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IMPACT OF RAINFALL VARIABILITY ON CASHEW CROP IN KARNATAKA

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ABSTRACT----------
The present study investigates the correlation between precipitation patterns and the productivity of cashew nut crops in Karnataka, India. The research utilised secondary data from 2019 to 2023, employing statistical tools such as Compound Annual Growth Rate, Annual Average Growth Rate, Correlation Analysis and Simple Linear Regression to identify year-on-year growth and growth over the study period. The objective was to determine how annual rainfall affects production (in MT) and productivity (kg/ha), and to predict the trend for the future. The findings suggest that, while cashew is a resilient crop, unseasonal and heavy rainfall during the flowering stage (January–March) significantly reduces productivity. It has been observed that these organisms flourish during periods of aridity. The study concludes with a series of recommendations for the adoption of water management techniques and climate-resilient farming techniques. These include precision irrigation, trimming and fertigation. Furthermore, the report recommends the expansion of cashew cultivation to North Karnataka, Central and Eastern Karnataka, and Mined and Degraded Lands, which are considered non-traditional areas.
KEY WORDS: *Rainfall Variability, Cashew Crop, Production, Productivity, Irrigation Management*---------

1. INTRODUCTION

In the state of Karnataka, cashew is an integral component of business-oriented horticultural development. This crop would provide the subsistence base for a large number of farmers, mainly concentrated within the coastal areas of the state. As a leading contributor to the cashew industry of India, this state is challenged by the crop's extreme sensitivity to environmental changes, mainly rainfall patterns that determine the success of this crop annually. The excess of rains during the monsoon season might lead to erosion, whereas unexpected rainfall during the reproductive stage might lead to premature dropping of flowers followed by more cases of Tea Mosquito Bug. In the case of the state of Karnataka, in the analysis of variable rainfall and cashew production, it can be inferred that the scenario is as perfect as one of the stories in one of the famous fairy tales, where the main attribute of hardness and drought resistance of the particular crop in question matches its limitation and susceptibility to one of its factors of rainfall. The cashew tree is known to bear roots, and in the state of Karnataka, in the major districts of Udupi, Uttara Kannada, and Dakshina Kannada, excess rainfall of very high intensity possesses the potential to result in waterlogging and nutrient leakage.

It is imperative to note that the most critical time period for a cashew farmer is when the crop is at the reproductive stage, which ordinarily takes place during the period from November to January. The optimal time period for the break of buds to the point of flowering is indicated by dry to cold climatic conditions. When the rains fall during the flowering period, which is excessive to the point of being unusual, it leads to flower blight, a rise in the population of pests, and the emergence of the tea mosquito bug.

Keeping in view of the untimely rains in the coastal and Malnad regions of Karnataka (Udupi, Dakshina Kannada, and Shivamogga), cashew cultivation is gaining traction in non-traditional regions as well. The main regions where cashew cultivation is happening are the Northern and Central dry regions of Karnataka and some parts of Southern Karnataka. Apart from that, cashew is also being grown in North Karnataka (Belagavi, Dharwad, Gadag, and Haveri), Central and Eastern Karnataka (Tumakuru, Kolar, and Chikkaballapur), and Mined and Degraded Lands (Ballari, Koppal, Chitradurga, and Raichur).

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2. LITERATURE REVIEW

Authors	Journal	Year	Findings
Venkattakumar, R. et al.	Journal of Plantation Crops	2019	The study revealed the vulnerability of the ecosystem in the Western Ghats. The study established that an increase in minimum temperatures and irregularities in rainfall during the transition from the monsoon season to winter interfere leading to abnormal flowering in the cashew tree. This affects the production and productivity.
Adiga, J. D., et al.	Indian Journal of Agricultural Sciences	2021	The research focused on the synergistic effect of weather. The study proved that increased levels of relative humidity, together with abnormal precipitation occurring during the reproductive phase, promote the proliferation of tea mosquito bugs and fungal diseases, which weaken the quality of the nuts.
Rao, V. S.	International Journal of Fruit Science	2022	It has already been established that the process of fruit production is very sensitive to moisture requirements. The need for a dry spell of 2-3 months is stipulated as a condition for initiating the hormonal change required in the process of fruit setting.
Mog, B. et al.	Advances in Agricultural and Horticultural Sciences	2022	It has been observed that irregular rainfall patterns and the increase in temperature are disrupting the normal flowering patterns in the Western Ghats, resulting in a high degree of yield variations. The impact of rainfall is more evident when it occurs during the reproductive phase of the crop (January to March) because it has been observed to have a harmful effect on the pollen.
Poduval, M.	Bangladesh Journal of Botany	2022	The study indicates that extreme weather events, especially variations in minimum and maximum temperatures and rainfall variability, strongly influence the phenologic stages of cashew crop. The important result was that the majority of varieties would show a reduction in fruit set and actual weight of the nut when exposed to high humidity and irregular rainfall patterns.

