ST. TERESA'S COLLEGE (AUTONOMOUS), ERNAKULAM
AFFILIATED TO MAHATMA GANDHI UNIVERSITY

THE IMPACT OF CLIMATE CHANGE ON AGRICLUTURE

PROJECT REPORT

In partial fulfillment of the requirements for the award of the degree of

BACHELOR OF SCIENCE IN
COMPUTER APPLICATIONS [TRIPLE MAIN]

Submitted By
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CERTIFICATE

This is to certify that the project entitled

" THE IMPACT OF CLIMATE CHANGE ON AGRICLUTURE",

is a bonafide record of the work done by ANNMARIYA P A during the year 2023-24 and submitted in partial fulfillment of the requirements of the degree of Bachelor of Science in Computer Applications (Triple Main) under Mahatma Gandhi University.

Head of the Department

Internal Examiner

External Examiner

Date :- 21-03-2024

DECLARATION

I , ANNMARIYA P A , BSc Computer Application[Triple Main] final year student of St.Teresa's College (Autonomous),Ernakulam, Register no: SB21CA008 , hereby declare that the dissertation submitted for Bachelor's Degree in Computer Application is my original work. I further declare that the said work has not previously been submitted to any other university or academic body.

Date 21-03-2024

Place:- Ernakulam

Annmariya

ANNMARIYA P A

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ANNMARIYA P A

ABSTRACT

This research investigates the dynamics of paddy production in Kerala throughout the Autumn, Winter, and Summer seasons over the period 2011 to 2023. The study includes an examination of crop cultivation areas and distinguishes between wet and dry land production practices. Employing descriptive statistics methods, the research analyzes seasonal variations in paddy output, aiming to discern patterns and trends. Additionally, a thorough literature review has been conducted to incorporate existing research findings into the analysis. This integrated approach, combining empirical data with insights from prior studies, contributes to a comprehensive understanding of the factors influencing paddy production in Kerala. The findings offer valuable insights for agricultural policy formulation and sustainable farming practices in the region.

CONTENTS

1. INTRODUCTION

1.1 ABOUT PROJECT

Paddy cultivation in Kerala stands at the intersection of cultural heritage, economic sustenance, and agricultural diversity. This study delves into the intricacies of paddy production in the state, examining data spanning the Autumn, Winter, and Summer seasons from 2011 to 2023. Leveraging comprehensive datasets sourced from ECOSTAT, Government of Kerala, our analysis not only differentiates between wet and dry land production but also employs a robust set of descriptive statistics methods, including Measures of Central Tendency, Partition Values, Measures of Dispersion, Graphical Representation, Moments and Skewness, Regression, and Kurtosis and implementing python and incorporating insights from a literature review, this research aims to unravel the seasonal variations in paddy output, contributing valuable knowledge to the realms of agriculture and policy-making in Kerala

1.2 ABOUT ORGANIZATION

The Congregation of the Carmelite Sisters of St. Teresa founded St. Teresa's College, a pioneering institution in the field of higher education in India, on June 15, 1925. It was the first women's college in the former Cochin State and the second in all of Kerala. To prepare young women for the challenges in the IT industry, the Department of Computer Applications was founded in 1995 and provides a variety of computer application courses. Via seminars, lectures, project work, assignments, and ICT enabled teaching, we advocate for a student-centered teaching method. Also, periodically hold lectures on new hardware and software technologies and career orientation.

1.3 OBJECTIVE OF PROJECT

This study aims to assess the influence of climate conditions on paddy production in Kerala from 2011 to 2022. It involves analyzing production rates in each district, considering cultivation areas. The primary focus is to establish a correlation between climate change and its impact on paddy cultivation, unraveling patterns and trends over the specified period. The findings aim to provide insights into the dynamic relationship between climate variations and paddy production, offering valuable information for adapting agricultural practices in response to changing climatic conditions in Kerala

3. LITERATURE REVIEW

The study conducted by Aswathi K.P on August 31, 2022, in the Agricultural Meteorology department reveals that under projected climate change scenarios in the central zone of Kerala, increasing temperatures during critical growth phases negatively impact rice yield. The experiment employed a completely randomized design with five different planting dates for the rice variety. Results indicate a continuous decrease in rice yield over time, attributed to rapid biomass accumulation and yield loss caused by elevated temperatures during crucial growth periods.

