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FOSTERING SUSTAINABLE AGRICULTURE: ANALYZING THE INFLUENCE OF DIVERSE RAINFALL SEASONS ON FRUIT YIELD USING PREDICTIVE MACHINE LEARNING MODELS

Khushboo Ishaq
Lecturer at the Department of Statistics
Shaheed Benazir Bhutto University
Shaheed Benazirabad, Pakistan

Shamim Jhatial
Lecturer at the Department of Statistics
Shaheed Benazir Bhutto University
Shaheed Benazirabad, Pakistan

Fozia Parveen
PhD Scholar at the Department of Statistics
University of Sindh Jamshoro, Pakistan
Correspondence should be addressed to Khushboo Ishaq
khushboo.pathan@sbbusba.edu.pk

Abstract

Rainfall is critical in fruit production because it provides plants with essential water. Fruit trees suffer stress when there is not enough rainfall, making it difficult to yield fruits of the best quality. Rainfall also significantly impacts soil moisture regulation, which is essential for fruit trees' healthy growth and development. This study examines the impact of rainfall on fruit production during the last ten years. The four districts of Sindh Larkana, Mirpur Khas, Khairpur, and Thatta were selected based on agricultural data and rainfall figures. The Climate Data Processing Center in Karachi of the Pakistan Meteorological Department provided the annual rainfall data in millimeters. At the same time, data on the tons of fruit produced annually between 2007 and 2016 were acquired from Pakistan's Agriculture Extension Department. The study analyzes how seasonal rainfall affects fruit production in the area using machine learning multiple regression techniques. The study's conclusions highlight the substantial effects of seasonal and annual rainfall fluctuations on fruit production in the study areas. Rainfall after monsoon has a negative impact on the production of mangoes in Larkana and guavas in the Sindh regions of Mirpur Khas and Thatta. Rainfall during the winter also has a negative effect on Khairpur's mango crop. Pre-monsoon rainfall in the Thatta region causes guava production to decline, while monsoon rainfall in the Larkana region has a negative impact on mango production. The study finds that implementing sustainable water management practices and investigating climate-resilient agricultural techniques are necessary to mitigate the adverse effects of weather conditions on fruit production. In the designated areas, these actions could increase fruit yields.

Keywords: Rainfall, Fruit Production, Machine Learning Models, Prediction, Modelling.

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Introduction

Predicting agricultural fruit production has become a significant concern for horticultural associations. Every farmer is keen to know how much fruit they can anticipate—efforts to address this issue date back to when the first farmers began cultivating the soil. The problem of predicting fruit production can be solved by employing data mining techniques. We can consider this sensor data, which has been available for some time, where proper fruit production has been recorded. This data is being used to create a collection of information that can be used to discover new ways to organize future production. This is possible because new sensor information is now available. Managing the risks associated with global fruit production is a continual challenge for Pakistan's government. This is because the variability of rainfall significantly impacts the yields of various fruit and crop types during different stages of growth and development. Any changes in the timing of rainfall can have an adverse effect on the strength and quality of fruit crops. Changes in the timing of precipitation can harm fruit due to its sensitivity during the growth process. On the other hand, extreme weather conditions can also severely impact the production and marketability of fruits. Wherever extreme weather events are reported, it is said that the food industry is facing intense threats around the globe.

Research Problem

This study focuses on how fluctuations in rainfall impact fruit yield in the Sindhi districts of Thatta, Khairpur, Larkana, and Mirpur Khas. This study aims to understand how seasonal and annual rainfall variations impact fruit tree productivity in these areas. This problem stems from our understanding of how crucial rainfall is to plants as a primary water source, impacting their growth and development. Inadequate rainfall can cause stress in fruit trees, lowering their capacity to yield nutritious, premium fruits. The study attempts to address this research problem by analyzing the relationship between rainfall patterns and fruit production over the previous ten years.