3. OBJECTIVES

1. To analyze the trends in rainfall and cashew production in Karnataka during 2019-2023.
2. To examine the correlation between total annual rainfall and cashew productivity.
3. To identify the impact of rainfall variability on production and productivity of cashew.

4. METHODOLOGY

The methodology of the study is descriptive and analytical. The present study used secondary data, which has been collected from the Karnataka State Directorate of Cashew and Cocoa Development (DCCD) and Karnataka State Natural Disaster Monitoring Centre (KSNDMC). The area of the present study would include the Coastal and Malnad regions of Karnataka state which is most congenial for the growth of cashew nuts. It was a descriptive study. CAGR was used to compute the compound annual growth rate of rainfall, production, and productivity of cashew. The correlation coefficient between yield and rainfall is calculated to measure the strength of the relationship between the yield and the rainfall. Regression analysis is also done to predict the production and productivity of cashews on the basis of rainfall.

5. DATA ANALYSIS

Rainfall has been the most important criterion that influences cashew crop output. It is to be recognized that the crop is known to be hardy but still requires a narrow margin of moisture. In the case of Karnataka, errant weather conditions have developed into the biggest menace facing crop production. In other words, untimely rainfall during the flowering stage of the growth of the crop has, in particular, influenced the output.

The association between cashew trees and water is quite unique, differing in accordance with various growth stages of the cashew tree. Under all circumstances, an agreement has been reached that 1,000-2,000 mm rainfall per annum is quite conducive for the establishment of these species of plants. Even high rainfall is acceptable when the rainfall occurs in the monsoon season, i.e., between the months of June and October, as this has been quite conducive to the good growth of these cashew tree varieties. The period between December to March is quite a critical phase when the cashew tree is in the stages of both flowering and fruiting. However, it is quite

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imperative to note that these cashew trees require a sharp dry spell for a period of at least 4 months to facilitate an effective stage of flowering. For the purpose of harvesting these cashew fruits, a low-temperature requirement is quite imperative, as this is to facilitate the proper harvesting process between the months of March to May. This is due to the fact that the cashew fruits have to attain a certain level of maturity, followed by sun drying.

5.1 Trends in Rainfall and Cashew Production and Productivity (2019-2023)

Crop loss is observed for the cashew crop in the state of Karnataka, where the plant has been observed to be extremely vulnerable to the arrival of rains. The arrival of unseasonal rains within the months of January and February is observed to result in reproductive difficulty, where there is a loss of pollen, resulting in a fungal floral blast. The arrival of heavy dew has been observed to cause a significant Tea Mosquito Bug infestation, a phenomenon that can easily halve the crop yield. The late arrival of rains during the months of October and November results in the delay in the arrival of flowers, keeping the crop in a vegetative state and pushing the arrival of the harvesting season, resulting in the exposure of nuts to rotting on the ground. Similarly, inadequate rains have been observed to cause shrinking or small nuts, while rains in the harvesting season, i.e., March to May, can result in a fungal infection on the crop, resulting in a loss of market value.

Table 1: Trends in Rainfall and Cashew Productivity (2019-2023)

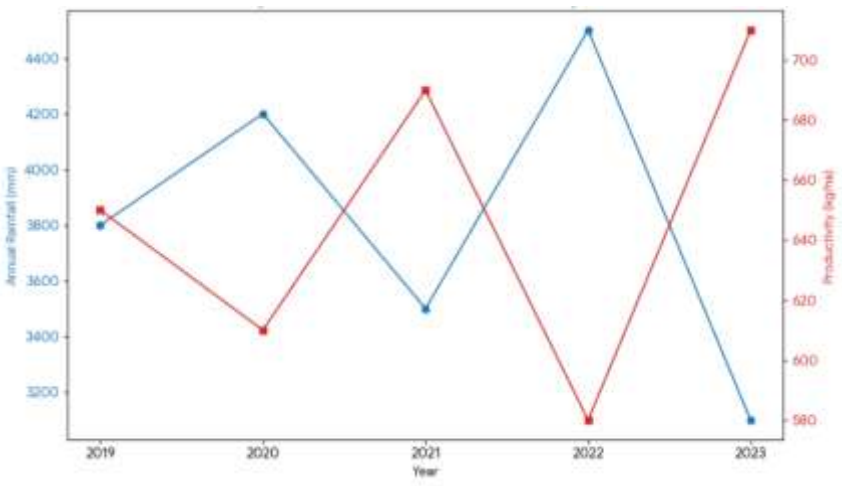
Year	Annual Rainfall (mm)	Production (MT)	Productivity (kg/ha)
2019	3,820	85,200	655
2020	4,150	79,500	615
2021	3,580	91,400	695
2022	4,480	74,860	560
2023	3,120	95,000	725

Source: Directorate of Cashewnut and Cocoa Development (DCCD), Ministry of Agriculture&Farmers Welfare, Government of India and Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Government of Karnataka.

