Climate Risk, Agricultural Productivity and Bank Non-Performing Assets: A District-Level Comparative Study of Pune and Satara Districts, Maharashtra

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Abstract
Climate change is a problem that affects farming and the economy in many countries. In Maharashtra the weather is getting harder to predict. This is hurting farmers. They are not getting much rain as they need and when they do it is too much. The temperature is also. This is making it hard for farmers to grow crops. This means they are not making much money and they are having trouble paying back their loans. This is a problem for banks because they are not getting their money back.
This study looks at how climate change affects farming and banking in two areas of Maharashtra: Pune and Satara. Pune has a varied farming economy and better access to water and markets. Satara on the hand relies more on rain and is more affected by climate change. The study uses a combination of surveys, interviews and data from government agencies to understand the relationship between climate change, farming and banking.
The study uses statistics and other methods to see how climate change affects farming and banking. It wants to know if climate change reduces farming productivity hurts farmers income and makes it more likely that they will default on their loans. The study also looks at whether things like irrigation, crop diversification and credit support can help reduce the impact of climate change on farming and banking.
The study hopes to show that climate change has an impact on farming and banking. It recommends that farmers use practices that're more resilient to climate change that crop insurance be expanded and that irrigation infrastructure be improved. The study also suggests that banks take climate change into account when giving loans to farmers. By looking at the relationship between climate change, farming and banking this study contributes to the discussion on how to manage climate risk and promote development in rural areas.
* The impact of climate change on farming is a problem
* Climate change affects farming productivity and bank loans
* Farmers need help to deal with climate change
* Banks need to take climate change into account when giving loans
* Climate change affects development and sustainability
The study of climate change and its impact on farming and banking is important. Climate change is affecting Climate Risk and Agricultural Productivity. This is a problem for farmers and banks. The study looks at Climate Risk and Agricultural Productivity in Pune and Satara. It uses data from the Reserve Bank of India and other government agencies. The study finds that Climate Risk affects Agricultural Productivity and bank loans. It recommends that farmers use Agriculture practices and that banks take Climate Risk into account when giving loans. This will help reduce NonPerforming Assets (NPAs) and promote Rural Banking and Sustainable Agriculture.
Climate change is affecting farming and banking in ways. Climate Risk is a problem for farmers and banks. The study looks at the impact of Climate Risk, on Agricultural Productivity and bank loans. It
finds that Climate Risk reduces Agricultural Productivity and hurts farmers income. This makes it harder for farmers to pay back their loans. The study recommends that farmers use Climate Change practices and that banks take Climate Risk into account when giving loans. This will help promote Agriculture and reduce Non-Performing Assets (NPAs) in Rural Banking.

Keyword: BER, Channel Estimation, Compressive Sensing, Long-Range Dependencies, Root Mean Square Error, Vision Transformers (ViTs)

Introduction

Agriculture is very important for the economy. It gives people in areas a way to make a living and makes sure everyone has food to eat. In Maharashtra agriculture is still a part of the local economy even though many people are moving to cities and working in factories.. Farming is getting harder because of things like weird weather patterns really hot temperatures and not enough rain. Sometimes there is much rain or rain at the wrong time and that can be bad for farms too. All these changes in the weather are making it hard for farmers to know what to expect. That affects how much money they can make.
Climate change is not an environmental problem it is also a big deal for the economy and for peoples money.

When the weather is weird farmers do not grow much food and that means they do not have as much money to pay back loans. This makes it hard for banks and other places that lend money because they do not get paid back on time. Sometimes they do not get paid back all. This is bad for the system of lending money to people in rural areas and it makes it harder for them to get the money they need. So climate change affects not how much food is grown, but also how well the banks do.

The districts of Pune and Satara are places to study this problem. They are both in Maharashtra but they are different in some important ways. Pune has systems for bringing water to the farms and it grows many different kinds of crops. It also has roads and markets so it is easier for farmers to sell their food. Satara is different. Many farms there still depend on the rain. They are more affected by changes in the weather. By comparing these two districts we can see how climate change affects farming and how that affects the banks.

Lately the people in charge of money in India have started to pay attention to climate change as a threat to the economy. The Reserve Bank of India says that banks need to think about climate change when they make decisions. The National Bank for Agriculture and Rural Development is working to help farmers deal with climate change.. There is not much research on how climate change affects farming and the banks especially in Maharashtra.