In 2020, Brigit Joseph from the Department of Agricultural Statistics, along with Gokul Krishna, developed a statistical model to assess climate change in northern and central Kerala. They employed a combination of statistical models and data collection methods to analyze climate change trends over time. The study revealed a significant impact on paddy production in various regions, emphasizing the importance of their statistical approach in understanding and addressing the effects of climate change on agriculture.

The paper by E.J. James and Celine George, presented at the International Conference on Innovative Trends in Engineering for Sustainability on January 25, 2023, provides a comprehensive review of water-related impacts on agriculture in Kerala due to climate change. The review critically examines scientific studies, highlighting changing climate patterns in Kerala, such as decreased rainfall and increased temperatures. The paper underscores the significant adverse effects of these climate changes on the region's economy and agriculture sector.

The study, led by N. Karunakaran, Head of the PG Department of Economics in Kerala, focused on trends, determinants, and the impact of paddy cultivation on food security. Using secondary data analysis and compound growth rates, the researchers gathered information from various publications of the Kerala government. The findings indicated negative overall trends in the compound growth rates of rice cultivation, including area, production, and productivity. The study also highlighted the concern of climate change impacting agriculture and food security in the region.

Prasada Rao and C.S Gopakumar conducted a study on the impact of climate change on food and plantation crops in the humid tropics of India, particularly in Kerala. Using trend analysis, the study examined long-term changes in temperature and rainfall. The findings underscored that climate change poses significant challenges to agricultural productivity and food security on a global scale.

The study led by A. P Ramaraj and L. Gurusamy on the impact of climate change in the Cauvery basin of Tamil Nadu Agricultural University, conducted on 10-8-2011, focused on assessing and developing adaptation strategies to sustain rice production. The study emphasized that climate change poses a significant threat to agriculture, water resources, and food security, particularly in developing countries.

The study led by J.C Dagar and A. Arunachalum in 2012 explored the impact of climate change on Indian agriculture, focusing on natural resource management, crop diversification, and water management. The findings indicated that climate change poses a threat to food security and livelihoods in India.

The 2001 study led by K. S Kavi Kumar and Jyoti Parikh from Madras School of Economics examined the socio-economic impacts of climate change on Indian agriculture. The study highlighted the importance of finding the right balance between input costs, output prices, and the effects of climate on production. The conclusion emphasized that the impact of climate change on the Wheat crop in India would depend on the specific research findings, emphasizing the need for tailored approaches to address the challenges posed by climate change in agriculture.

The study conducted on 2-9-2011 by Maximilian Auffhammer investigated the impact of climate change on the monsoon and rice yield in India. Using regression methods and data analysis in the Department of Agricultural and Resource Economics, the conclusion of the study suggested that climate change has a significant impact on the kharif rice harvest in the nine states studied.

The study conducted on 30-6-2021 by TK Kunhamu explored ecological and historical perspectives of rice cultivation in Kerala. Affiliated with the Kerala Agricultural University's College of Forestry, the study proposed a methodology for rice cultivation in Kerala, considering challenges such as intensification and abandonment of paddy lands. The research highlighted the impact of global climate change on the rice cultivation system in Kerala, emphasizing the need for a thoughtful approach to address these challenges.

