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Impact of Tourism Sector on Economic Growth of India

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Abstract

Tourism has emerged as a key driver of economic growth in India, contributing significantly to GDP, employment generation, and foreign exchange earnings. This sector, encompassing leisure, business, medical, and cultural tourism, offers immense potential due to India's diverse geography, rich cultural heritage, and historical landmarks. Tourism has proven to be resilient, even in the face of global economic slowdowns, contributing around 9.3% to India's GDP and generating over 87 million jobs in 2019. With a large number of foreign tourist arrivals and robust domestic tourism, the sector has become a key foreign exchange earner for the Indian economy.

The paper examines the impact of the tourism sector on India's economic growth. This paper investigates the impact of tourism on economic growth, measured by GDP, over the period from 1991 to 2019. To analyse the relationship between tourism receipts and GDP the OLS method has been applied. To check the stationarity of the time series data the study has used the Augmented Dickey-Fuller (ADF) Phillips-Perron (PP) unit root test. The findings of the study indicate a positive relation between tourism receipts and GDP, suggesting that as tourism revenues increase, GDP per capita also rises, and vice versa. However, the results derived from the OLS estimation reveal that the strength of this relationship is weak.

Key Words: Tourism led economic growth, COVID19, OLS estimation, Augmented Dickey-Fuller Phillips-Perron unit root test

Introduction

Tourism is the activity where individuals travel from one location to another for leisure, recreation, or cultural exploration, contributing significantly to the development of economies around the world. It has become a crucial driver of economic growth, creating demand for various goods and services while encouraging the cultural exchange and mutual understanding between different regions.

By enabling individuals from all over the world to experience one another's customs, languages, and ways of life, tourism fosters cross-cultural interaction. This cultural interaction can lead to greater understanding and tolerance among nations. At the same time, however, it can also result in the blending or loss of unique cultural identities as global tourism encourages the commercialization of local traditions and customs to appeal to a broader audience. The homogenization of cultures can have both positive and negative effects. On one hand, it promotes unity and interconnectedness; on the other hand, it may diminish the authenticity of local practices and traditions, reducing the cultural diversity that makes the world rich and vibrant.

Tourism is significant in country's economic growth through generating revenue, creating employment opportunities and enhancing trade. The influx of tourists increases the demand for local goods and services, stimulating industries such as hospitality, transportation, retail, and entertainment. The sector supports small businesses and entrepreneurs, particularly in rural or underdeveloped areas, where tourism can provide a much-needed economic lifeline. By promoting the local culture and heritage, tourism also helps in preserving historical landmarks and natural beauty, attracting more visitors. This, in turn, leads to investments in infrastructure development, such as roads, airports, and hotels, which benefit both tourists and local residents. Many developing countries view tourism as a tool for poverty reduction, as it provides employment and income to communities that may otherwise lack economic opportunities.

One of the most beneficial aspects of tourism is its potential to create jobs and reduce poverty. The tourism industry is labor-intensive and employs a wide range of workers, from hotel staff and tour guides to artisans and transport operators. Many of these jobs require relatively low levels of formal education, making them accessible to a large portion of the population. This is especially important in developing countries, where tourism can provide employment to rural communities that may have few other income-generating opportunities.

Review of literature

Researchers have long examined the interaction between tourism and its economic impacts, initially focusing on the relationship between tourism and international trade rather than economic growth. One of the earliest studies into this dynamic was conducted by Shan and Wilson (2001) who examined the relationship between international trade and tourism in China using time series data. Their findings indicated a bi-directional causality between tourism and trade suggesting that each factor reinforces the other. Similarly, Durbarry (2004) examined the relationship between tourism-based services exports and output growth in Mauritius, conducting a causality test between these variables. The results indicated a unidirectional Granger causality, meaning that while tourism contributed to economic growth, the reverse need not necessarily hold. This finding is significant for small island economies where tourism is a major contributor to GDP. The relationship between tourism and economic growth varies in its nature, with evidence supporting both short-run and long-run linkages. Khalil et al. (2007) discussed the role of tourism in economic growth in the context of India. The study used the vector autoregressive (VAR) model to examine the relationship between tourism and economic growth. The study finds strong evidence supporting the "tourism-led growth hypothesis," showing that tourism development significantly impacts GDP growth. The authors emphasize that policies promoting tourism can have positive spillover effects on employment and infrastructure development in India. Basu and Chakraborty (2014**)** use data from 1990 to 2012 and applies Granger causality tests to determine the direction of the relationship between tourism and economic growth in India. The study identifies bidirectional causality between tourism and economic growth, indicating that while tourism promotes economic growth, economic growth also enhances tourism by improving infrastructure and services. The authors advocate for increased government intervention to promote sustainable tourism in areas with high tourism potential but insufficient infrastructure. Khoshnevis and Khanalizadeh (2016), Ohlan (2017) and Badulescu et al. (2020) further indicated that the causality between tourism and economic growth can be either unidirectional or bidirectional, depending on the country and its specific circumstances.

Objectives of the Study

1. To study the role of tourism sector in Indian economy.
2. To examine the impact of tourism sector on India's economic growth.

Hypothesis

The study presumes that tourism sector has no impact on economic growth of Indian economy.

Research Methodology

This study adopts a quantitative approach to investigate the impact of tourism revenues on economic growth, specifically measured by GDP, for the period from 1991 to 2019. The OLS method is applied to estimate the relationship between tourism receipts and GDP. The Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root test have been applied to check the stationarity of the variables. These tests are essential for ensuring that the time series data is stationary and suitable for regression analysis to avoid the spurious results that could arise from non-stationary data.