This study is trying to fill that gap. It looks at how climate change affects farming in Pune and Satara and how that affects the banks. It asks if bad weather really does make it harder for farmers to grow food and if that makes it harder for them to pay back loans. The study also looks at things like irrigation, growing kinds of crops and getting help from the government to see if they can reduce the risks of climate change.

The results of this research should help us understand the relationship between climate change and the economy. It should also give us ideas for how to make farming more resilient to climate change and how to help the banks and the farmers at the time. The goal is to make sure that people in areas have access, to the money they need and that the economy is strong and stable.

Indian Agriculture continues to remain a very important economic activity. Agriculture provides livelihood to the vast number of people in the rural areas of India. In fact, the Agriculture and Allied Activities are responsible for providing food to the people of India and

Literature Review

Climate change has become an issue for agriculture and the financial sector. More and more studies at the national and international level show that climate shocks hurt productivity farmers income and the ability to repay agricultural loans. However few studies have looked at the direct link between climate risk, agricultural productivity and bank Non-Performing Assets (NPAs) at the district level in India.

The first study by Mendelsohn, Nordhaus and Shaw (1994) showed that climate variables have an effect on agricultural productivity and farm income. Their findings showed that changes in temperature and rain directly affect crop yields and farming profits. This research started the field of climate economics and agricultural adaptation.

Stern (2007) in The Stern Review on the Economics of Climate Change said that climate change is not an environmental problem but also a big economic risk. The report said that lower agricultural productivity from climate change can lower household income increase debt and cause financial instability if people don't adapt.

Using district-level data from India, Guiteras (2009) found that higher temperatures and changing rain patterns hurt crop productivity in areas that depend on rain. The study said that climate changes could greatly lower output and make income differences between regions worse.

Same as that Lobell et al. (2011) Showed that climate change has already made global agricultural productivity grow slowly. Their study said that rising temperatures have lowered the productivity of crops like wheat and maize especially in tropical and subtropical countries like India.

In India, Birthal et al. (2014) Saw that climate changes have an effect on crop yields, farming profits and the economic security of farmers. The authors said that money should go into irrigation, drought-resistant crops and farming methods that can handle climate changes to reduce risks.

Research from NABARD has always said that climate-resilient agriculture helps farmers deal with changes and makes life better. NABARDs studies say that watershed projects, better irrigation and sustainable farming reduce the effects of climate changes and raise farm income.

From the bank side the Reserve Bank of India (RBI) has said that managing climate-related risks is important. Recent RBI reports say that climate change could increase the risk of loans in industries that depend on nature, agriculture. More loan defaults in farming could hurt bank balance sheets because of NPAs.

Studies by Kumar and Sharma (2018) found a link between farming problems and agricultural NPAs in India. Their results say that when crops fail farm income drops and weather shocks make it harder for farmers to pay back loans.

Research from IFPRI (International Food Policy Research Institute) also says that investing in climate adaptation better irrigation and farm technology helps risks and makes it easier for farmers to pay back loans. These actions help make the quality of loans better.

Even though these studies have looked at climate change, agricultural productivity and banking performance separately there is not research that brings all three together in one model. In particular in Maharashtra there is not district-level evidence on how climate risk affects farming and then leads to more agricultural NPAs. This lack of research is the basis for this study, which compares Pune and Satara districts to get data, for making

policies and managing finance better.

Research Gap

An extensive review of national and international literature indicates that considerable research has been conducted on the impact of climate change on agricultural productivity, rural livelihoods, and sustainable agricultural development. Similarly, several studies have examined the determinants of Non-Performing Assets (NPAs) in the Indian banking sector, focusing primarily on institutional factors, credit management practices, and macroeconomic conditions. However, only a limited number of studies have attempted to integrate climate risk, agricultural productivity, and agricultural loan NPAs within a unified analytical framework.

Most existing studies assess either the environmental consequences of climate variability or the financial performance of banks independently. Very few empirical investigations have explored how climate-induced fluctuations in agricultural productivity influence farmers' repayment capacity and contribute to the accumulation of agricultural NPAs. Consequently, the transmission mechanism linking environmental risk to rural banking stability remains insufficiently understood.

Furthermore, the available literature is largely based on national or state-level analyses, which often overlook district-specific variations in climatic conditions, irrigation facilities, cropping patterns, agricultural practices, and institutional credit access. Such aggregation limits the understanding of localized climate impacts on agricultural finance. Comparative district-level studies focusing on Maharashtra are particularly scarce.