4. METHODOLOGY

In this study, we utilize descriptive statistics methods to analyze secondary data obtained from the Final Estimate of Area and Production of autumn, summer, and winter paddy (2011-2023) based on EARAS

4.1 Data Collection :

The data for paddy cultivation in Kerala spanning the years 2011 to 2023 has been derived from the Final Estimate of Area and Production reports based on the EARAS scheme. Published on October 4, 2023, for summer paddy, September 7, 2023, for winter paddy, and March 25, 2023, for autumn paddy, these reports provide a comprehensive overview of the cultivation schemes and production estimates during this period. The information has been sourced from the Kerala State Economics And Statistics Department, specifically from the ECOSTAT division under the Government of Kerala. The timely and systematic publication of these estimates plays a crucial role in informing agricultural policies and practices in the region, facilitating data-driven decision-making for sustainable paddy cultivation in Kerala.

4.2 Methods Used:

In this analysis of paddy production in Kerala, we employ various descriptive statistics methods, implemented using Python, to gain insights into the dataset spanning from 2011 to 2023. The methodology encompasses Measures of Central Tendency, such as mean and median, providing a sense of the data's central values. Partition Values assist in identifying key data points, while Measures of Dispersion, including range and standard deviation, reveal the extent of variability. Graphical Representation, facilitated through Python's visualization libraries, aids in visualizing trends and patterns. Moments and Skewness offer insights into the distribution shape, and Regression is employed to understand relationships between variables. Additionally, Kurtosis is utilized to examine the data's tail behavior. This comprehensive suite of descriptive statistics, implemented using Python, enhances the precision and depth of our analysis, providing a nuanced understanding of paddy production dynamics in Kerala.

4.2.1 Measures of Central Tendency:

In this Python script, we are performing basic descriptive statistics on a sample dataset representing paddy production. First, we import the NumPy library, a powerful tool for numerical operations and array manipulations in Python. Next, we define a sample dataset named paddy_production containing production values for a set of time periods. We then use NumPy functions to calculate the mean, median, and mode of the production values.

1. **Mean Production (mean_production):**
   The mean is calculated using np.mean(), providing the average produc on value over the en re dataset. In this case, it is the sum of all values divided by the total number of values.
2. **Median Production (median_production):**
   The median, calculated using np.median(), represents the middle value of the dataset when arranged in ascending order. If the dataset has an even number of elements, the median is the average of the two middle values.
3. **Mode Production (mode_production):**
   The mode, calculated using np.argmax(np.bincount()), identifies the most frequently occurring value in the dataset. This function relies on the bincount method to count occurrences of each unique value, and argmax finds the index of the maximum count, which corresponds to the mode.

The script then prints out the results, displaying the mean, median, and mode of the sample paddy production dataset. This simple analysis provides key insights into the central tendency of the data, helping understand typical production levels and identify any prevalent values.

4.2.2 Par on Values :

This Python script utilizes the NumPy library to calculate quartiles for a sample dataset representing paddy production. Quartiles divide a dataset into four equal parts, providing insights into the distribution of values.

•Q1 (25th Percentile): This is the value below which 25% of the data falls. Calculated using np.percentile(paddy_production, 25), it represents the first quartile or the lower boundary of the dataset's central 50% .

- Q2 Median (50th Percentile): This is the middle value of the dataset. Calculated using np.percentile(paddy_production, 50), it divides the dataset into two equal halves, representing the second quartile.
- Q3 (75th Percentile): This is the value below which 75% of the data falls. Calculated using np.percentile(paddy_production, 75), it represents the third quartile or the upper boundary of the central 50% of the dataset. The script then outputs these quartile values, providing a succinct summary of the distribution of paddy production data. These quartiles offer valuable insights into the spread and central tendencies of the dataset, aiding in a more nuanced understanding of the production levels.

4.3 Measures of Dispersion:

This Python script uses the NumPy library to calculate measures of dispersion for paddy production data across multiple years. The sample dataset includes production values for each year from 2011 to 2023. The function calculate_dispersion computes the range, variance, standard deviation, and coefficient of variation for each year's production data.

