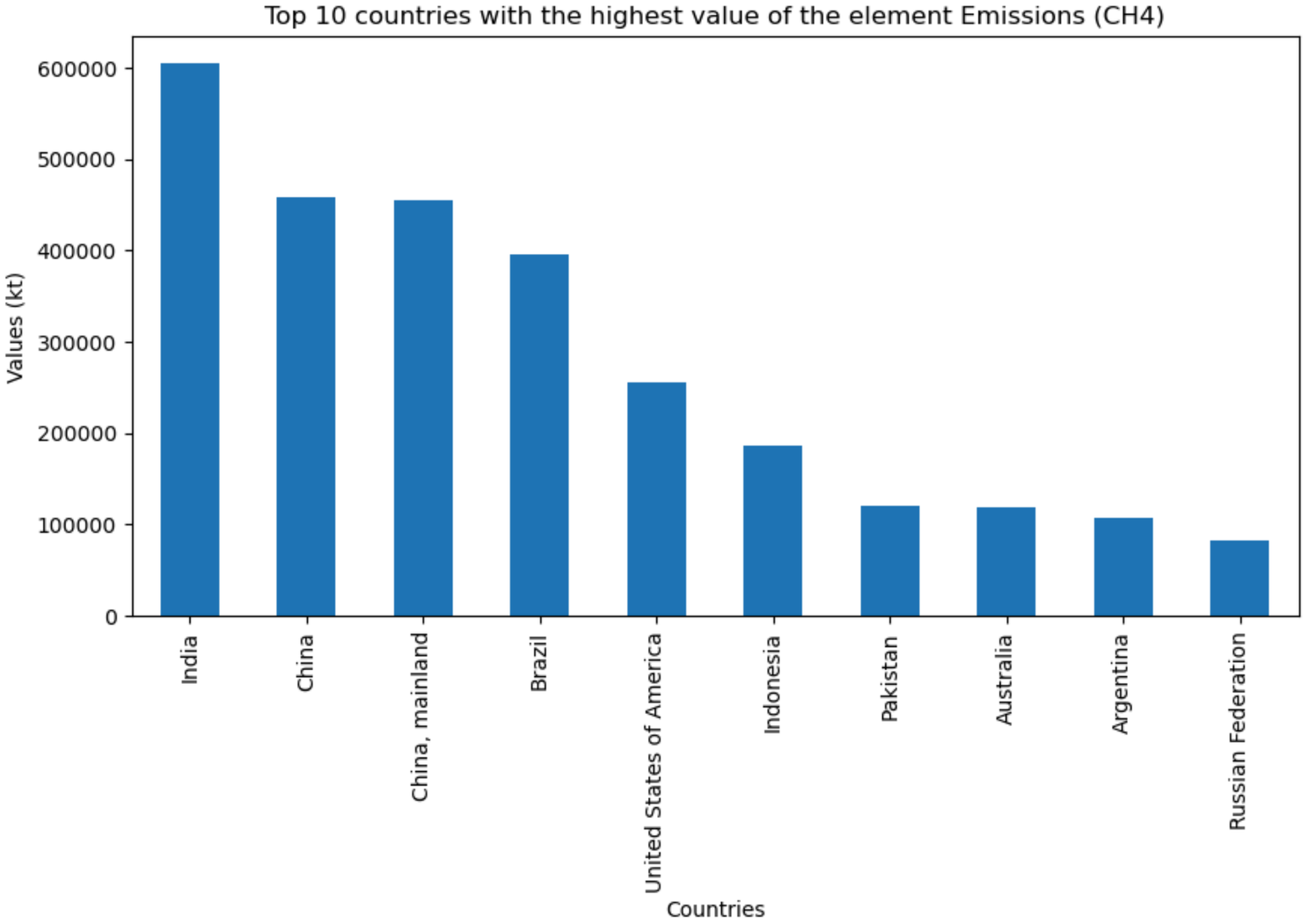
Models

Following models were used:

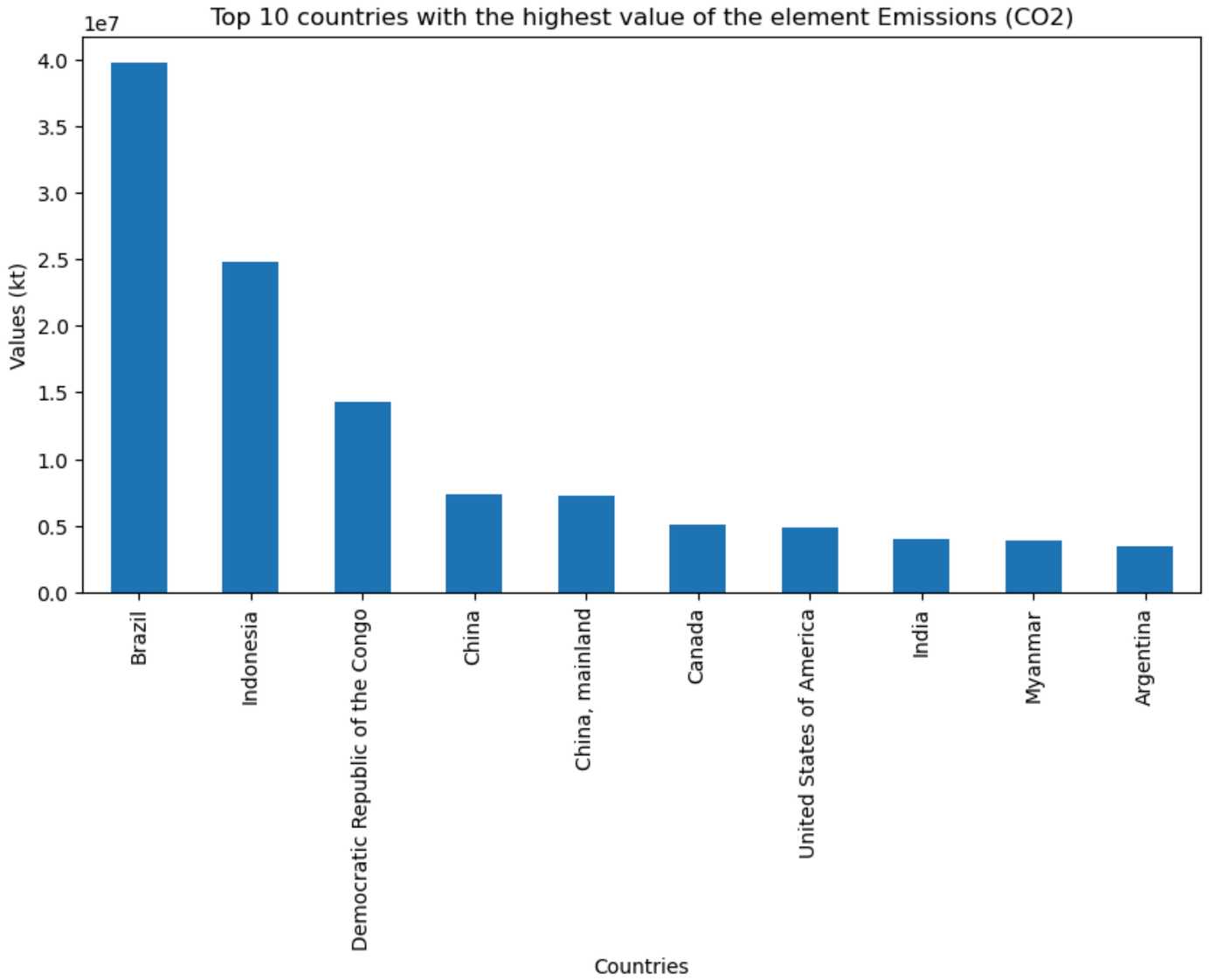
1. **ARIMA**
2. **SARIMA and SARIMAX**
3. **Random Forest**
4. **XGBoost**
5. **LSTM**
6. **GRU**
7. **Prophet**