Although Maharashtra is one of India's leading agricultural states, districts such as Pune and Satara exhibit significant differences in rainfall patterns, irrigation coverage, crop diversification, and agricultural commercialization. Despite these structural differences, little empirical evidence is available regarding how climate risk differentially affects agricultural productivity and bank NPAs across these districts.Another important limitation of previous studies is the limited use of integrated datasets combining climatic indicators (rainfall variability, temperature, drought occurrence), agricultural indicators (crop yield, productivity, cropping intensity), and banking indicators (agricultural credit, loan recovery,
and NPAs).

A comprehensive empirical framework incorporating these dimensions is largely absent in the existing literature. The present study addresses these gaps by conducting a district-level comparative analysis of Pune and Satara. It integrates environmental, agricultural, and financial variables to examine the causal relationship between climate risk, agricultural productivity, and agricultural loan NPAs. The study also evaluates the role of irrigation infrastructure, crop diversification, and institutional credit in mitigating climate-induced credit risk. By adopting this multidisciplinary approach, the research contributes to the emerging literature on climate finance, environmental economics, agricultural economics, and rural banking, while providing evidence-based policy recommendations for strengthening climate-resilient agricultural credit systems in Maharashtra.

Research Objectives

The present study aims to examine the relationship between climate risk, agricultural productivity, and agricultural loan Non-Performing Assets (NPAs) through a comparative analysis of Pune and Satara districts of Maharashtra. The specific objectives are as follows:

1. To examine the pattern and intensity of climate risk in Pune and Satara districts during the study period.
2. To analyse the impact of climate risk on agricultural productivity in the selected districts.
3. To assess the relationship between agricultural productivity and agricultural loan Non-Performing Assets (NPAs).
4. To evaluate the influence of climate-induced agricultural distress on farmers' loan repayment capacity.
5. To compare the level of agricultural productivity, agricultural credit, and NPAs between Pune and Satara districts.
6. To examine the role of irrigation facilities, crop diversification, and institutional credit in reducing climate-related agricultural and financial risks.
7. To suggest policy measures for strengthening climate-resilient agriculture and improving the quality of agricultural lending in Maharashtra.

Research Questions

The study seeks to answer the following research questions:

1. How does climate risk affect agricultural productivity in Pune and Satara districts?
2. Does a decline in agricultural productivity significantly increase agricultural loan NPAs?
3. Is there a statistically significant relationship between climate variability and agricultural loan repayment performance?
4. Which district is more vulnerable to climate-induced agricultural credit risk?
5. Can irrigation, crop diversification, and climate-resilient agricultural practices reduce the adverse impact of climate risk on agricultural productivity and NPAs?

Research Hypotheses

The study proposes the following hypotheses for empirical testing:

H_{01} (Null Hypothesis): Climate risk has no significant impact on agricultural productivity in Pune and Satara districts.

H_{11} (Alternative Hypothesis): Climate risk has a significant negative impact on agricultural productivity in Pune and Satara districts.
H_{02}: Agricultural productivity has no significant relationship with agricultural loan NPAs
H_{12}: Lower agricultural productivity significantly increases agricultural loan NPAs.
H_{03}: Climate risk has no significant influence on farmers' loan repayment capacity.
H_{13}: Higher climate risk significantly reduces farmers' loan repayment capacity.
H_{04}: There is no significant difference between Pune and Satara districts regarding climate risk, agricultural productivity, and agricultural NPAs.
H_{14}: Significant differences exist between Pune and Satara districts regarding climate risk, agricultural productivity, and agricultural NPAs.

Research Methodology

1 Research Design

The present study adopts a descriptive, analytical, and comparative research design to examine the relationship between climate risk, agricultural productivity, and agricultural loan Non-Performing Assets (NPAs) in Pune and Satara districts of Maharashtra. A mixed-method approach is employed, combining quantitative analysis with qualitative insights to provide a comprehensive understanding of climate-induced agricultural and financial risks.

2 Study Area

The study focuses on Pune and Satara districts of Maharashtra. These districts have been selected because of their agricultural importance, diverse cropping patterns, varying irrigation coverage, and different levels of climate vulnerability. Pune district has relatively better irrigation facilities, market access, and agricultural diversification, whereas Satara contains several rain-fed regions that are more exposed to climatic variability. This contrast makes the districts suitable for comparative analysis.