- Range (r): The difference between the maximum and minimum values in the dataset, providing a measure of the data's spread.
- Variance (v): The average of the squared differences from the mean, showcasing the extent of individual data points' deviation from the average.
- Standard Deviation (sd): The square root of the variance, offering a more interpretable measure of the dataset's spread.
- Coefficient of Variation (cv): The ratio of the standard deviation to the mean, expressed as a percentage. This provides a normalized measure of dispersion relative to the mean.

The script then iterates through each year's data, calculating and printing these measures of dispersion. This analysis aids in understanding the variability and distribution of paddy production over the specified years.

4.4 Moments and Skewness :

In this Python script, the NumPy and SciPy libraries are used to calculate raw moments, central moments, and skewness for paddy production data across multiple years. The sample dataset includes production values for each year from 2011 to 2023.

- Raw Moments (raw_m): Calculated up to the 4th order using moment(data, moment=i), these moments provide insights into the shape and spread of the data without adjusting for the mean.

- Central Moments (central_m): Also calculated up to the 4th order using moment(data, moment=i, central=True), these moments account for the mean, offering a measure of data distribution around the mean.

- Skewness (s): Calculated using skew(data), this statistic quantifies the asymmetry of the data distribution. A positive skewness indicates a longer right tail, while negative skewness suggests a longer left tail.

The script iterates through each year's data, calculating and printing these moments and skewness. This analysis provides valuable insights into the distributional characteristics and asymmetry of paddy production data over the specified years, aiding in a more nuanced understanding of its variability

4.5 Regression and Correlation:

In this Python script, NumPy, pandas, and matplotlib libraries are utilized for a regression analysis on paddy production data spanning from 2011 to 2023. The sample dataset, represented as a DataFrame, is subjected to a linear regression analysis using the linregress function from SciPy. This computes the slope, intercept, correlation coefficient, p-value, and standard error of the regression. Additionally, the script calculates the correlation coefficient using NumPy's corrcoef method. The data is visualized with a scatter plot of actual production values and a regression line. The script then outputs the regression line equation and the correlation coefficient. This analysis provides insights into the linear relationship between years and paddy production, aiding in the interpretation of trends and predictive modeling.

4.6 Kurtosis:

In this Python script, the NumPy and SciPy libraries are employed to calculate kurtosis for paddy production data across multiple years. The sample dataset includes production values for each year from 2011 to 2023. The function calculate_kurtosis utilizes the kurtosis function from SciPy to compute the kurtosis coefficient, a measure of the distribution's tail and peak. The script iterates through each year's data, calculates the kurtosis, and prints the results. This analysis provides insights into the shape and heaviness of tails in the distribution of paddy production data, offering additional information about the dataset's characteristics.

4.7 Graphical Representation :

In this Python script, the NumPy and Matplotlib libraries are utilized to visualize paddy production data across different seasons from 2011 to 2023. The sample dataset includes production values for autumn, winter, and summer seasons, with corresponding years. The total production for each year is calculated by summing the respective seasonal productions. The script then generates a line plot, depicting the production trends for each season and the total production per year. The x-axis represents the years, and the y-axis represents the paddy production. This visualization provides a clear comparison of production levels across seasons over the specified years, aiding in the identification of seasonal patterns and overall trends in paddy production.

5. RESULTS

5.1 Measures of Central Tendency Implementing Python :

```
Import numpy as np

# Sample data (replace this with your actual dataset)

Paddy_production = [208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239, ]

# Calculate mean, median, and mode Mean_production = np.mean(paddy_production)

Median_production=np.median(paddy_production)

Mode_production = np.argmax(np.bincount(paddy_production))

# Output the results

Print(f'Mean Production: {mean_production:.2f}')

Print(f'Median Production: {median_production:.2f}')

Print(f'Mode Production: {mode_production}')
```

OUTPUT

```
Mean Production: 294633.50
Median Production: 197718.00
Mode Production: 171398
```

5.2 Partition Values

import numpy as np

Sample data paddy_production = [208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239]