Research Question

How do variations in annual and seasonal rainfall impact fruit production in the selected districts of Sindh, specifically Larkana, Mirpur Khas, Khairpur, and Thatta, and what are the specific effects on mango and guava production in these regions?

Research Objective

This study aims to determine the threats to Sindh's fruit crops from rainfall variability. It will examine and evaluate the trending behavior and forecast of rainfall, including the impact of rain on different fruit products, which directly affects the fruit sector of the agriculture industry in Sindh. The main fruit crops taken were banana, mango, date, and Guava. This study will analyze the impact of the amount of rainfall on these selected crops through classical regression models.

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Literature Review

For the past two decades, Pakistan has made significant strides in developing its industrial sector, but it remains predominantly agricultural(Ali et al., 20170). The country boasts the world's most extensive contiguous canal and distribution system, supported by a rich irrigation system mainly reliant on the Indus River. The British Government had initially planned this irrigation system to cultivate the agricultural land of the subcontinent and to develop the agro-business for better tax collection in the government's interest. (Mensah, 2019; Ayanlade et al.,, 2016)

The fluctuation in primary fruit production and its market can be attributed to the variability and irregularity of rainfall. Sindh, a predominantly agricultural province, has a minimal industrial sector. The province's sole dependence on agriculture is a significant economic source, leaving it vulnerable to climate change and rainfall shortfalls (Winifred et al., 2018). This, in turn, directly affects the number of bumper fruit products in districts across Sindh, including upper, lower, and others (Singh et al., 2015; Amogne et al.,2014).

The shortfall and irregular rainfall caused by climate change in southern areas of Pakistan have adversely affected agricultural production, particularly in Sindh. Unfortunately, irrigation facilities in Sindh remain inadequate or absent in many locations, resulting in low crop yields, particularly in the fruit sector. Since agriculture is a significant sector of Pakistan's economy, technically, unsound growers in Sindh cannot achieve optimal crop yields. Moreover, irregular rainfall, extreme weather events, and climate change have led to fluctuations in fruit prices (Ghazal et al., 2013). The analysis of climate change and an extreme shortage of rainfall was considered. Still, changes in rainfall were mainly analyzed because they "Consider that direct or indirect losses caused by extreme rainfalls affect farmers and investors (Jain et al., 2012; Rajan, 2012).

Agriculture-dependent nations like Pakistan, particularly its agricultural provinces like Sindh, urgently need to comprehend the problems associated with controlling rainfall, adapting to climate change, and enhancing irrigation systems. (Malla, 2012). Sindh, known for its ideal climate and soil, has been a significant grower, producer, and exporter of fruits such as Mangoes, bananas, dates, and guavas. However, the inefficiency in technology and scientific methods is increasingly affecting Sindh's agribusiness (Naheed & Rasul, 2011; Nail & Momani, 2010). Extreme weather changes and irregular rainfall are the two most prominent problems that directly affect the production and quality of fruits (Nail & Momani, 2010). Weather changes shorten the fruit season, which dominates the market, means, and supply of fruits (Olivares et al., 2009). The irregular rainfall is also a significant factor in producing different fruits, which can vary throughout the year. Research has shown that all levels of rainfall have an impact on different fruit production. Furthermore, due to its geographical location, Pakistan's horticulture zone is in danger of climate change (Khushk & Smith, 2008; Bergamasch et al., 2007).

Agricultural countries like Pakistan, especially its agricultural provinces like Sindh, need to understand the issues of managing rainfall, climate change, and

improving the irrigation system (Binbol et al., 2006; Ahmad & Smead, 2005). These major fruits contribute a significant portion of the country's economy. For instance, bananas are planted on 34,800 hectares with a yield of 154,800 tones, with a total share of 78 percent in Sindh province, where the soil and climatic conditions are ideal (Zhang, 2003). Mango is considered a summer fruit in Pakistan and has a pivotal impact on consumers. Sindh mangoes are world-famous due to their taste and quality (Qureshi & Akhtar, 2004). Guava is also a popular fruit in Pakistan, cultivated in practically all the country's regions. In Sindh, it commonly grows in Hyderabad, Noshehro Feroz, Nawabshah, and mainly in Larkana. "Guava production in Pakistan increased from 19,000 tons in 1958 to 552,000 tons in 2008, a 6.9% annual growth rate (Qureshi & Akhtar, 2004; Zhang, 2003).