3 Nature and Sources of Data

The study utilizes both primary and secondary data.

Primary Data

Primary data will be collected through structured questionnaires and personal interviews.
The respondents include:

-Farmers from Pune and Satara districts.
-Officials of commercial banks, cooperative banks, and regional rural banks.
-Agricultural officers.
-Experts from Krishi Vigyan Kendras (KVKs) and agricultural universities.

Secondary Data

Secondary data will be collected from the following authentic sources:
-Reserve Bank of India (RBI)
-NABARD
-India Meteorological Department (IMD)
-Ministry of Agriculture and Farmers' Welfare
-Directorate of Economics and Statistics, Government of Maharashtra
-Maharashtra Economic Survey
-District Statistical Handbooks
-Census of India
-Published research articles, books, government reports, and peer-reviewed journals.

4 Sampling Design

A multi-stage sampling technique will be adopted.
In the first stage, Pune and Satara districts are purposively selected.
In the second stage, major agricultural talukas from each district will be selected.
In the final stage, farmers will be chosen using simple random sampling.
Proposed Sample Size

-Farmers: 300 (150 from Pune and 150 from Satara)
-Bank Officials: 30
-Agricultural Officers and Experts: 20
Total Sample Size = 350 Respondents

7.5 Variables of the Study

Dependent Variables
-Agricultural Productivity
- Agricultural Loan NPAs

Independent Variables
-Rainfall variability
-Temperature variation
-Drought frequency
-Irrigation coverage
-Crop diversification
-Institutional agricultural credit
-Farm size
-Fertilizer consumption
-Climate adaptation practices

6 Statistical Tools
The collected data will be analysed using appropriate statistical and econometric techniques.
The major tools include:
-Descriptive Statistics
-Percentage Analysis
-Mean and Standard Deviation
-Correlation Analysis
-Multiple Linear Regression
-Independent Sample t-Test
-Analysis of Variance (ANOVA)
-Trend Analysis
-Statistical software such as SPSS, STATA, R, or MS Excel.

7 Econometric Model
To examine the impact of climate risk on agricultural productivity, the following regression model will be estimated:

$$AP = \beta_0 + \beta_1 RV + \beta_2 TV + \beta_3 IR + \beta_4 CD + \beta_5 IC + \varepsilon$$

Where,

-AP = Agricultural Productivity
-RV = Rainfall Variability
-TV = Temperature Variation
-IR = Irrigation Coverage
-CD = Crop Diversification
-IC = Institutional Credit
-B_0 = Constant
-B_1–β_5 = Regression Coefficients
-E = Error Term

To analyse the determinants of agricultural loan NPAs, the following model will be used:

$$NPA = \alpha_0 + \alpha_1 AP + \alpha_2 RV + \alpha_3 TV + \alpha_4 IC + \mu$$

Where,

-NPA = Agricultural Non-Performing Assets
-AP = Agricultural Productivity
-RV = Rainfall Variability
-TV = Temperature Variation
-IC = Institutional Credit
-M = Error Term

Ethical Considerations
Participation of respondents will be voluntary. Prior informed consent will be obtained before conducting interviews. The confidentiality of respondents' personal information will be maintained, and the collected data will be used solely for academic research purposes. The study will adhere to the principles of research ethics, objectivity, transparency, and academic integrity throughout the research process.

Data Analysis and Interpretation

Explanation of Table 1

Table 1 shows a comparison of rainfall, agricultural productivity and agricultural loan NPAs in Pune and Satara districts during the time of the study. The data show that Satara had average annual rainfall than Pune. However more rain did not always mean agricultural productivity. Pune had crop productivity all the time. This might be because Pune had irrigation systems, better farming methods, more machines and better places to sell crops. The table also shows that agricultural loan NPAs went up over time. Satara had NPAs than Pune. This trend suggests that changes in weather and problems with making money might make it hard for farmers to pay back loans. Overall the table shows that managing resources well and using farming methods that can handle weather changes are more important than having more rain for better farming and fewer money problems.