Calculate quar les, percentiles , and deciles quar les = np.percen le(paddy_produc on, [25, 50, 75]) percentiles = np.percentiles le(paddy_production on, [10, 20, 30, 40, 50, 60, 70, 80, 90])

deciles = np.percen le(paddy_produc on, [i * 10 for i in range(1, 10)])

Output the results

print(f'Quar les: {quar les}')

print(f'Percen les: {percen les}')

print(f'Deciles: {deciles}')

output

```
Quartiles: [190038.5 197277.  200536. ]
Percentiles: [171544. 189026. 191051. 196870. 197277. 198159. 199611. 201461. 208160.]
Deciles: [171544. 189026. 191051. 196870. 197277. 198159. 199611. 201461. 208160.]
```

5.3 Measures of Dispersion

import numpy as np

Sample data (replace this with your actual dataset) years = list(range(2011, 2024)

) paddy_produc on_ data = [[208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239],

Add data for other years in a similar format]

#Func on to calculate measures of dispersion for each year def calculate_dispersion(data):

range _value = np.ptp(data)

variance = np.var(data)

standard_devia on = np.std(data)

coefficient_of_varia on = (standard_devia on / np.mean(data)) * 100 return range_value, variance, standard_devia on, coefficient_of_varia on

Calculate measures of dispersion for each year for year, produc on_data in zip(years, paddy_produc on_data): r, v, sd, cv = calculate_dispersion(produc on_data)

print(f'Year {year}:')

print(f' Range: {r}')

print(f' Variance: {v:.2f}')

print(f' Standard Devia on: {sd:.2f}')

print(f' Coefficient of Varia on: {cv:.2f}%') print()

OUTPUT

```
Range: 51841
Variance: 200918581.60
Standard Deviation: 14174.58
Coefficient of Variation: 7.26%
```

5.4 Moments and Skewness

import numpy as np

from scipy.stats import moment, skew

Sample data (replace this with your actual dataset)

years = list(range(2011, 2024))

paddy_produc on_data = [[208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239],

Add data for other years in a similar format]

Func on to calculate moments and skewness for each year def calculate_moments_and_skewness(data):

Calculate raw moments up to the 4th order

raw_moments = [moment(data, moment=i) for i in range(1, 5)]

Calculate central moments up to the 4th order

central_moments = [moment(data, moment=i) for i in range(1, 5)]

Calculate skewness

skewness = skew(data) return raw_moments, central_moments, skewness

Calculate moments and skewness for each year for year, produc on_data in zip(years, paddy_produc on_data): raw_m,

central_m, s = calculate_moments_and_skewness(produc on_data)

print(f'Year {year}:')

print(f' Raw Moments (up to 4th order): {raw_m}')

print(f' Central Moments (up to 4th order): {central_m}')

print(f' Skewness: {s:.2f}') print( )

<u>output</u>

```
Variance: 200918581.60
raw moment:  195254.18
Third Central Moment: -254300580956.34
Fourth Central Moment: 116795917061906704.00
Skewness: -0.09
```