Notebook time

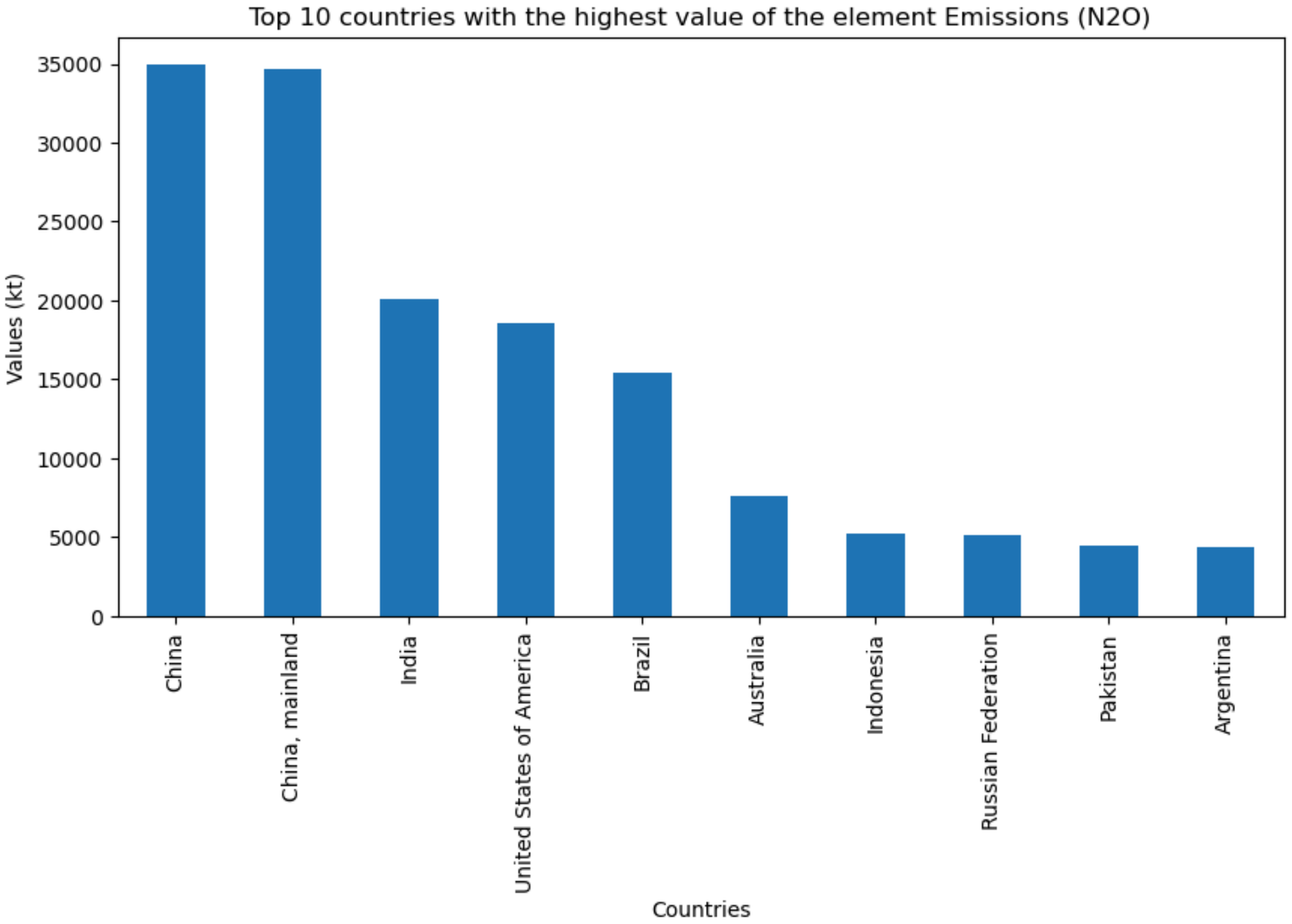
Trends


Top 10 countries with the highest value of the element Emissions (CH4)
Values (kt)
600000
500000
400000
300000
200000
100000
0
India
China
China, mainland
Brazil
United States of America
Indonesia
Pakistan
Australia
Argentina
Russian Federation
Countries