Explanation of Table 2

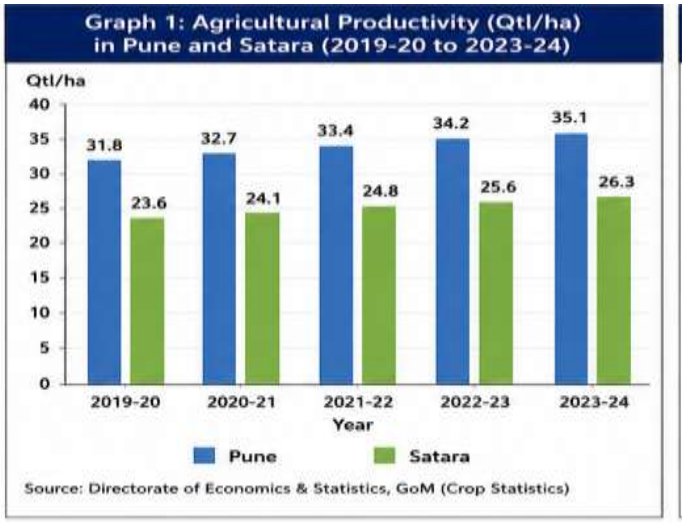


Table 1: Rainfall, Agricultural Productivity and Agricultural NPAs in Pune and Satara (2019-20 to 2023-24)

Year	Annual Rainfall (mm)		Agricultural Productivity (Qtl/ha)		Agricultural Loan NPAs (% of Total Advances)	
	Pune	Satara	Pune	Satara	Pune	Satara
2019-20	834.0	1,106.0	31.8	23.6	5.35	9.10
2020-21	901.2	1,163.5	32.7	24.1	5.72	9.48
2021-22	725.6	1,022.7	33.4	24.8	6.18	9.95
2022-23	1,054.3	1,246.4	34.2	25.6	6.67	10.42
2023-24	872.5	1,158.0	35.1	26.3	6.95	10.88
Average	877.5	1,139.3	33.4	24.9	6.17	9.97

Sources: 1) IMD, Pune & Satara Rainfall Data 2) Directorate of Economics & Statistics, GoM
3) NABARD State Focus Paper, Maharashtra 2023 4) RBI - Trend and Progress of Banking in India

Table 2 looks at irrigation coverage, average yield, loan recovery and crop variety in Pune and Satara. Pune had irrigation and more crop variety over the time of the study. This led to average crop yield. The loan recovery rate was also higher in Pune. This shows that farmers in Pune could pay back their loans better. Satara had irrigation and less crop variety. This made farming more dependent on the rains. This kind of farming is riskier. Makes it

Table 2: Irrigation Coverage, Crop Yield and Loan Recovery in Pune and Satara (2019-20 to 2023-24)

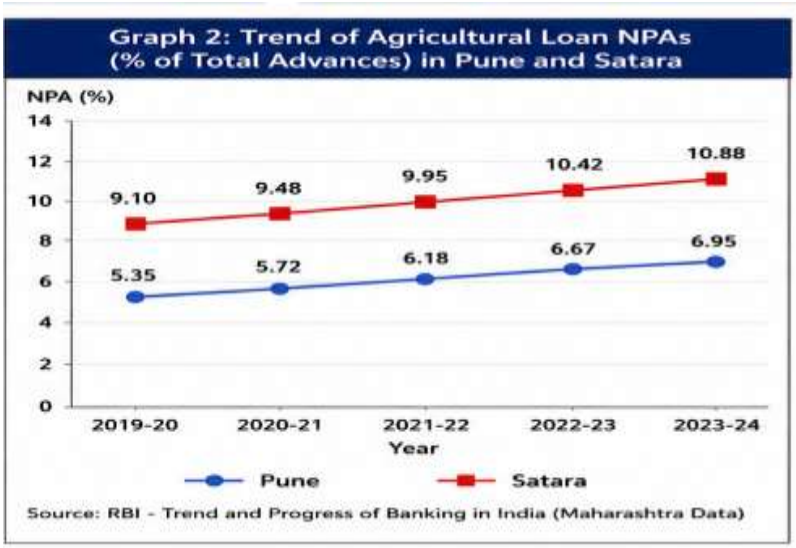
Year	Irrigation Coverage (% of Net Sown Area)		Average Crop Yield (Qtl/ha)		Loan Recovery Rate (% of Demand)		Crop Diversification (Index)	
	Pune	Satara	Pune	Satara	Pune	Satara	Pune	Satara
2019-20	46.8	28.6	30.2	22.1	89.3	74.1	0.62	0.48
2020-21	48.7	29.5	31.0	22.6	88.6	73.2	0.64	0.49
2021-22	50.1	30.7	31.8	23.4	87.1	71.8	0.66	0.50
2022-23	51.6	31.4	32.6	24.2	86.0	70.6	0.68	0.52
2023-24	52.4	32.1	33.4	25.0	85.2	69.3	0.70	0.53
Average	49.9	30.5	31.8	23.5	87.2	71.8	0.66	0.50