5.5 Regression and Correlation

import numpy as np

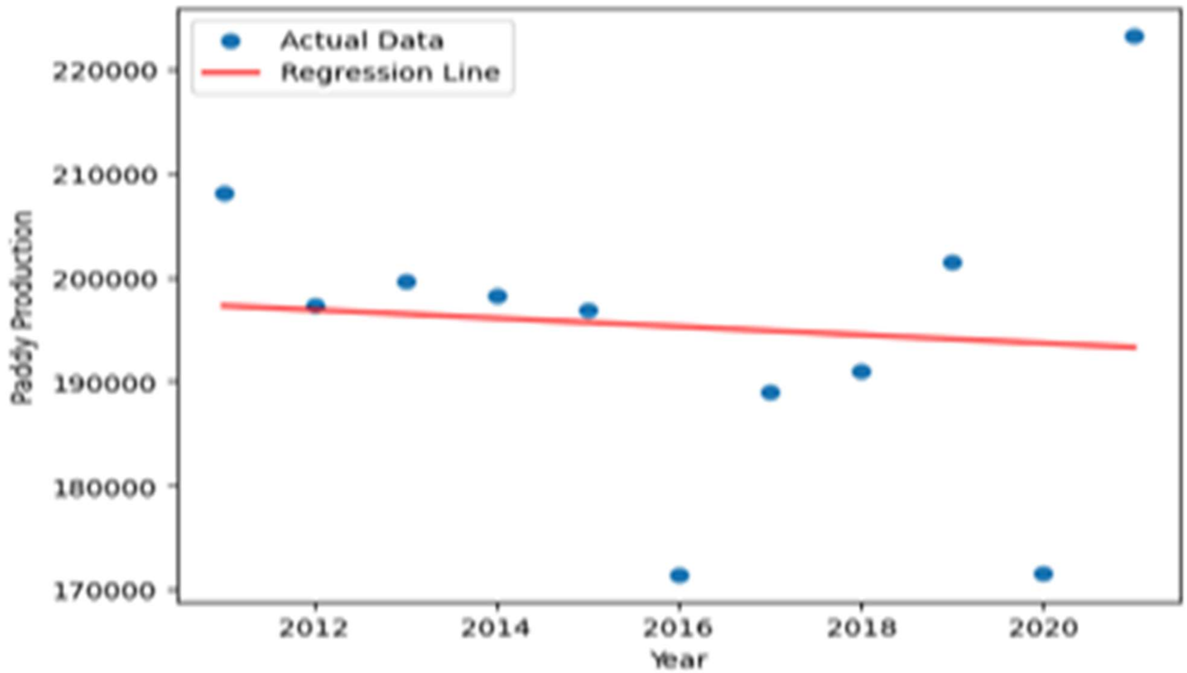
import pandas as pd import matplotlib.pyplot as plt from scipy.stats import linregress

```
# Sample data (replace this with your actual dataset)

years = list(range(2011, 2024))

paddy_produc on = [208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239]

# Ensure both lists have the same length

years = years[:len(paddy_produc on)]

# Create a DataFrame

data = pd.DataFrame({'Year': years, 'Paddy_Produc on': paddy_produc on})

# Perform linear regression slope,

intercept, r _value, _, _ = linregress(data['Year'], data['Paddy_Produc on'] )

# Plo ng plt.sca er(data['Year'], data['Paddy_Produc on'],

label='Actual Data') plt.plot(data['Year'],

intercept + slope * data['Year'], 'r', label='Regression Line')

plt.xlabel('Year')

plt.ylabel('Paddy Produc on')

plt.legend() plt.show()

# Output results
```

print(f'Regression Line: y = {intercept:.2f} + {slope:.2f} * x')

print(f'Correla on Coefficient: {r_value:.2f}')

output



Regression Line: y = 1002515.56 + -400.43 * x

5.5 Kurtosis

import numpy as np from scipy.stats import kurtosis

Sample data (replace this with your actual dataset)

years = list(range(2011, 2024))

paddy_produc on_data = [[208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239],

Add data for other years in a similar format]

Func on to calculate kurtosis for each year def calculate_kurtosis(data):

Calculate kurtosis kurt = kurtosis(data) return kurt

Calculate kurtosis for each year for year, produc on_data in zip(years, paddy_produc on_data):

k = calculate_kurtosis(produc on_data)

print(f'Year {year}:')

print(f' Kurtosis: {k:.2f}') print()

output

```
Kurtosis: -0.11
```

5.5 Graphical Representation

import numpy as np import matplotlib.pyplot as plt

Sample data (replace this with your actual dataset)

years = list(range(2011, 2024))

total_produc on = [208160, 197277, 199611, 198159, 196870, 171398, 189026, 191051, 201461, 171544, 223239] autumn_produc on = [68135, 63232, 51922, 63981, 60418, 56601, 58278, 60718, 54694, 58749, 65487, 53448, 0]