The date is also among the most important factors to consider as the chief fruit product of Pakistan. The product of dates makes Pakistan one of the world's largest data exporters. "Pakistan is the world's fourth-largest producer of dates, with yearly production averaging over 650,000 tones and around 300 types. Pakistan produces a wide variety of products (Caprio & Quamme, 2002)." Despite the success, multiple dimensions still exist to divert the agribusiness of Sindh, especially fruit products, on track with technology to halt the effects of climate change, shortfall, and extreme weather (Caprio & Quamme, 2002; Ishaq & Talpur, 2019). Extreme rainfall or changes in rainfall timing can change soil water content, likely affecting the plant's progression. This suggests that depending on the district and soil types, food production, forestry, ecology, carbon cycling, and water cycling may be affected. Extreme rains could also impact interactions with pests, diseases and invasive species (Caprio & Quamme, 2002; Ishaq & Talpur, 2019).

Methodology

Area of Study

The present study refers to different stations, i.e. (Mirpur Khas, Thatta, Larkana, and Khairpur) in Pakistan's Sindh province. This study used secondary data from the last Ten years (2007 -2016). Historical rainfall records and statistical data on fruit production were used for the study. I.e. Mangoes, bananas, dates, guavas etc.

Source of Data

The rainfall data were collected from the Climate Data Processing Center (CDPC) meteorological complex, Pakistan Meteorological Department (PMD). The horticultural data for similar districts' production of different fruits were collected from the Agriculture Extension Department of Pakistan for ten years from 2007 to 2016.

Analysis of Data

Various statistical techniques were used to analyze the data in this study. Rainfall data was analyzed at seasonal and yearly time scales to identify long-term mean values and calculate indices of variability and trends. The statistical descriptors used to analyze rainfall variability included the coefficient of variation and the Precipitation

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Concentration Index (PCI). Correlation and multiple regression analyses examined the relationships between seasonal rainfall and fruit production.

Supervised Machine Learning Multiple Linear Regression

Model (MRM)

Multiple linear regression is a supervised learning model used in machine learning to predict a continuous numerical output variable based on various input variables or features. The model assumes a linear relationship between the input and output variables.

In multiple linear regression, the model takes the form:

$yi = \beta 0 + \beta 1xi + \epsilon i$ for i=1,...for i=1,...,n

If we let $i = 1, ..., n$, we see that we obtain n equations:

$$y1 = \beta 0 + \beta 1x1 + \epsilon 1$$
$$y2 = \beta 0 + \beta 1x2 + \epsilon 2$$
$$\vdots$$
$$yn = \beta 0 + \beta 1xn + \epsilon n$$

It is also called the general linear model or a linear model.

here

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & x_1 \\ 1 & x_2 \\ \vdots & \vdots \\ 1 & x_n \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

$$\boldsymbol{Y = X\beta + \varepsilon}$$

yi the dependent variable of the model, i.e., i= production of mango, dates, banana, Guava

β_0 is n x 1 vector denoted by the intercept term of the model

β_I is kx1 **represented by coefficient** of regression in the model, i.e., = 1, 2, 3,4,5,6 and $x_1, x_2, x_3 .. _k$ are the independent variables, where the random error term is added to make the model probabilistic rather than deterministic. The goal of the model is to find the values of the coefficients that minimize the difference between the predicted values and the actual values of the output variable in the training data set. This is typically done using a technique called least squares regression. To make predictions using the model,

we plug the input variables' values into the equation and calculate the predicted value of the output variable. The model's accuracy can be evaluated by comparing the predicted values with the actual values of the output variable in a separate validation data set.