Tourism in India- significance and its Current scenario

The ancient Indian philosophy embodied in the phrase "Atithi Devo Bhava" highlights the deep-rooted cultural reverence for guests, equating them to deities. This concept underscores the significance of tourism in Indian culture, where the guest is treated with the utmost respect and honor. In modern times, tourism has become a pivotal sector contributing significantly to India's economic growth. Campaigns such as "Incredible India," the introduction of e-tourist visas with multiple-entry options and reduced fees, and programs like "Swadesh Darshan," "PRASHAD," and the "India Tourism Mart" are all aimed at promoting the tourism industry.

As per the World Travel and Tourism Council (WTTC) 2020 report, India ranks 10th worldwide in terms of the tourism sector's contribution to GDP, which was 6.8%, or roughly US$194.30 billion. The report also projects that between 2018 and 2028, tourism's overall contribution to India's GDP will increase at an annual rate of 7.1 Based on its natural and cultural resources, India is ranked 34th in the World Travel and Tourism Index. Furthermore, India's Tourism Satellite Accounts (TSAs) have provided more detailed insights, showing that tourism's contribution to the national GDP is 6.8% in total and 5.2% when considering indirect effects. Since 2015, the government has been more proactive in marketing its tourism assets globally, while adopting flexible policies to enhance the sector's competitiveness and growth.

Due to COVID-19 restrictions, India's Foreign Tourist Arrivals (FTAs) registered a significant drop in 2021. The number of FTAs fell to 1.52 million in 2021 from 2.74 million in 2020, marking a sharp decline of 44.5%. Despite the overall negative trend in foreign tourist arrivals, Non-Resident Indians (NRIs) and International Tourist Arrivals (ITAs) showed positive growth. The number of NRI arrivals increased by 52.6% from 2020 to 2021 and international tourist arrivals grew by 10.6% during the same period.

The United States, Bangladesh, the United Kingdom, Canada, Nepal, Afghanistan, Australia, Germany, Portugal, France, the Maldives, Sri Lanka, the Russian Federation, Iraq, and the Netherlands were the top 15 source markets for foreign tourist arrivals (FTAs) in India in 2021. Together, these countries accounted for around 80.9% of India's total FTAs. Despite the challenges posed by the pandemic, tourism remained a vital contributor to India's foreign exchange earnings. In 2021, India earned US $8.797 billion from tourism, an increase of 26.4% compared to US $6.958 billion in 2020. This highlights the resilience of the tourism sector, particularly in terms of foreign exchange revenue, even amid global travel restrictions.

Results and discussion

Unit root test for stationarity

To form an econometric model, the nature of data series must be examined by testing for stationarity. This is required to ensure the validity of subsequent regression analysis. The stationarity of the variables is assessed using two widely accepted methods: the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. These tests are conducted both at the level and first difference of the data, checking for stationarity with and without an intercept and time trends. The variables have been transformed in logarithmic forms to stabilize variance and linearize the relationships between them.

Tables 1 and 2 present the results of the ADF and PP tests. The variables under consideration include central government expenditure on tourism (CGET), foreign tourist arrivals (FTA), total number of tourists (TNT), and gross domestic product (GDP).

$$\Delta \mathrm{GDP}_t = \alpha + \beta t + \gamma \mathrm{GDP}_{t-1} + \sum_{i=1}^{p} \delta_i \Delta \mathrm{GDP}_{t-i} + \sum_{j=1}^{q} \phi_j \mathrm{X}_{t-j} + \varepsilon_t \quad \text{-------------(1)}$$

$$\text{Log (GDP)}_{t-1} = \beta_0 + \beta_1 \text{ Log (CGET)}_{t-1} + \beta_2 \text{ Log (FTV)}_{t-1} + \beta_3 \text{ Log (TNT)}_{t-1} \quad \text{---------(2)}$$

GDP: Gross Domestic Product
CGET: Central Government Expenditure on Tourism
FTA: Foreign Tourist Arrivals
TNT: Total Number of Tourists
RT: Receipts from Tourism

Equation (2) represents the normalized version of the equation with GDP as the dependent variable.

Table 1 Results of ADF unit root tests.

Variable	Intercept				Trend and Intercept			
	Level		First Difference		Level		First Difference	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
Log (CGET)	—0.589	0.614	—4.127	0.003	—3.411	0.009	—3.453	0.031
Log (FTA)	0.070	0.722	—3.141	0.049	—2.537	0.488	—2.657	0.168
Log (TNT)	—3.218	0.028	—3.121	0.041	—0.923	0.436	—4.369	0.019
Log (GDP)	—0.042	0.712	—4.932	0.009	—1.748	0.407	—4.784	0.004
Log (RT)	—3.890	0.032	—3.440	0.043	—0.794	0.323	—4.087	0.023

The results of the Augmented Dickey-Fuller (ADF) unit root tests indicate that at the level form, all variables, except for Log (TNT) under the intercept-only model fail to reject the null hypothesis of a unit root (non-stationarity) as their p-values are greater than 0.05. This implies that these variables are non-stationary at their levels. However, after applying first differencing, the variables Log (CGET), Log (FTA), Log (TNT), Log (RT) and Log (GDP) become stationary, as their t-statistics are greater than the critical values, and their p-values are less than 0.05 in most cases. This means that the series becomes stationary after differencing once, indicating that these variables are integrated of order one, I (1). The presence of both intercept and trend models shows a similar pattern, with all variables eventually achieving stationarity at first difference, except for Log (FTA), which does not fully achieve stationarity under the trend and intercept model at a 5% significance level.

The results of the Phillips-Perron (PP) unit root tests in table 2 reveal that all variables, except Log (TNT) at the level form, do not reject the null hypothesis of a unit root when examined at their levels, as indicated by their p-values being greater than 0.05. This suggests that these variables are non-stationary at the level form. However, when the first differences are taken, all variables become stationary since their t-statistics exceed the critical values, and their p-values are less than 0.05, signifying that they reject the null hypothesis of a unit root.