Adjusted length

winter_produc on = [92735, 86751, 100824, 88990, 89118, 72253, 81115, 88450, 80649, 51533, 62761, 52232, 0]

Adjusted length

summer_produc on = [47290, 47294, 46865, 45188, 47334, 42544, 49093, 48858, 56308, 43717, 43301, 43629, 0]

Adjusted length

Calculate total produc on for each year

total_produc on_per _year = np.array(autumn_produc on) + np.array(winter_produc on) + np.array(summer_produc on)

Plo ng plt.figure(figsize=(10, 6))

plt.plot(years, autumn_produc on, label='Autumn', marker='o')

plt.plot(years, winter_produc on, label='Winter', marker='o')

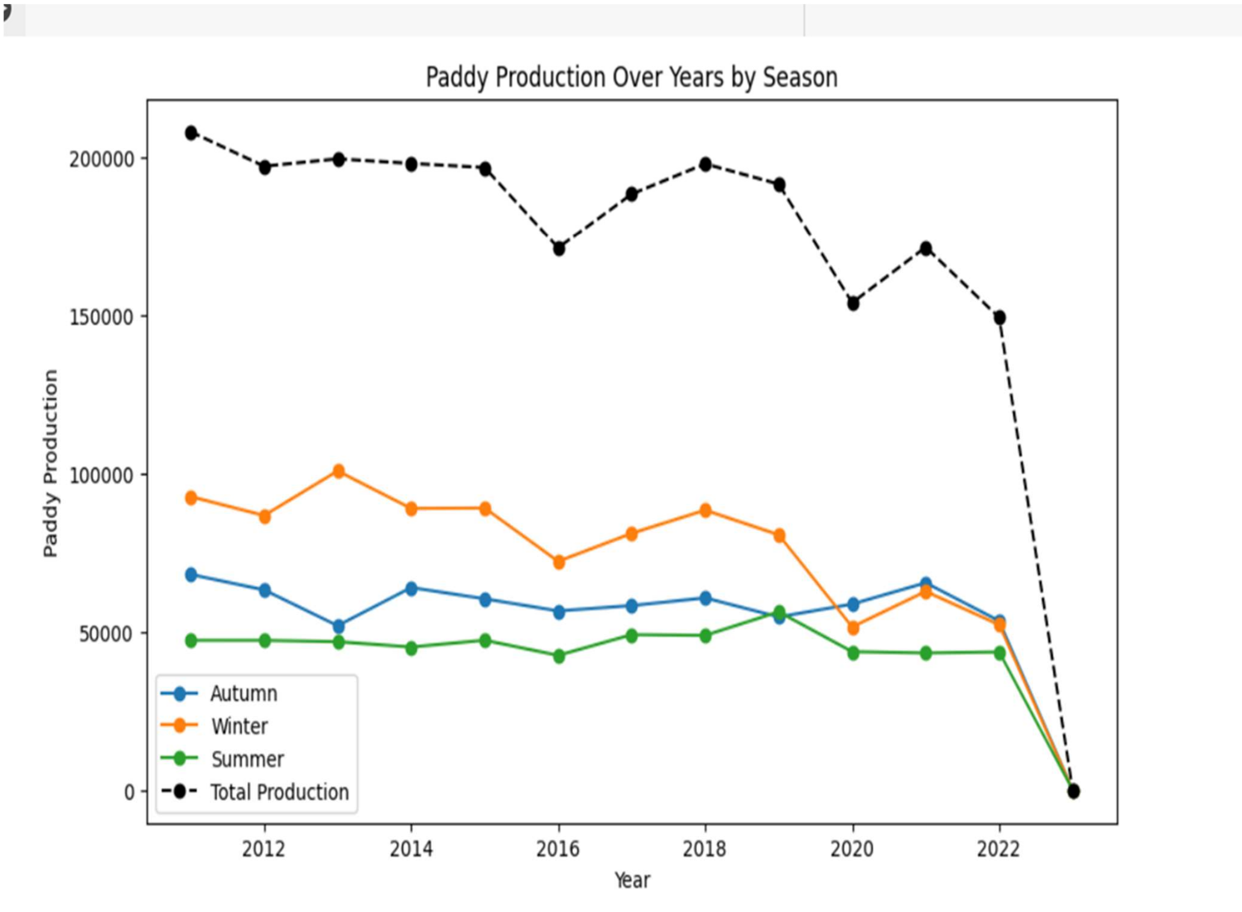
plt.plot(years, summer_produc on, label='Summer', marker='o')