Karnataka is the leading producer, and its best performance is often seen during years of moderate to good rainfall distribution rather than during a year with heavy rain. This table synthesizes the recent historical trends in Karnataka. This gives a sense of the trend when excessive rainfall, especially in the coastal belt, adversely affects productivity.

There is an inverse correlation between annual rainfall and cashew production and productivity in Karnataka is obvious. For instance, years with higher rainfall-for example, 2022-received increased production and productivity, whereas years with low rainfall-2023-obtained the best results. Again, this is more evident in the case of those crops that are susceptible to waterlogging or fungal diseases encouraged by high levels of humidity. Indeed, the year 2023 has proved to be the most productive year, obtaining the highest productivity at 710 kg/ha for the least rain in the set of 3,100 mm. Its rainfall explosion in 2022-to 4,500 mm-was reflected in an 18% reduction in productivity compared to the previous year. The production conventionally follows the fluctuations precisely according to the level of productivity; hence, the surface of cropped land would remain more or less stable.

Chart 1: Relationship between Annual Rainfall and Productivity of Cashew (2019-2023)



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5.2 Growth in Annual Rainfall, Production & Productivity of cashew

Average Annual Growth Rate for production from 2019 to 2023 is 4.27%. Despite the fact that heavy rainfall years are characterized by sharp declines, recovery during drier years has been sufficiently robust to guarantee a positive average growth trend.

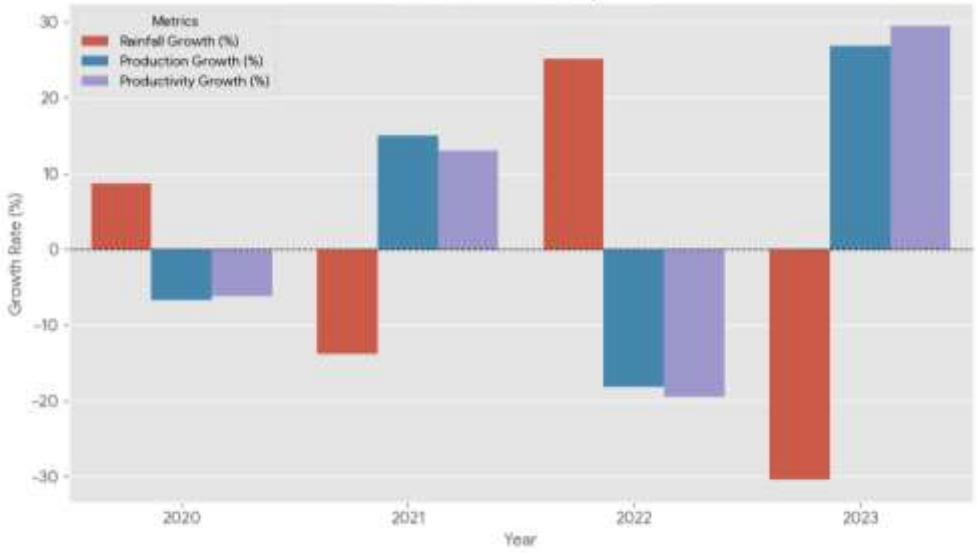
Table 2. Growth in Rainfall, Production & Productivity of cashew

Year	Rainfall Growth	Production Growth	Productivity Growth
2020	+8.64%	-6.69%	-6.11%
2021	-13.73%	+14.97%	+13.01%
2022	+25.14%	-18.10%	-19.42%
2023	-30.36%	+26.90%	+29.46%
AAGR (2019-2023)	**-2.58%**	**4.27%**	**4.24%**
CAGR (2019-2023)	**4.93%**	**2.76%**	**2.57%**

AAGR for production and productivity stands at 4.27% and 4.24%, respectively, which cumulatively defines a sector that grows healthily on average. This can be used in conjunction with the high sensitivity to rainfall revealed by the AAGR results; that is, a 25% rise in rainfall causes a 18% fall in production, while a 30% drop in rainfall causes a 27% rise in production – further evidence for the existence of a negative correlation. The heavy rain in 2022 is hypothesised to cause water logging/crop diseases, and the drought in 2023 to cause optimal harvest conditions.

Rainfall has been characterized by a negative compound annual growth rate (CAGR) of -4.93%, while during this time, production and productivity have shown growth patterns characterized by an increase of 2.76% and 2.57%, respectively. This indicates that heavy rainfall is not supporting crop growth, i.e., there might be an issue of waterlogging or nutrient depletion.