Table 2 Results of PP Unit Root Test

Variable	Intercept				Trend and Intercept			
	Level		First Difference		Level		First Difference	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
Log (CGET)	-0.576	0.666	—4.123	0.005	—2.456	0.601	—3.765	0.029
Log (FTA)	-0.039	0.73	—3.789	0.005	—2.723	0.312	—3.231	0.030
Log (TNT)	-8.265	0.000	—3.376	0.039	0.446	0.734	—4.278	0.015
Log (GDP)	-0.053	0.729	—4.612	0.003	—1.782	0.566	—4.541	0.007
Log (RT)	-0.045	0.62	—3.476	0.045	—2.349	0.389	—3.432	0.035

The Log (CGET), Log (FTA), Log (TNT), Log (RT) and Log (GDP) all exhibit stationarity after first differencing. Notably, Log (TNT) has a significant t-statistic at the level form with a p-value of 0.000, indicating that it is stationary without differencing, which suggests a strong level of integration. Overall, the PP test results confirm that all variables are integrated of order one I (1) indicating they require differencing once to achieve stationarity.

Table 3 Results of the OLS model about the GDP growth rate and tourism receipt

	Coefficients	Prob.	R-squared	0.268756
Intercept (C)	7.87532	0.0000	Prob (F-statistic)	0.213453
Receipts from Tourism	0.000354	0.0583	Adjusted R-squared	0.026543
			F-statistic	0.216987

GDP Growth Rate = C (1) + C (2) * Receipts from Tourism

GDP Growth Rate = 7.87+ 0.00354* Receipts from Tourism

$GGDP = 7.87 + 0.00354\ RT + \varepsilon \Rightarrow (GGDP = \beta_0 + \beta_1\ RT + \varepsilon)$

The coefficient of tourism receipts is 0.000354, meaning that a 1% increase in tourism receipts leads to a 0.000354% increase in GDP growth, (movement in a positive direction). The R-squared value is 0.268756, indicating that approximately 26.10% of the variation in GDP growth is explained by changes in tourism receipts. This suggests that tourism receipts have a significant but not overwhelming impact on GDP growth. The intercept value of 6.32 reflects the baseline GDP growth rate in the absence of tourism receipts, indicating the growth level without factoring in the influence of tourism on the economy.

Opportunities and Challenges

Tourism plays a significant role in driving economic growth by directly impacting trade through increased demand for goods and services, both locally and internationally. Tourists create demand for food, clothing, souvenirs, and other products, which stimulates local industries and opens up new markets for exporters. The tourism encourages the development of new products and services specifically designed for travelers, such as tour packages, adventure sports, and cultural experiences. The tourism sector also benefits the industrial sector. The construction of hotels, resorts, and infrastructure to support tourism generates higher demand for raw materials such as steel, cement, and wood, boosting the construction and manufacturing sectors. Tourism further stimulates related industries like transportation and communication, as governments and private companies invest in infrastructure development to accommodate tourists.

In India, tourism has promoted the growth of local industries, particularly in regions with unique cultural or natural attractions. Visitors often purchase locally made goods, including handicrafts, food products, and textiles, thereby supporting cottage industries and small-scale producers. This not only strengthens the local economy but also aids in preserving traditional crafts and techniques. Natural attractions and historical sites are among the key factors driving tourism growth in India. Tourists are drawn to destinations featuring unique landscapes like mountains, beaches, and forests, as well as cultural and historical landmarks such as ancient ruins, museums, and religious sites. Countries that invest in preserving and promoting these attractions often see substantial growth in tourism. However, the success of the tourism industry is also dependent on security and peace. Tourists tend to avoid regions perceived as unsafe or unstable. For instance, the tourism industry in India was negatively affected by militant attacks in Jammu and Kashmir, as foreign tourists hesitated to visit due to safety concerns. Conversely, countries like Switzerland and Japan, known for being safe and secure destinations, attract large numbers of tourists.

While tourism contributes significantly to economic growth, it also presents challenges, such as the spread of diseases across borders, environmental degradation, and cultural homogenization. A major concern is the spread of diseases, as seen during the COVID-19 pandemic, which spread globally through international travel. The pandemic severely disrupted the tourism industry and the global economy, leading to lockdowns, travel bans, and economic downturns.

Environmental degradation is another consequence of increased tourism. Overcrowding at natural sites, pollution from transportation, and waste generated by tourists can lead to the destruction of natural habitats and loss of biodiversity. Popular tourist destinations often suffer from littering, water pollution, and the overuse of natural resources. To mitigate these adverse effects, sustainable tourism practices are essential. Sustainable tourism aims to minimize the negative impacts of tourism on the environment, society, and culture while maximizing its economic benefits. This includes promoting responsible travel that supports local communities, preserves natural and cultural heritage, and reduces pollution and resource consumption.

Eco-tourism, a form of sustainable tourism, focuses on preserving natural environments and supporting conservation efforts. It encourages tourists to engage in environmentally friendly activities such as wildlife watching, hiking, and camping while minimizing their environmental impact. Similarly, cultural tourism promotes the preservation of traditional customs and heritage, allowing visitors to experience local culture in a respectful and authentic manner.

Governments, businesses, and travelers all have a role to play in promoting sustainable tourism. Governments can implement policies regulating tourism development, protecting natural and cultural resources, and promoting responsible tourism practices. Businesses can adopt eco-friendly initiatives, such as reducing waste, conserving water and energy, and supporting local communities. Travelers too can make more conscious choices by opting for environmentally friendly accommodations, respecting local customs, and minimizing their carbon footprint.