In our study, x_1 = winter rainfall, x_2 = pre-monsoon rainfall, x_3 = monsoon rainfall, and x_4 = post-monsoon rainfall and y shows the production in tons of Mango, banana, dates, and Guava.

The model has been run through R-studio with the following codes;

```
# Load required libraries

library(tidyverse)

# Create a data frame with the predictor variables x1, x2, x3, and x4, and the response variable y

data <- data.frame(x1 = c(),

x2 = c(),

x3 = c(),

x4 = c(),

y = c())

# Fit multiple linear regression model

model <- lm(y ~ x1 + x2 + x3 + x4, data = data)

# Print model summary

summary(model)

# Compute R-squared

r_squared <- summary(model)$r.squared

cat("R-squared:", r_squared, "\n")

# Predictions

predicted <- predict(model, data)

residuals <- data$y - predicted

# Compute Mean Squared Error (MSE)

mse <- mean(residuals^2)
```

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```
cat("Mean Squared Error (MSE):", mse, "\n")
```

After fitting the multiple linear regression model using the lm() function and printing the model summary using the **summary()** function, we compute the R-squared value using **summary(model)$r.squared**, which extracts the R-squared value from the model summary. We then compute the predictions using the **predict()** function and calculate the residuals by subtracting the predicted values from the actual response variable values. Finally, we compute the Mean Squared Error (MSE) by taking the mean of the squared residuals using **mean(residuals^2).**

Results and Discussions

According to Table 1, the Khairpur district had the lowest average annual rainfall, measuring 132mm ± 8mm, compared to the other three districts. Conversely, the Mirpur district had the highest average annual rainfall, recording 211mm ± 107mm. In the winter, the Mirpur district had the lowest average rainfall, 1.7mm ± 0.4mm, while Khairpur experienced the highest average rainfall at 8.7mm ± 2.3mm. During the pre-monsoon season, the Thatta district recorded the lowest average rainfall of 3.7mm ± 3.0mm, while the Larkana district experienced the highest average rainfall of 8.9±4.0mm. Moving on to the monsoon season, the maximum average rain was noted in the Mirpur district, with a recorded amount of 61.2mm ± 11.7mm.

In comparison, the minimum was observed in the Khairpur district with an average amount of 27.1mm ± 5.2mm. Finally, in the post-monsoon season, the Khairpur district experienced the highest average rainfall at 10.1mm ± 0.22mm. In comparison, the Larkana district observed the lowest average rainfall at 6mm ± 0.11mm.

Table 1 (See Annexure -I) shows the observed perception concentration index (PCI) values. If the PCI value is less than 11, it suggests a uniform monthly rainfall distribution, while 11 and 20 signal a high concentration, and over 21 signals a very high concentration. The maximum value was observed in the Mirpur district, with a PCI of 48%. All the studied areas have high concentrations (Ishaq & Talpur, 2019).

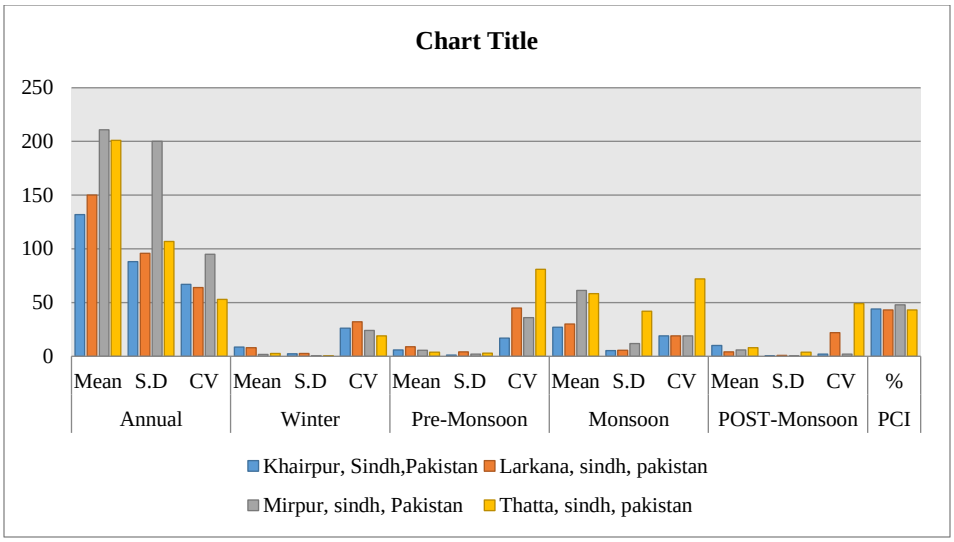


Figure No 1: Descriptive statistics of fruit production from 2007 to 2016 in different districts of Sindh province.