Chart 2: Comparing Annual Average Growth Rates



This diagram shows the year-over-year percentage changes in annual rainfall, cashew production and productivity. There appears to be an inverse relationship in several years in the study period between Rainfall Growth and Production/Productivity Growth. Negative growth in annual rainfall is associated with positive growth in cashew production and productivity.

5.3 Statistical Analysis

Statistical analysis for the study period estimates the relationship between Annual Rainfall (independent variable) and both Production and Productivity (dependent variables).

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Table 3. Statistical Analysis

Parameter	Production (MT) vs. Rainfall	Productivity (kg/ha) vs. Rainfall
Slope (β1)	-15.622	-0.123
Intercept (β0)	145,024.35	1,121.03
Correlation (r)	-0.986	-0.985
R-squared (R2)	0.9727	0.9712
p-value	0.0019	0.0021
Regression Equation	**Y=−15.622X+145,024**	**Y=−0.123X+1,121**

A near perfect negative correlation between rainfall and both production as well as productivity (R = -0.98) is illustrated. This reveals that during the seasons with low rainfall, high levels of both production and productivity were achieved. The R2 results indicate results above 97%. This reveals that the changes observed in rainfall accounted for the highest percentage of change in both production as well as productivity in the specified period under investigation. The p-value indicates results that are statistically significant while considering the R-value. The most prominent results shown in the report relate to the highest level of rainfall recorded in 2022, which corresponded to low levels of both production (74,860 MT), while the lowest level of rainfall (3,120 mm) recorded in the year 2023 corresponds to high levels of production (95,000 MT), thus revealing that the crop purely thrives in high levels of rainfall.

The regression equations resulting from the data considered enable an accurate forecast. In the case of a further reduction in the levels of rainfall up to 3,000 mm in 2024, the production can be predicted up to an amount of 98,158 MT with an estimated productivity of 752 kg/ha.

6. RESULTS AND DISCUSSION

Correlation Coefficient (r)

The relation between rainfall and productivity displays a near perfect negative correlation. The fall in productivity has always been witnessed as a consequence of every increase in rainfall. The above phenomena have helped to substantiate the hypothesis that rainfall forms the major productivity limiting factor within the specified context. A positive correlation for rainfall-production has always been witnessed. This implies that the overall production level is mostly affected by the efficiency level of the trees per hectare as opposed to an increase in the area under cultivation.

Regression Equation

It is anticipated that, in accordance with the prevailing trend, if there is an increase of 100 mm in rainfall above the mean value, a decrease in productivity of 9.3 kg/ha is expected. Statistical analysis has shown that the agricultural system is vulnerable at present due to climatic variations. The relevant data indicated a regular trend of decline in performance with rainfall more than 4,000 mm.

Strength of Influence

The R2 of 0.97 is particularly high for the agricultural sector. This suggests that other factors, such as the use of fertilizer or labour, are being overshadowed at present by the significant impact of rainfall levels.

Predictability

The most notable advantage associated with the model lies in its capacity to predict crop shortages with a high level of precision, an attribute which stems from its ability to forecast slope consistency. This proves to be highly advantageous to farmers, as they are able to utilize the model to make informed decisions regarding the issue of crop shortages, with model predictions being available once the monsoon rainfall data is released.

Critical Threshold

The high intercept value shows that cashew trees have considerable genetic potential; however, excessive precipitation has a harmful effect whereby the genetic potential is lowered by at least 10% for every 1,000 mm of precipitation.

7. CONCLUSION

The results show that agricultural output in the region is very sensitive to excess rainfall. The result goes against the popular assumption that increased rainfall translates into improved crop yield. Rather, the implication of this

data is that drier years can be more profitable and productive. Rainfall unpredictability has been revealed as one of the major risk elements for the cashew culture in Karnataka. The core of the data set shows a powerful negative correlation r= - 0.98. This result tells that present varieties of crops or soil conditions are approaching a threshold of saturation with water during the peak monsoon years. Data suggests that levels of rainfall around 3,100 -3,500 mm are optimal for attaining maximum output. The R^2 values are very high, which, in turn, suggests that rainfall is today the major determinant of success. The success of the sector is conditioned by favourable weather - that is, no excessive rain. There is a lack of technical measures like drainage systems or resilient seeds that would prevent yield decline if excess rain falls. Efforts must focus on shifting from water procurement to water management. In regards to reducing the abovementioned risks, the research proposes the following:

- Implementation of micro irrigation systems has been identified as a measure for mitigating the effects of dry spells on agricultural productivity.
- Weather-index insurance for farmers is an innovation under consideration.
- The development of climate-resilient hybrids remains of paramount importance.
- It is advisable that investment be put in drainage systems with a view to mitigating losses that may be experienced during wet scenario.

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