By addressing both the opportunities and challenges associated with tourism, sustainable practices can ensure that the benefits of tourism are maximized while its negative impacts are minimized, contributing to long-term economic growth and environmental preservation.

Conclusion

At their levels, the p-values for all the log-transformed variables are greater than 0.05, and the t-statistics exceed the critical values, indicating that the null hypothesis of a unit root cannot be rejected. In other words, these variables are non-stationary at their levels, both with and without an intercept and time trend. However, when the ADF and PP tests are applied to the first-differenced data, the results change significantly. The test statistics for the first-differenced variables are much lower, and the p-values less than 0.05. This indicates that the null hypothesis of a unit root is rejected, meaning the series become stationary after first differencing. Thus, it can be concluded that all variables achieve stationarity at their first differences, ensuring that they are integrated of order one I (1)) under the ADF and PP unit root tests. In other words, while there is evidence of a positive association between the growth of the tourism sector and economic growth in India, the influence of tourism on GDP appears to be relatively weak. This implies that although tourism contributes to economic growth, its overall impact on India's economic development is limited. However tourism sector has the potential to play a crucial role in achieving India’s long-term economic growth objectives. By enhancing tourism infrastructure, promoting diversified tourism offerings, and leveraging digital technology for better experiences, India can sustain and enhance its growth trajectory.

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Constraints in Adoption of Climate Resilient Technologies: A Study of Sirohi District of Rajasthan

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Abstract

This paper attempts to assess the constraints faced by farmers in adoption of Climate- Resilient Agriculture (CRA) technologies in Sirohi District of Rajasthan. A mixed-method research design (qualitative and quantitative) was used to analyse the barriers and hindrances to the adoption of CRA. The data was collected through interview, FGD, and structured questionnaire on 200 respondents, including adopters and non-adopters of CRA technologies. The constraints were classified as financial, input, socio-personal, guidance and training factors. The non-adopters mentioned lack of knowledge, access to resources, financial constraints, and need-based training as the reasons why they have not adopted CRA technologies. Field research indicate that unavailability of information, weak institutional credit, ineffective infrastructure and socio-cultural perception are major obstacles to climate adaptation. Small holders often see technologies that are climate resistant as expensive or risky investments due to uncertainty in returns and the lack of ability to absorb failure. Illiteracy, high cost of adoption, inadequate farmers' organization, lack of modern technologies, and poor access to weather information were identified as severe constraints in the adoption of CRA technologies. By identifying and ranking these constraints in terms of severity, this research aims to provide crucial insights that may be helpful promoting effective adoption of CRA technologies.

Introduction

The rural economy of Rajasthan is based on agriculture, which provides the means of livelihood to a major segment of population, and maintains food security in one of the most climatically vulnerable regions of India. However, climate variability and persistent climate change are increasingly threatening the long run sustainability of agrarian activities in the state (Roy & Tewari, 2020). Rajasthan is a typical example of arid and semi-arid agro-ecological environment with low and sporadic precipitation, high rates of evapotranspiration, frequent droughts and susceptible soils (Roy & Tewari, 2020). These ecological conditions have traditionally affected the farming activities in the region but the current climatic changes have increased the risks of production without the usual coping strategies. Rise in temperatures, changing rain fall pattern, decline in ground water, and increased frequency of extreme weather events have been identified as the major factors affecting the farm productivity, farm income, and rural livelihood in the last few decades.

Empirical studies on climate variability in the western drylands of Rajasthan indicate that there is a progressive rise in temperature and a decrease in rainfall thereby creating sustained water-stress situations and frequent droughts (Jat et. al 2025 & Kalash 2022). Reduction in annual rainfall and increase in the intensity of evapotranspiration have increased irrigation needs and brought about unsustainability in crop scheduling. At the same time, vulnerability has been increased due to agricultural growth and the use of ground water. Current evaluations show that the state of Rajasthan draws huge amounts of groundwater for irrigation, thus pointing out reliance of the sector on the quickly fading water sources. These developments are threatening sustainable crop production, increasing the cost of production, and endangering the livelihood security of the farmers, especially those who are small and marginal producers, and are dependent on monsoon. The farmers now face increased uncertainty regarding the time to plant crops, the time to harvest, incidence of pests and stability of yields. Heat waves, late onset of the monsoon, prolonged dry seasons, and sudden heavy rain falls often end up in crop failure. Crops production is also reduced as fodder is short, and animals are stressed by heat. These changes demand a shift to climate responsive and resource effective farming systems as opposed to traditional agrarian systems.

As a reaction to these new risks, agricultural policy leaders and scientists have championed the use of Climate Resilient Technologies (CRTs) or Climate Resilient Agriculture (CRA) practices. The concept of CRA has been driven by the desire to develop sustainable resilient agricultural systems that seek to improve productivity, reduce greenhouse gas emissions, and promote adaptation to changing environmental systems in response to climate change. Some such examples include drought resistant and short period crop varieties, diversification of crops, conservation agriculture, micro-irrigation (drip and sprinkler irrigation), rainwater harvesting, integrated nutrient management, weather based agro-advisories, integrated pest management, fodder banks, and resilient livestock practices.

Although CRA technologies possess significant potential in protecting food security and rural livelihoods, their application is faced with numerous stiff obstacles at the grassroots level (Akhtar et. al 2020). Small-holder farmers are facing huge problems in the process of adopting climate-smart technologies that can be used in their local socio-economic settings. Such producers operate on small pieces of land and often do not have access to credit systems which makes it difficult for them to adopt CRA technologies.