Table 2: Summary statistics of fruit production from 2007 to 2016 in different districts of Sindh province

Districts	Descriptive Statistics	Mango	Banana	Dates	Guava
Khairpur	Minimum	27074	21563	177951	1129
	Maximum	35014	37682	257194	2983
	Mean	29542	27810	222333	1777
	CV	8	27	12	32
Larkana	Minimum	1065	-	1077	27563
	Maximum	3903	-	1260	41050
	Mean	1433	-	1146	35601
	CV	61	-	16	14
Mirpur	Minimum	38234	583	62	1189
	Maximum	79770	6014	333	5306
	Mean	65194	3670	218	3323
	CV	22	31	43	44
Thatta	Minimum	1085	13041	74	61
	Maximum	3861	25278	169	221
	Mean	1944	20966	91	91
	CV	62	17	31	53

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Table 2 provides a comprehensive overview of fruit production in the Khairpur district from 2007 to 2016. Among the various fruits cultivated, dates were the most significant in production, followed by mangoes, bananas, and guavas. The Larkana region's primary industry was guava farming, but the district of Mirpur Khas produced the most mangoes. Thatta was also where the majority of bananas were grown.

The statistics exhibit that there are giant annual versions in fruit manufacturing. Various elements, along with versions in rainfall styles, the provision of land appropriate for cultivation, and climatic conditions, likely prompt this variability. These findings underscore the complex interaction between environmental factors and agricultural practices, emphasizing the need to apprehend and manipulate these impacts to optimize fruit production inside the Khairpur district.

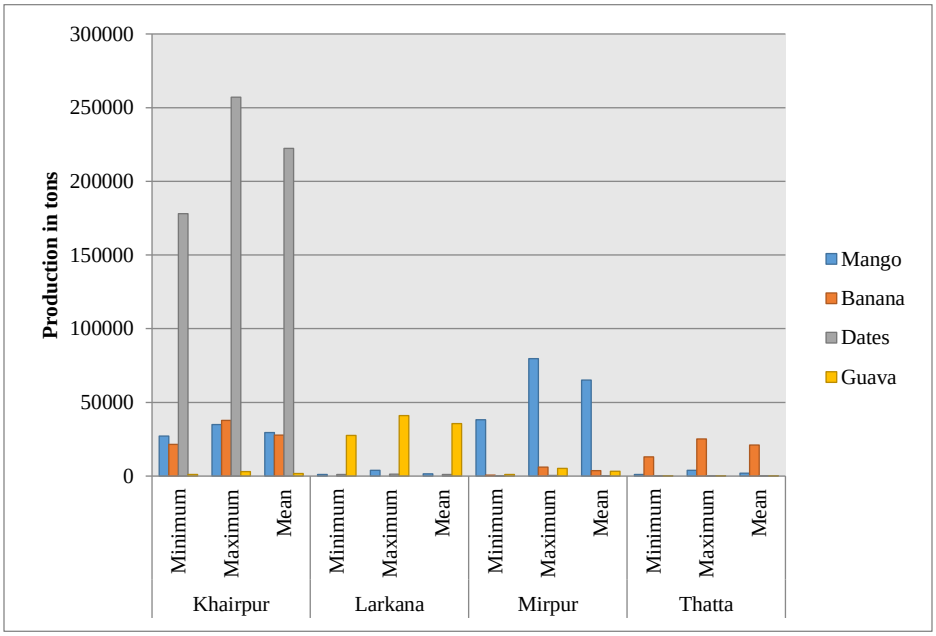


Table 3: Correlation between fruit production and seasonal rainfall

Fruits Production	MirpurKhas Rainfall	Khairpur Rainfall	Larkana Rainfall	Thatta Rainfall
Mango	-0.85**	0.314**	-0.374	0.56*
Banana	0.484*	0.053*	0.01	0.733**
Dates	0.475**	-0.928	0.158	-0.144*
Guava	0.444	0.106	-0.813***	-0.168

The Sindhi districts of Larkana, Khairpur, and Mirpur Khas were included in the research investigation. The study investigated the relationship between rainfall and fruit crop yield. Rainfall and banana yields have been located to have an advantageous

(zero.484) dating in Mirpur Khas, suggesting that better rainfall became connected to higher banana yields. There was also a slightly positive correlation (coefficients of 0.475 and 0.444, respectively) between rains and the crops of dates and Guava. Rainfall and mango crops in Khairpur showed a weak positive correlation (0.314), indicating that increased rainfall would marginally increase mango yields. Rainfall and banana crops showed a very weak positive correlation (0.053). At the same time, dates showed a strong negative correlation (-0.928), indicating that increased rainfall led to a significant decrease in date yields due to their drought-tolerant nature. Guava crops in Khairpur had a weak positive correlation (0.106) with rains.

Moving on to the Larkana region, there was a moderate negative correlation (-0.374) between mango crops and rainfall, suggesting a decrease in mango yields with increased rainfall. There was no significant relationship (correlation coefficient of 0.001) between banana crops and rainfall in this region. Dates crops showed a weak positive correlation (0.158) with rainfall, indicating a slight yield increase with higher rainfall. The guava crop exhibited a strong negative correlation (-0.813), indicating a significant decrease in guava yields with increased rainfall.