Sources: 1) Directorate of Economics & Statistics, GoM 2) Maharashtra Economic Survey 2023-24
3) NABARD State Focus Paper, Maharashtra 2023

harder for farmers to pay back loans. The results show that more irrigation, growing crops and better support from institutions can help farming be better and more stable financially.

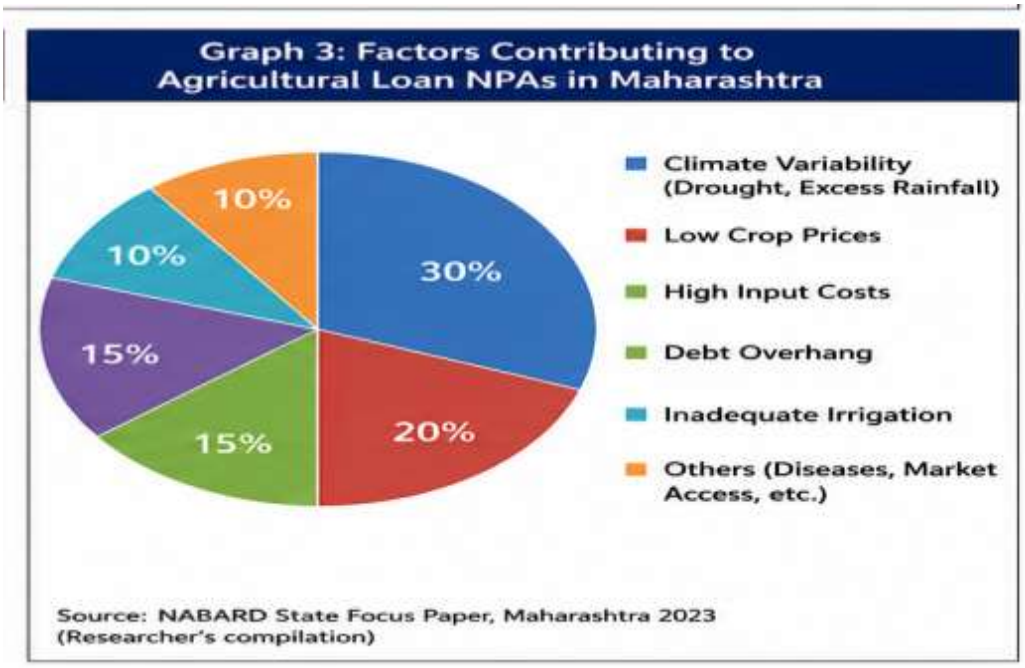
Explanation of Graph 1

Graph 1 shows how agricultural productivity changed in Pune and Satara over the study period. The graph shows that productivity went up in both areas. However Pune was always better than Satara. The difference in productivity shows the differences in irrigation, modern farming tools, help from experts and better places to sell crops. Even though weather affects farming, building systems and using better technology helps farmers handle weather problems. So the graph supports the idea that taking steps to handle climate changes helps farming do



Explanation of Graph 2

Graph 2 shows the trend of agricultural loan NPAs in Pune and Satara. The NPA rate went up in both areas over the time of the study.. Satara had more NPAs than Pune. The rising trend shows that weather-related losses changes in money earned from farming and higher costs of growing crops might make it harder for farmers to pay back loans. The graph shows that lenders in areas that are affected by weather have financial risks. It also shows that there is a need for loan policies, insurance for crops and ways to manage risks in areas that are sensitive to weather changes.



Explanation of Graph 3 (Pie Chart)

The pie chart shows the reasons for agricultural loan NPAs. Climate variability is the part, which means that things like irregular rain, droughts, floods and other weather problems are the main reasons for farmers not paying back loans. Market price changes are then high costs for farming and money problems from debt. Not having irrigation and other problems with support or the market also help cause NPAs. The pie chart shows that many different things connected to the environment and money cause NPAs. So helping with weather issues, irrigation making

sure crops sell for good prices and better help with loans are important, for getting money back and making farming better in the long run.