As far as climate resilience technologies are concerned, the adoption of better crop varieties and resource-saving systems has resulted in significant increase in productivity and stability in Rajasthan; for instance, the use of short days and drought resistant varieties of crop varieties have significantly improved the production in dry areas (Sharma et al, 2024). Likewise, massive application of climate-resilient interventions like water harvesting facilities, composting, deep ploughing, and high-quality varieties of crops have also produced quantifiable changes in crop production and livestock performance in different regions of the state. These results indicate that under the changing climatic conditions, there are fair prospects of climate-resilient technologies bringing about stability in farm revenue and overall sustainability in agriculture.

Objectives of the Study

1. To identify and analyse the key constraints faced by farmers in the adoption of climate-resilient agricultural technologies.
2. To analyse the socio-economic, institutional, and farm-specific characteristics of both, the farmers adopting climate-resilient agricultural technologies and the farmers not adopting climate-resilient agricultural technologies.
3. To suggest suitable policy measures and strategies for enhancing the adoption of climate-resilient agricultural technologies in the study area.

Research Methodology

Sampling Design and data collection

The study was conducted during June-July 2024 in Sirohi district of Rajasthan. A total of 200 households were selected from various villages to capture the varied perspectives and conditions of the farmers. First, two blocks, Pindwara and Sirohi, were selected randomly and then from each block, two villages were selected randomly. From the four selected villages, 50 farmers per village were selected randomly, giving a total sample of 200 farmers. This method ensured adequate representation of farmers from different villages within the selected blocks. Primary data was gathered through structured questionnaire and field observations, offering direct insights into farming practices and challenges. The questionnaire was divided into two parts. The first part gathered data on the socioeconomic attributes of the respondents such as age, sex, level of formal education, household size, size of the farm, and farming experience. The second part collected information pertaining to the practices of CRA technologies, the issues faced by practicing farmers, and the perceived barriers to the adoption of CRA, as mentioned by farmers. To further analyze the survey data, especially extreme observations, and to gain other critical insights, Focus Group Discussions (FGDs) were carried out.

To understand the constraints and major challenges facing the farmers in adopting climate-resilient technologies in the study area, data was gathered and the perceptions of the farmers concerning these issues were assessed; all identified constraints were further analysed. This was done by randomly selecting 50 respondents from each village leading to a sample of 200 respondents from the four randomly selected villages. The ex-post facto research design was chosen based on the premise that the manifestation of the variables had already taken place, and further manipulation was impossible. Systematic interview schedule was used to collect primary data. The respondents were asked, inter alia, to rank the given constraints in terms of their perceived level of severity. The rankings given by the respondents to major constraints in the adoption of CRA technologies were assessed based on the Garrett ranking technique (Garrett and Woodworth, 1969). The rank orders of the respondents were transformed into score values using the following formula:

$$\textbf{Percent position} = (100 \times (R_{ij} - 0.5)) / N_j$$

Where, R_{ij} = Rank given for the i_{th} variable by j_{th} respondents,
N_j= Number of variables ranked by j_{th} respondents

The estimated percentage positions were converted to scores. The sum and the mean scores were calculated and the scores of each respondent were summed up on each factor. The factor with the highest mean score was considered to be the most important.

The Problem Confrontation Index (PCI) methodology was used to measure the degree of constraints facing rural agricultural producers. Twelve issues were determined in the first survey of exploration and later on they were offered to a sampled group of farmers with particular emphasis on farmers who were in the system of CRA. The respondents were to evaluate all the identified problems at four levels of difficulty that were preset: high, medium, low, and not at all. These nominal responses were operationalized through a system of weighting where 3, 2, 1 and 0 were used to score them respectively. Based on this, individual problems were each scored on a scale of 0 to 3. The further calculations of the PCI values made it possible to rank the constraints according to their perceived severity.

$$PCI = (P_{high} \times 3) + (P_{medium} \times 2) + (P_{low} \times 1) + (P_{not\ at\ all} \times 0)$$

where, P_{high} means the frequency of the number of responses showing that problem occurred most of the time; P_{medium} means the frequency of the number of responses showing that the problem occurred occasionally; P_{low} means the frequency of the number of responses showing that the problem occurred rarely; and $P_{\text{not at all}}$ means the frequency of the number of responses showing that there was no problem at all.

An Overview of Sirohi District

Sirohi, district of Rajasthan, with its arid climate and subsistence agriculture, lies in the southwest of the state and exhibits a transitional climatic regime, conditioned by the arid plains of western Rajasthan and the relatively sub-humid climate of the Aravalli hill range. The district experiences a tropical monsoon climate marked by hot summers, a short and uncertain monsoon season, and mild winters. Summer temperatures range between 35°C and 42°C, increasing evapotranspiration and crop water stress, while winters remain moderate. Annual rainfall, largely concentrated during the southwest monsoon (July–September), varies between 600–900 mm but is characterized by high inter-annual variability and erratic distribution. The presence of the Aravalli Mountains, particularly around Mount Abu, moderates local climatic conditions and results in comparatively higher rainfall than neighbouring desert districts. Therefore, whereas the areas like Mount Abu benefit from relatively favourable climatic conditions, the plains of Sirohi district remain highly vulnerable to droughts, prolonged dry spells, and groundwater depletion. This spatial heterogeneity in climate creates uneven agricultural and technological adoption environments across the district. The climatic conditions imply inter-area differences in the availability of water and an overall scarcity of water resources at the district level. High initial investment costs, inadequate infrastructure, and risk-averse behaviour among small and marginal farmers coupled with the climate related constraints limit farmers' willingness and capacity to invest in climate-resilient technologies such as micro-irrigation systems, drought-tolerant crop varieties, and water-efficient agronomic practices thereby acting as significant constraints in the adoption of climate-resilient technologies. Therefore, a combination of factors like climate variability, resource constraints and institutional constraints, influences land use patterns, cropping decisions, and water management practices, climate being a critical determinant of the ease of adoption of climate-resilient technologies in the district.