Table 4: MRM training models for fruit production and seasonal rainfall

District	MRM Training Models	P-value	R2	MSE
Khairpur	Y(mango) = -1234.99 (X1) + 420.17 (X2) + 295.02 (X3) + 411.23 (X4)	0.12	0.79	123.43
	Y(Banana) = 471.49(X1) + 1236.27(X2) + 182.84(X3) + 99.54(X4)	0.01< 0.05	0.88	182.72
	Y(Dates) = 1994.83(X1) + 2547.83(X2) + 987.95(X3)	0.04 < 0.05	0.79	1032.32
	Y(Guava) = 68.92(X1) + 4.99(X2) + 16.82(X3) + 7.03(X4)	0.08 <0.05	0.73	43.12
Larkana	Y(mango) = 299.37(X1) + 84.48(X2) –53.64(X3) –4.83(X4)	0.01< 0.05	0.88	98.14
	There is no Production.	--	--	-----
	Y(Dates) = 16.97(X1) + 7.05(X2) + 5.32(X3)	0.09 < 0.10	0.82	32.56
	Y(Guava) = 1700.98(X1) –327.32(X2) + 220.34(X3) + 193.72(X4)	0.01 < 0.05	0.88	134.67
MirpurKhas	Y(mango) = 1459241.041(X1) – 350.615(X2) + 600.991(X3) + 363.449(X4)	0.06	0.75	1124.78
	Y(Banana) = 351.675(X1) + 77.874(X2) + 47.132(X3) - 19.22(X4)	0.09 < 0.10	0.72	153.56
	Y(Dates) = 1.516(X1) + 1.499(X2) –0.388(X3)	0.17	0.81	12.88
	Y(Guava) = 100.279(X1) + 146.42(X2) + 45.735(X3) –17.33(X4)	0.07 < 0.10	0.84	34.44
Thatta	Y(mango) = 225.7(X1) – 23.98(X2) + 3.48(X3) + 14.71(X4)	0.17	0.83	144.22
	Y(Banana) = 261.03(X1) + 1819.61(X2) + 108.58(X3) + 68.28(X4)	0.09 < 0.10	0.73	124.73
	Y(Dates) = 0.17(X1) + 0.66(X2) +0.17(X3)	0.02 < 0.05	0.75	17.86
	Y(Guava) = 27.75(X1) - 32.49(X2) + 0.72(X3) –0.01(X4)	0.04 < 0.05	0.81	27.76

In the Thatta region, a moderate positive correlation (0.56) between mango crops and rainfall suggests that higher rainfall resulted in increased mango yields. Banana crops showed a strong positive correlation (0.733) with rainfall, indicating a significant increase in banana yields with higher rainfall. Dates crops had a weak

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negative correlation (-0.144), implying a slight yield decrease with increased rainfall. The guava crop in Thatta also showed a weak negative correlation (-0.168), indicating a slight decline in guava yields with higher rainfall.

The relationship between fruit production and different types of rainfall in the Khairpur district of Sindh is mentioned in Table 4. The relationship indicates that the amount of rainfall in the winter season has a negative impact on the production of mangoes. In contrast, rainfall in other seasons positively impacts the production of mangoes in this region. Similarly, for other fruits, rainfall of all seasons had a positive impact on the output except in the case of dates, in which post-monsoon rain had a negative effect on its production. In the Larkana district of Sindh, the negative impact of monsoon and post-monsoon rainfall was observed on mango production. In the case of guava production, the pre-monsoon rainfall contributed negatively to its output. However, rainfall of all four types of seasons contributed positively towards the Dates production. Considering the MRM model for the MirpurKhas region, post-monsoon rainfall negatively affected the production of bananas, while mango production was negatively affected by monsoon rainfall. Dates production was also affected negatively by the post-monsoon season rainfall, while other rainfall seasons positively affected its production.