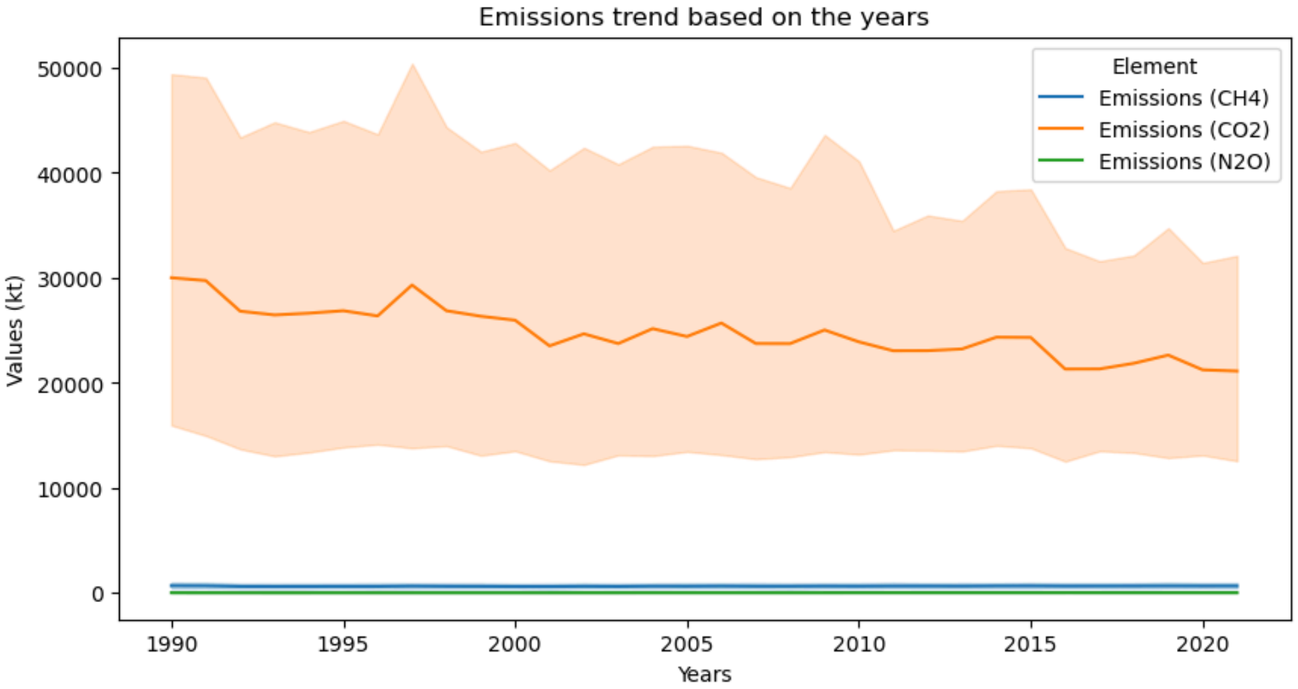
Trends

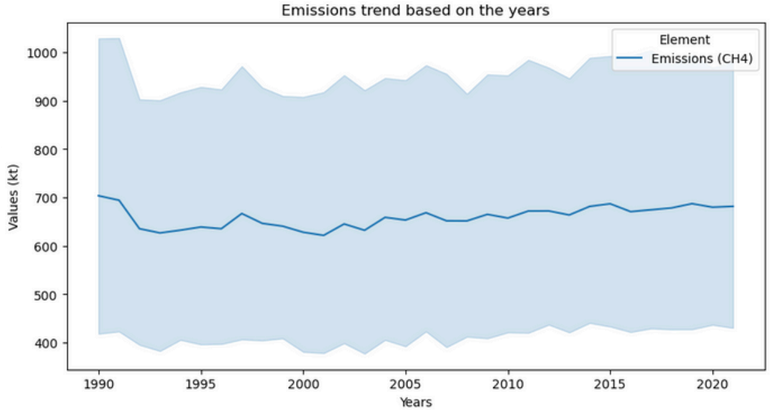

Top 10 countries with the highest value of the element Emissions (CO2)
1e7
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Values (kt)
Brazil
Indonesia
Democratic Republic of the Congo
China
China, mainland
Canada
United States of America
India
Myanmar
Argentina
Countries