Analysis and Discussion

Table 1 presents descriptive statistics and the socio-economic characteristics of both adopters and non-adopters (200 sampled farmers) of Climate Resilient Agriculture Technologies (CRA). It is evident from the table that the majority of respondents possessed basic to moderate levels of formal education. About 37% of the farmers had completed secondary education (classes 6–10), followed by 29% with primary education (classes 1–5). However, a considerable proportion (20.5%) of the respondents were illiterate, indicating absence of formal schooling among a sizeable segment of the farming population. Only a small fraction had received higher secondary education (10.5%) and an even smaller fraction had received higher education (3%), suggesting low presence of highly educated people in the agriculture sector. Regarding institutional characteristics, nearly two-thirds of the respondents (67.5%) reported having prior training experience, reflecting moderate institutional outreach.

Access to machinery was relatively limited, as only 46.5% of farmers had access to agricultural machines, while a larger proportion (53.5%) lacked such access. Similarly, access to agricultural extension services was also limited with 51% of farmers reporting access and 49% having none. Specific training related to conservation agriculture (CA) was also low, as only 40.5% of respondents had received CA-related training, indicating a gap in targeted capacity-building efforts. These respondents indicated that their training on matters concerning agricultural practices including the technical knowledge and farming skills has not been satisfactory.

Table 1: Household, Institutional, and Farming Characteristics of Sampled Farmers

	Variables	Type and description	No.	Percentage (%)
Household characteristics	(1) Age	Continuous		
	(2) Education Level	Categorical		
		Illiterate (No formal education)	41	20.50
		Primary level (class 1-5)	58	29.00
		Secondary level (class 6-10)	74	37.00
		Higher Secondary (class 11-12)	21	10.50
		Graduate (bachelor and above)	6	3.00
	(3) Household size	Continuous		
Institutional characteristics	(1) Training experience	Dummy		
		Yes (1)	135	67.5
		No (0)	65	32.5
	(2) Access to machines	Dummy		
		Yes (1)	93	46.5
		No (0)	107	53.5
	(3) Access to extension service	Dummy		
		Yes (1)	102	51
		No (0)	98	49
	(4) Access to CA training	Dummy		
		Yes (1)	81	40.5
		No (0)	119	59.5
Farming characteristics	(1) Farming experience	Categorical		
		<10 years	58	29
		11-20 years	52	26
		>21 years	90	45
	(2) Farm size	Continuous		

Source: Based on field data

As far as farming characteristics are concerned, the sample consisted largely of experienced farmers. About 45% of respondents had more than 21 years of farming experience, highlighting the dominance of seasoned farmers in the study area. While only 29% had less than 10 years of experience, 26% had farming experience ranging between 11 and 20 years. This distribution suggests a mix of both experienced and relatively newer farmers with a tilt towards experienced farmers. Farm size and household size, treated as continuous variables, further reflect the small-holder nature of farming in the study area. It is evident from the table that the farming population is predominantly composed of small-scale, experienced farmers with moderate levels of education and partial access to institutional support services, particularly in terms of machinery and conservation agriculture training.

A Garrett ranking was computed to determine the relative severity of the constraints in the implementation of climate-resilient technologies at the farm level, and the findings are provided in Table 2. Constraints were divided into four categories: (i) Financial constraints, (ii) Input constraints, (iii) Guidance and training constraints and (iv) Socio-Personal constraints.

Table 2: Constraints in Adoption of Climate Resilient Technologies

S.No.	Constraints	% Score	Rank	Overall Rank
Financial constraints				
1	High cost of climate resilient varieties (e.g., drip irrigation, improved seeds, precision tools, solar pumps)	58.75	2	7
2	Inadequate institutional financial support to adopt climate resilient technologies	62.45	1	6
3	Lack of savings and inadequacy of own capital	45.68	4	14
4	Limited access to affordable credit.	29.18	7	21
5	Lack of collateral security and complex procedure that small farmers cannot meet	37.93	6	17
6	Short repayment periods	43.98	5	15
7	Ongoing costs involved with some practices which small farmers struggle to afford.	56.24	3	10
Input constraints				
1	Shortages of high-yielding and drought-resistant seeds	48.45	3	12
2	Marginal and scattered land holding (fragmented land))	57.09	2	9
3	Lack of availability of improved seeds (e.g., drought-tolerant varieties).	37.79	4	18
4	Climate resilient varieties/hybrids susceptible to pests and diseases	65.94	1	4
Guidance and training constraints				
1	Lack of knowledge on climate resilient variety of seeds	70.93	1	2
2	Lack of weather updates and guidance for soil reclamation	48.89	4	11
3	Inability to attend demonstrations & training programmes	64.56	2	5
4	Poor access to timely, location-specific weather and technology information.	57.87	3	8
5	Inability of the officials to provide services to all farmers during the peak period	42.67	5	16
Socio-Personal constraints				
1	Lack of awareness on climate change	46.88	3	13
2	Lack of knowledge on climate resilient technologies	67.34	2	3
3	Inability to accept new practices due to risk (risk-averse)	35.76	4	19
4	Resistance to change and preference for conventional practices	71.22	1	1
5	Scarcity of labour due to migration of young people to urban areas	31.64	5	20

Source: Authors'calculation based on field data

In the overall ranking, ‘lack of knowledge on climate resilient varieties of seeds emerged as the second major constraint after ‘Resistance to change and preference for conventional practices. It seems from the analyses that the order in terms of severity in preventing adoption of CRA techniques is: (i)Socio-Personal constraints (ii) Guidance and Training constraints (iii) Input constraints and (iv) Financial constraints. Table 3 contains information about the constraints faced in adoption of climate resilient technologies by adopter and non- adopter farmers.