Regarding the guava production in this region, all the rainfall seasons positively impacted its production, while post-monsoon affected its production negatively. In the Thatta region, banana production was positively impacted by all rainfall seasons, while monsoon reduced the production of mangoes. However, in the rest of the rainfall seasons, they have helped increase its production. Dates production was also positively influenced by all four types of rainfall seasons. However, pre-monsoon and post-monsoon negatively impacted the production of Guava fruit. All the MRM models were significant at 5 and 10 % significance levels since the p-value was less than the threshold point except the MRM models for producing mangoes. The model selection criteria R2 was also close to 1, showing the best-fitted results, and Mean square error (MSE) also showed the best-fitted models for all the fruit productions.

Table 5 (see Annexure -II) shows that for the MirpurKhas region, mango fruit production will be around 68232 by 2026, more than the 2017 prediction results. The Banana, Dates, and Guava will also face increased production till 2026. Considering the Khairpur district, mango production will decline in 2026 compared to previous years, and date production will not increase compared to the last prediction results. Similarly, Guava will be facing a decline in production till 2026 compared to 2017, which was 1977 tons. In Thatta district, the average output of mangoes will also decline to 1835 tons compared to 1947 tons in 2017.

Similarly, for banana production, the average will be around 20757 tons less than the average in 2017. Dates and guava production will also suffer from a decline compared to previous years' data. Considering the data of the Larkana region, mangoes and dates will face a decrease in their production compared to the previously forecasted production. In contrast, the average guava production will be around 39201 tons, which is more than the 2017 production.

Conclusion

The challenge of predicting rainfall in Sindh province's dynamic environment is emphasized by applying predictive machine learning models to examine the impacts of different rainfall seasons on fruit yield. The study recognizes the inherent challenges caused by the region's extreme variations in rainfall patterns. Despite the difficulties in predicting rainfall with precision, the value of forecasting cannot be emphasized. This is particularly true for essential domains such as water collection, urban planning, flood control, and irrigation system optimization for agricultural production—with a particular emphasis on fruit farming.

Throughout the study, variations in seasonal and annual rainfall were evident, highlighting the intricate nature of the local climate. Surprisingly, no discernible relationship was found between the recorded fluctuations in rainfall and fruit yield. Both positive and negative relationships were found in the complex correlation between rainfall and various fruit productions, highlighting the possibility that excessive rain could lead to production losses. Contrary to the theory of a negligible negative relationship between rainfall and fruit production, the correlation analysis reveals a non-significant negative association between rainfall variability and fruit yields.