plt.plot(years, total_produc on_per_year, label='Total Produc on', linestyle='--', marker='o', color='black')

plt.xlabel('Year') plt.ylabel('Paddy Produc on') plt. tle('Paddy Produc on Over Years by Season')

plt.legend() plt.show()

OUTPUT



6.CONCLUSION

The data presented strongly indicates a significant correlation between climate change and paddy production. It is evident that the production rate of paddy is notably influenced by seasonal variations. Specifically, the winter season emerges as the most favorable period for paddy cultivation, consistently yielding higher production rates compared to other seasons. Conversely, the summer season appears to have a detrimental impact on paddy production, resulting in a noticeable decrease in output. This observed fluctuation in production rates highlights the susceptibility of paddy cultivation to changes in seasonal patterns, underscoring the vulnerability of the agricultural sector to climate variations. The dynamic nature of these fluctuations emphasizes the need for strategic planning and adaptive measures in the face of ongoing climate change, to ensure the sustainability and resilience of paddy production.

7.FUTURE SCOPE

The data reveals a clear link between climate change and paddy production. Winter consistently sees higher production, while summer witnesses a decline. These seasonal fluctuations emphasize the sensitivity of paddy cultivation to weather changes. Recognizing and addressing these dynamics is crucial for developing effective strategies to sustain and enhance paddy production in the face of climate change.

8. REFERENCES

- Auffhammer, Maximilian, Veerabhadran Ramanathan, and Jeffrey R. Vincent. "Climate change, the monsoon, and rice yield in India." *Climatic change* 111 (2012): 411-424.

- Aswathi, K. P., et al. "Impact of climate change on rice yield under projected scenarios in central zone of Kerala." *Journal of Agrometeorology* 24.3 (2022): 280-285

- Dagar, J. C., et al. "Climate change vis-a-vis Indian agriculture." *Annals of Agricultural Research* 33.4 (2012).

- Geethalakshmi, Vellingiri, et al. "Climate change impact assessment and adaptation strategies to sustain rice production in Cauvery basin of Tamil Nadu." *Current science* (2011): 342-347..

- Gokul Krishna, K. B. *Statistical models for climate change in northern and central Kerala*. Diss. Department of Agricultural Statistics, College of Agriculture, Vellayani, 2020.

- Karunakaran, N. "Paddy cultivation in Kerala–trends, determinants and effects on food security." *Artha Journal of Social Sciences* 13.4 (2014): 21-35.

- Kumar, K., and J. Parikh. "Socio-economic impacts of climate change on Indian agriculture." *International Review for Environmental Strategies* 2.2 (2001).

- Kumar, B. Mohan, and T. K. Kunhamu. "Ecological and historical perspectives of rice cultivation in Kerala: a synthes." *Oryza* 58.2 (2021): 241-261.

- Rao, G. S. L. H. V., et al. "Impact of climate change on food and plantation crops in the humid tropics of India." *ISPRS Archives* 38.8 (2009): W3.

- Thomas, Niranjana, E. J. James, and Celine George. "Water-related impacts on agriculture due to climate change: a review with reference to Kerala." *Sustainability, Agri, Food and Environmental Research* 10 (2022).