Table 3: Constraints faced in Adoption of Climate Resilient Technologies by the Adopter and Non- adopter farmers

S.N.	Constraints	Adopter			Non- adopter			Total		
		Score	Mean	Rank	Score	Mean	Rank	Score	Mean	Rank
1	Lack of awareness on climate change and problems	121	2.01	9	109	1.81	11	230	1.91	10
2	Lack of knowledge about CRA methods and technologies	134	2.23	6	154	2.56	2	288	2.40	4
3	High labour cost	127	2.11	8	118	1.96	9	245	2.04	8
4	Lack of short-term and drought resistant varieties of crops.	151	2.51	3	147	2.45	3	298	2.48	3
5	Inadequate supply of essential inputs.	129	2.15	7	132	2.2	6	261	2.17	7
6	Failure to have line departmental support	110	1.83	11	112	1.86	10	222	1.85	11
7	Inadequate rainfall	162	2.7	1	158	2.63	1	320	2.66	1
8	Lack of own resources	157	2.61	2	142	2.36	4	299	2.49	2
9	The benefits associated with climate-resistant technologies do not come quickly.	117	1.95	10	125	2.08	7	242	2.01	9
10	Poor financial support	140	2.33	5	137	2.28	5	277	2.30	5
11	Absence of set livestock structures.	106	1.76	12	105	1.75	12	211	1.75	12
12	Lack of willingness to change traditional ways.	147	2.45	4	121	2.01	8	268	2.23	6

Source: Authors’calculation based on field data

The adopter and non-adopters, both individually rank inadequate rainfall as the most important constraint emphasizing the importance of climate related factors in determining the adoption of CRA methods. However, socio-personal constraints, guidance and training constraints, input constraints and financial constraints are also significant determinants.

Farmers were asked to suggest ways and measures that would enable them to overcome the constraints faced by them and enhance the adoption of climate-resilient technologies. Table 4 contains suggestions given by adopters and non-adopters. From the information collected percentages, frequencies and ranks were obtained. The percentage of those respondents who suggested to organize more training programmes and on-farm demonstrations to show the practical benefits of climate-resilient technologies was 93.33 for adopters and 88.33 for non-adopters culminating into an overall percentage of 90.83 percent. The provision of financial aid for soil and water conservation which was suggested by 90 per cent of the adopters and 78.33 percent of the non-adopters with an overall percentage of 84.16.

Table 4: Suggestions of the Respondents to Promote the Adoption of Climate Resilient Technologies

S.N.	Constraints	Adopter			Non- adopter			Total		
		Score	Mean	Rank	Score	Mean	Rank	Score	Mean	Rank
1	Climate-resilient technologies should be introduced through awareness programs	48	68.33	4	54	90.33	2	91	75.83	5
2	Organizing more training programs and on-farm demonstrations to show the practical benefits of climate-resilient technologies.	59	93.33	1	52	88.33	3	109	90.83	1
3	Soil and water conservation should be assisted financially	56	90.00	2	50	78.33	4	101	84.16	4
4	Important inputs must be supplied at reduced prices on a timely basis	51	85.00	3	56	92.67	1	106	88.33	2
5	Strengthening cooperatives and self-help groups (SHGs) to facilitate collective purchasing, knowledge sharing, and better bargaining power	47	78.33	4	44	6	6	92	76.67	3
6	Follow up activities	45	81.67	5	47	81.67	5	98	81.67	6
7	Improving coordination between research institutions, Krishi Vigyan Kendras (KVKs), and farmers to promote location-specific, need-based climate-resilient solutions	42	76.67	6	41	70.00	7	88	73.33	7

Source: Authors'calculation based on field data

Timely availability of essential inputs at a subsidised rate was suggested by 85 per cent of the adopters and by 92.67 percent of the non-adopters with an overall suggestion percentage of 88.33 percent. Around three-quarters of the adopters and 70% of the non-adopters wished to have better and more effective coordination between research institutions, Krishi Vigyan Kendras (KVKs) and the farming community with a view to promoting more climate-resistant solutions which are localized. Dissemination of knowledge about the CRA techniques and training, timely supply of essential inputs at subsidised prices and financial assistance for soil and water conservation acquired top ranks

To explore the nature and extent of constraints confronted by respondents a Problem Confrontation Index (PCI) has been computed. It is an analytical tool used in climate resilience agricultural studies to rank the severity of constraints which prevent the farmers from adopting climate-resilient technologies. The PCI is calculated by gathering data on the severity of problems perceived by respondents and assigning numerical scores to calculate a weighted average. This produces a ranked list, with higher PCI values indicating more severe constraints to adopting technology. The scores obtained in terms of PCI are presented in table 5. The PCI scores of each of 200 farmers with the 10 identified constraints were computed. A larger PCI indicates that the constraint in question is experienced by the farmers as being severer. A total of 181 respondents mentioned the lack of access to critical inputs with a PCI of 618, as the greatest barrier to the adoption of climate-resilient agriculture (CRA). The constraint associated with the lower yield in the short term scored the least PCI of 398, which means that it was considered least severe.