In the districts under investigation, excessive precipitation causes issues by overflowing drainage and sewage systems and posing social and economic challenges to the local population. Notably, the multiple regression results indicate that rainfall variability has some effect on fruit production in the study districts. It is advised that little reservoirs be constructed in the impacted areas as a preventative measure to use rainwater efficiently. This research might reduce the issues brought on by too much rain and increase agricultural productivity in the future. This calculated move supports the region's larger objective of encouraging sustainable agriculture.

Recommendations

The present study will recommend a better understanding of various climate-related strategies in the studied area. It should help PMDC and agriculture departments, as well as irrigation professionals, better understand the ups and downs in fruit production and focus on providing modern techniques for fruit production. Fruit production in the studied area. This paper proposed a plan to increase fruit production in four districts of Sindh based on rainfall variability and suggested that tiny reservoirs be built in the regions to properly use rainwater for agricultural output.

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Annexure - I

Table 1: Rainfall (mm), coefficient of variation, and PCI for the years 2007 to 2016 in the studied area

Station	Annual			Winter			Pre-Monsoon			Monsoon			POST-Monsoon			PCI
	Mean	S.D	CV	Mean	S.D	CV	Mean	S.D	CV	Mean	S.D	CV	Mean	S.D	CV	%
Khairpur	132	88	67	8.7	2.3	26	6.0	1.0	17	27.1	5.2	19	10.1	0.22	2	44
Larkana	150	96	64	7.9	2.5	32	8.9	4	45	30.0	5.7	19	4.0	0.91	22	43
Mirpur	211	200	95	1.7	0.4	24	5.6	2	36	61.2	11.7	19	6.0	0.11	2	48
Thatta	201	107	53	2.6	0.5	19	3.7	3	81	58.3	42	72	8.0	3.9	49	43

Annexure - II

Table 5: The predicted value of fruit production using the MRM training model

YEARS	MIRPURKHAS				KHAIRPUR				THATTA				LARKANA			
	Mango	Banana	Dates	Guava	Mango	Banana	Dates	Guava	Mango	Banana	Dates	Guava	Mango	Banana	Dates	Guava
2017	59923	3777	209	2835	32263	28197	226412	1977	1947	22456	111	149	3701	0	1143	33327
2018	68071	3947	244	4548	32121	30234	219529	1972	1824	25212	92	82	1441	0	1155	31384
2019	57844	4591	196	2793	29352	28427	229134	1709	1067	20333	78	83	979	0	1152	30282
2020	51078	4742	152	4755	28101	31795	226580	2248	1168	19272	79	100	1287	0	1161	38041
2021	68721	422	127	1139	26839	26447	224384	1672	1443	16630	95	88	1015	0	1143	40094
2022	70314	3060	261	2739	29330	24442	240726	1751	2314	17612	71	34	1269	0	1124	40906
2023	67561	4381	235	3417	31136	29520	222643	2118	1812	21237	107	77	684	0	1159	33266
2024	79649	3537	268	3165	29039	28966	229959	1786	2389	23743	95	71	1239	0	1153	34207
2025	60538	3231	221	2753	28836	25851	180012	1303	3645	22409	75	116	1130	0	1115	35299
2026	68232	5012	219	5086	28402	24223	223944	1237	1835	20757	109	107	1582	0	1153	39201