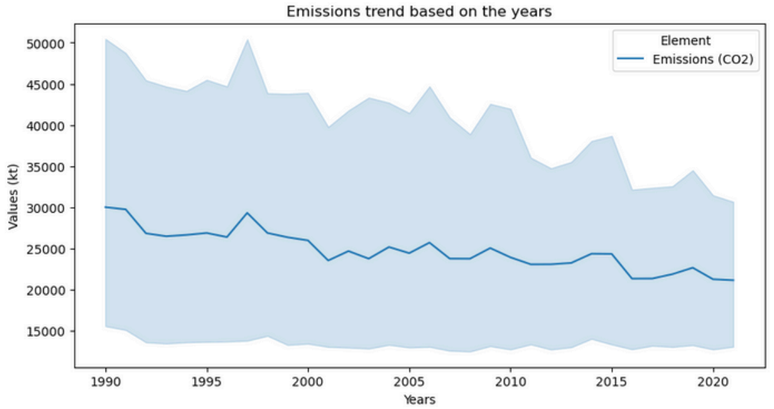
Trends

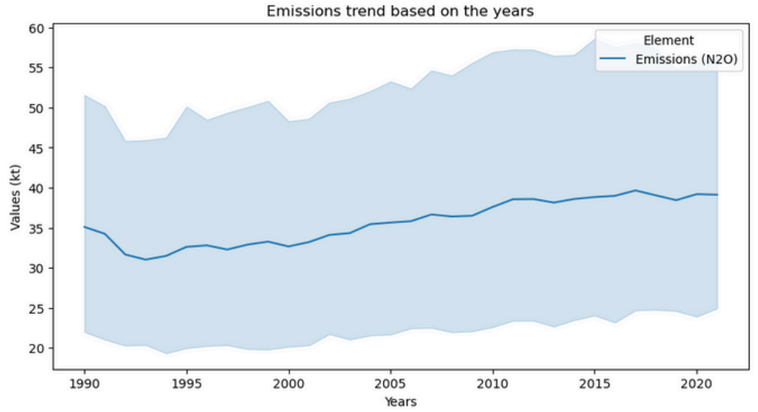

Top 10 countries with the highest value of the element Emissions (N2O)
Values (kt)
35000
30000
25000
20000
15000
10000
5000
0
China
China, mainland
India
United States of America
Brazil
Australia
Indonesia
Russian Federation
Pakistan
Argentina
Countries

Trends

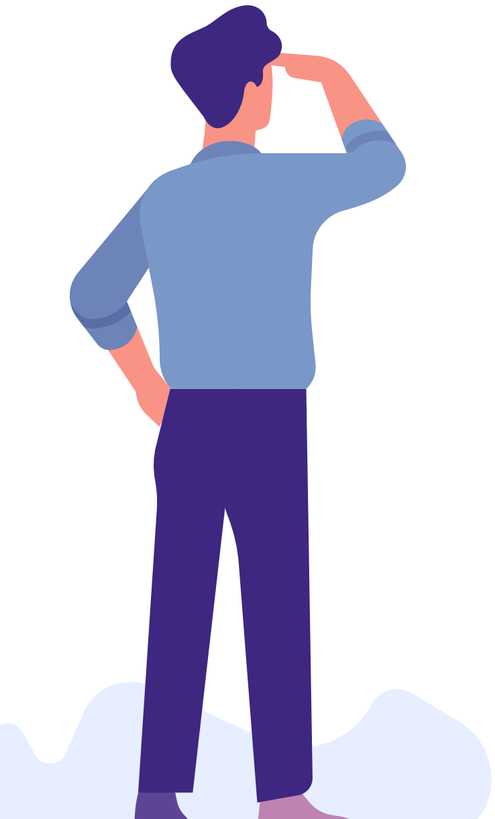

Emissions trend based on the years
Element
Emissions (CH4)
Emissions (CO2)
Emissions (N2O)
Values (kt)
Years
50000
40000
30000
20000
10000
0
1990
1995
2000
2005
2010
2015
2020


Emissions trend based on the years
Element
Emissions (CH4)
Values (kt)
Years
1000
900
800
700
600
500
400
1990
1995
2000
2005
2010
2015
2020


Emissions trend based on the years
Element
Emissions (CO2)
Values (kt)
Years
50000
45000
40000
35000
30000
25000
20000
15000
1990
1995
2000
2005
2010
2015
2020


Emissions trend based on the years
Element
Emissions (N2O)
Values (kt)
Years
60
55
50
45
40
35
30
25
20
1990
1995
2000
2005
2010
2015
2020