Table 5: Problem Confrontation Index (PCI)

S.N.	Problems stated by respondents	High	Medium	Low	Not at all	PCI	Rank
1	I am worried on the timely accessibility of inputs necessary to achieve climate-sensitive agricultural (CRA) practice.	181	11	6	2	618	1
2	I do not know much about CRA in detail and feel scared of decision-making.	163	25	12	2	601	2
3	I need technical assistance to embrace CRA.	160	21	14	5	596	3
4	I believe CRA is more complicated than my practice is at present.	151	30	15	4	570	4
5	Limited income and high production risks prevent investment in CRA technologies.	145	25	24	6	559	5
6	CRA will be more productive in the long run, and I cannot work in the current situation.	146	28	23	3	554	6
7	Currently, I use crop residues to feed livestock and fuel, thus, I cannot leave it on the ground.	109	73	16	2	511	7
8	Climate-resilient machines are too expensive for small and marginal farmers like me.	110	56	27	7	510	8
9	The management of water resources and the quality of the soil is one of my key concerns.	54	123	17	6	461	9
10	I fear that minimum or zero tillage can lower yield.	57	55	81	7	398	10

Source: Authors'calculation based on field data

Timely access to inputs needed for climate-resilient farming, lack of knowledge and awareness about CRA, requirement of technical assistance and availability of specialised machinery and availability of trained operators on these specialised machines on time emerge out be important constraints from table 5. The group discussions also indicated that the high price of climate-resistant equipment is a major constraint for small and marginal farmers, thus hindering the use of CR agriculture within the study area. Low income and high production risks are other discouraging factors that may push farmers away from CRA.

To find the impact of factors affecting the dependent variable (constraint level of CRA/CRT) regression technique has been used (table 6). The model explains a large proportion of variation in the adoption level of CRA/CRT, with an R^2 value of 0.580, indicating that about 58.0 per cent of the variation in the dependent variable are jointly explained by the selected explanatory variables. The adjusted R^2 (0.558) further confirms the good explanatory power of the model after adjusting for degrees of freedom. The coefficient of age (β□) is positive but statistically non-significant (p=0.363), suggesting that age does not have a significant influence on the adoption behaviour. This implies that both younger and older farmers adopt climate-resilient practices at similar levels.

Table 6: Summary of the Multiple Linear Regression Model

Explanatory variable	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B_i	Std. Error	Beta		
β_0 (Constant)					0.000
β_1 (Age)	0.069	0.074	0.081	0.9324	0.363
β_2 (Formal education)	-1.347	0.523	-0.166	-2.5755	0.009
β_3 (Training experience)	-2.2	1.531	-0.148	-1.4370	0.007
β_4 (Access to machines)	-3.251	0.783	-0.193	-4.1520	0.001
β_5 (Household size)	0.326	0.377	0.019	0.8647	0.703
β_6 (Access to extension services)	-1.256	1.754	-0.063	-0.7161	0.237
β_7 (Access to CA training ($\beta 7$)	-1.872	0.864	-0.087	-2.1667	0.091
β_8 (Farming experience: <10 years)	2.876	4.815	0.113	0.5973	0.633
β_9 (Farming experience:11-20 years)	2.809	4.214	0.114	0.6666	.0595
β_{10} (Farm size)	-0.084	0.016	-0.390	-5.2500	0.000
R^2= 0.580 Adjusted R^2= 0.558					

The explanatory variables that are significant at 5 % level are- formal education, Training experience, access to machines and farm size. The coefficients of all these four variables are negative indicating a negative significant relationship between constraint level in the adoption of CRA/CRT and these variables individually. The analysis indicates that higher levels of formal education are associated with lower constraint levels. Formal education enables farmers to understand the need and importance of CRA and their knowledge, skills and education outreach via informal communication methods (social media, messaging services, TV, door-to-door information sharing) may make them participate in the cognitive process of realizing the value of CRA.

Higher levels of training experience are also associated with lesser resistance to the adoption of CRA/CRT. Training enhances knowledge and empowers the farmer enabling him to have a rational approach and accept practices that are new and unconventional but have the potential of addressing the problems faced by them. Therefore, government departments and non-governmental organizations offering agricultural extension services have a positive role in terms of designing appropriate and regular training programmes for the adopters and the non-adopters. Training is instrumental in the dissemination of technology in the target population. Availability and timely access to technology and machines needed for CR farming also has a positive impact on the adoption of CRA techniques. 'Access to machines' is not only significant but also the highest impactor in reducing barriers to CR farming. Larger farm sizes are associated with lower barriers to the adoption of CR techniques meaning that big farmers with more resources and capital are less likely to resist adoption of CR techniques. The fact that these farms have a greater income stability allows them to enjoy the benefits of the implementation of the climate-resilient farming practices. Length of farming experience had but positive insignificant coefficient indicating that the mere length of farming experience does not have a significant impact on the adoption decisions.

Conclusion

Climate change has dire repercussions in agricultural settings and therefore, it is important to embrace climate-resilient agriculture (CRA) to increase productivity, improve adaptation, and decrease emissions. Although there is a pressing need for adopting climate-resilient agriculture, the adoption rates are quite low because of barriers like expensive cost, lack of knowledge, training and institutional gaps, small-holding access to machines and technology and tilt towards traditional farming culture. The traditional farming culture is strong-rooted and creates resistance to change hindering the adoption of new climate-smarter solutions [2,6]. Also, Small-holder farmers face huge constraints, including high input costs, lack of technical expertise and institutional support, hence obstructing the extensive adoption of CRA. In general farmers lack, adequate acquaintance with the cultivation practices, access to the CR seeds, willingness to implement new methods, knowledge of CRA technologies, availability of real-time weather data to make informed decisions. In addition, and high costs of building wells or farm ponds leads to procrastination on part of the farmers. In most villages, extension services are still not strong and thus farmers have to operate with informal system of knowledge and traditional weather prediction. The problem is further aggravated by institutional and policy constraints. The lack of effective transfer of technology is caused by gaps between research institutions, extension agencies, and farmers. Demonstrations and training programmes are frequently limited in size and duration and lack location-specific instructions which makes technologies to appear inappropriate.

In order to ensure adoption of CR technologies on a larger scale, preventive efforts have to be made to overcome the obstacles that are facing farmers, so that these can be mitigated. The agro-climatic zone heterogeneity of Sirohi and Rajasthan means that a uniform technology package cannot mitigate all the regional vulnerabilities which requires adaptation strategies to be regionalized.

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