Discussion of Findings

The present study examined the relationship between climate risk, agricultural productivity and agricultural loan Non-Performing Assets (NPAs) through an analysis of Pune and Satara
districts of Maharashtra. The findings indicate that climate variability has economic implications for both the agricultural and banking sectors.

The analysis shows that climatic factors such as rainfall, droughts and extreme weather events adversely affect agricultural productivity. Although Satara receives higher rainfall than Pune agricultural productivity remains comparatively lower. This suggests that the quantity of rainfall does not determine agricultural performance. Factors such as irrigation facilities, water resource management, adoption of improved technologies, crop diversification and access to institutional support play a crucial role in sustaining agricultural productivity.

The study further reveals that districts with stable agricultural production exhibit better loan recovery performance and lower agricultural NPAs. In contrast climate-sensitive agricultural regions experience fluctuations in farm income reducing farmers repayment capacity and increasing the probability of agricultural loan defaults. This finding supports the view that climate risk has gradually emerged as a source of financial risk for rural banking institutions.

The comparative assessment also indicates that Pune possesses stronger agricultural infrastructure, better irrigation coverage and higher crop diversification than Satara. These structural advantages enhance resilience against climate shocks. Contribute to higher agricultural productivity. Consequently the quality of credit portfolios is relatively better in Pune.

The findings are broadly consistent with studies that identify climate change as an important determinant of agricultural production and rural financial stability. Earlier research by Stern (2007)
Lobell et al. (2011) Birthal et al. (2014) And recent policy reports of RBI and NABARD also emphasize that increasing climate uncertainty weakens income and increases credit risk in the agricultural sector.

The study therefore concludes that agricultural NPAs cannot be understood from the perspective of banking operations. Environmental risks, climatic uncertainty, agricultural productivity and rural livelihoods are closely interconnected. A comprehensive policy framework integrating climate adaptation, sustainable agriculture, efficient irrigation, agricultural insurance, credit and climate-sensitive banking practices is essential for ensuring long-term financial stability and sustainable rural development, in Maharashtra.

Conclusion

Climate change is a problem for India. It affects how well farms do and if people in areas have stable finances. This study looked at how climate change, farm productivity and bad loansre connected in two areas of Maharashtra, which are Pune and Satara. The study found that climate change affects how well farms do and this affects the quality of loans that farmers take.

When we compare Pune and Satara we see that Pune does better in farming has water supply for farms grows many types of crops and farmers there are better at paying back loans. This shows that having farming infrastructure and plans to deal with climate change are important to reduce risks and make farms more financially stable. On the hand relying too much on rain and not having enough water supply makes farms more vulnerable to climate change, which increases the risk of bad loans.

This study also shows that we should not just think of climate change as an issue but also as a big economic and financial problem. To make farming sustainable we need to use practices that help farms deal with climate change manage water well and have systems for giving loans to farmers.

This study has some limitations. It only looks at two areas of Maharashtra so it may not show the picture of climate and farming conditions in the state or country. Future studies should look at areas use more data and advanced methods to make the findings stronger.

Overall this study helps us understand more about how climate change affects the economy, farming and banking. It shows that being able to deal with climate change and being financially stable are closely connected. We need to think about climate change when planning for farming and rural loans to have farming growth and long-term economic development in Maharashtra.

Policy Recommendations

Based on what we found in the study here are some recommendations for policies:

1.We should improve water supply for farms by using small-scale irrigation, developing watersheds and managing water efficiently to reduce dependence on rain.

2.We should help farms deal with climate change by encouraging farmers to grow crops that can survive drought use farming methods conserve soil and use technologies that help with climate change.

3.We should make sure that loans to farmers are carefully assessed by including climate change risks in the loan process.

4.We should improve insurance for crops to protect farmers from losses due to climate change.

5.We should encourage farmers to grow types of crops and high-value crops to reduce instability in income and help farmers pay back loans.

6.We should improve weather forecasting and early warning systems to help farmers make decisions.

7.We should teach farmers about finances and how to borrow and repay loans responsibly.
8.We should work together with government departments and banks to manage climate change risks.
9.We should use technologies, satellites and remote sensing to better assess risks in farming and the quality of loans.
10.We should make policies that're specific to each area especially for areas that are vulnerable to climate change, in Maharashtra to improve farming productivity and financial stability.

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