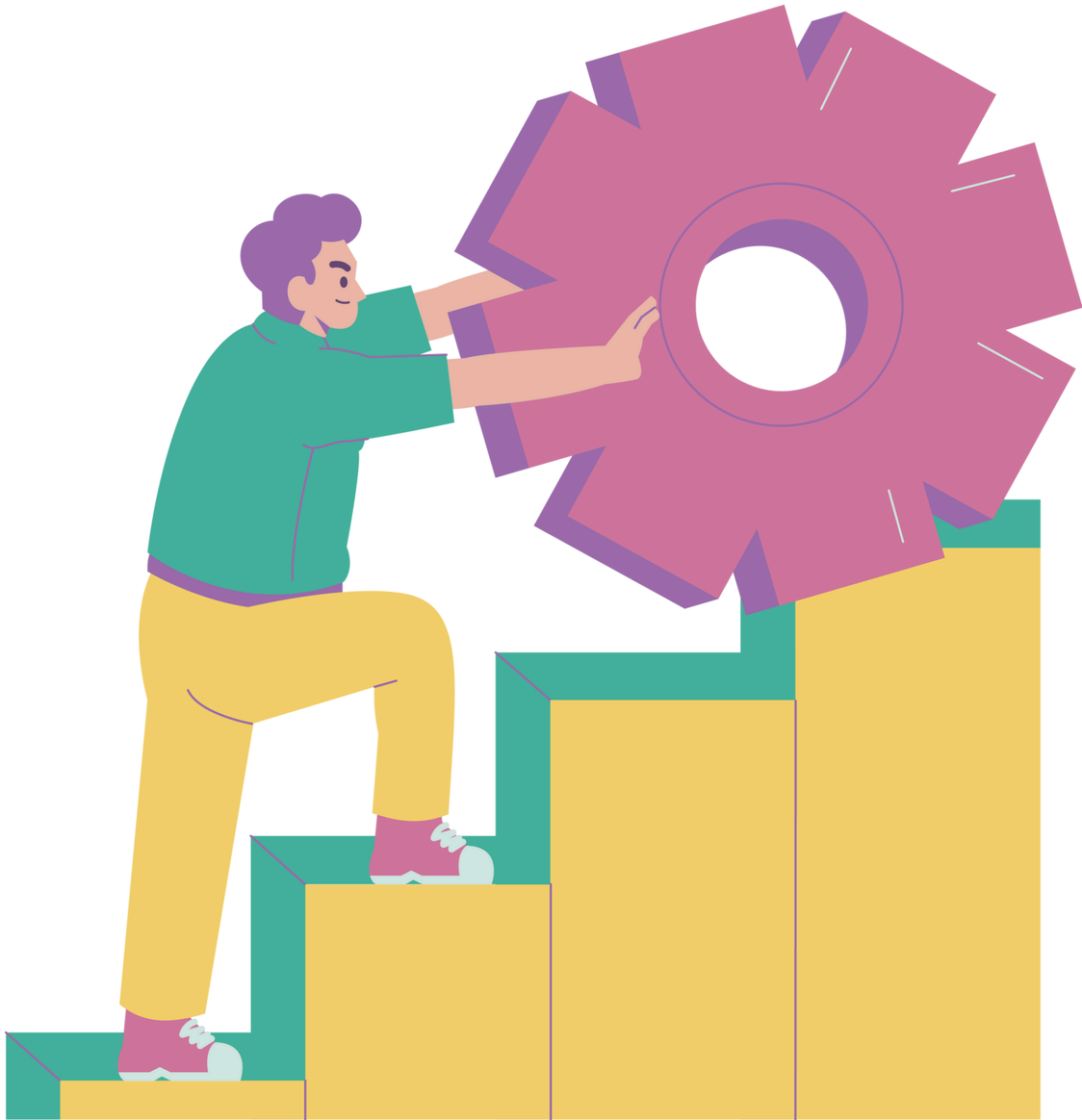
Next plan is to use multivariate data



1. **Pre-process multivariate data from multiple sources, concatenate and train compare multiple models.**
2. **Train a model to predict GHGs from Agricultural Land.**
3. **Write Policy Recommendation and mitigation strategies by comparing Developed vs. Developing Countries.**
4. **Finalize Manuscript.**

Challenges I encountered

1. I have multivariate data based on process based model but did not have enough time to work with.
2. Running transformers is not an easy task due to computational capacity of my PC.
3. Need more time for hyperparameter tuning.




Q
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