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RESEARCH PAPER

Environmental Justice Interventions and Poverty Alleviation in Climate-Vulnerable Regions: Evidence from South Asia

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ABSTRACT

This study explores how environmental justice interventions impact rural poverty reduction in seven South Asian countries from 1999 to 2023, focusing on gender and pro-poor linkages. Rural poverty in South Asia is exacerbated by structural inequalities, climate change, and limited access to resources. Environmental justice, including clean energy, sustainable water management, and agricultural innovations, is a critical pathway to poverty alleviation, yet its mechanisms remain understudied. Using panel data from World Governance Indicators (WGI) and World Development Indicators (WDI), the study employed advanced econometric techniques such as fixed effects and fully modified ordinary least squares (FMOLS) models to analyze causal relationships among key variables. Access to electricity emerged as the most significant driver of poverty reduction. GDP per capita strongly correlated with poverty alleviation, while climate impacts on agriculture and healthcare expenditure showed nuanced, context-dependent effects. Policymakers should integrate equitable resource distribution, sustainable development, and climate resilience into coordinated frameworks aligned with global sustainability goals. Micro-level and longitudinal studies are suggested for future research.

KEYWORDS Environmental Justice, Poverty Alleviation, Clean Energy Access, Water Management, Agricultural Productivity, Rural Development

Introduction

Rising climate urgency in the current era makes emerging economies have to confront the double challenge of alleviating rural poverty while applying equitable environmental justice approach to the climate vulnerable regions. The fight against this struggle is particularly visible in South Asia, which is home to some of the climate sensitive world populations and where the effects of climate change deepen the existing socio economic disparities (Mbah et al., 2022; Rao et al., 2025). While adaptation strategies for climate change have increasingly drawn the attention of researchers, there is a massive knowledge gap of how environmental justice interventions specifically impact poverty alleviation in poor agricultural communities facing climate change risks.

In the rural context of South Asia, smallholder farmers, indigenous communities and excluded groups are hardest hit by the shocks induced by climate change (Sarfo-Adu & Kokofu, 2023; Zhou et al., 2022). Thus, frameworks of environmental justice, which concentrate on equitable distribution of resources and policy-making involving all stakeholders, sound as a promising way to reduce the aforementioned vulnerabilities. Yet little empirical evidence exists regarding the effect of such policies on reducing rural

poverty. This paper attempts to fill this gap by investigating the role of environmental justice interventions in poverty reduction particularly in South Asia's climate vulnerable areas.

However, there has been a lack of studies regarding their impacts on rural poverty specifically. The disproportionate effects of climate change on marginalised communities in agrarian economy where lives are closely related to natural resources have recently been drawn attention (Diedrich, 2024; Jayawardena, 2024). For example, in studies conducted in Ethiopia and Nigeria (Folorunso, 2024; Yimam & Holvoet, 2023) highlight as to how climate shock induce poverty because of impact on agricultural productivity and food insecurity.

Climate change has emerged to be erratic rainfall, rising temperatures, and increased frequency of extreme weather events in South Asia, which jeopardises rural livelihoods (Aadhar & Mishra, 2023; Yan & Alvi, 2022). The lack of adaptive capacity makes them particularly vulnerable, especially the smallholder farmers who represent a large proportion of the poor in the region (Dixit et al., 2024; Zhou et al., 2022). Climate smart agriculture and policy interventions have been proposed as solutions but they are implemented without paying attention to just consideration in which the marginalized group continues to be disadvantaged (Basiru et al., 2022; Rao et al., 2025).

It is also evident in the literature, that gender sensitive and inclusive climate policies are needed. According to (Danilenko et al., 2024; Scholastica & Olanrewaju, 2022) women, as the central figures in agricultural production in South Asia, are vulnerable by nature of structural inequalities. In addition, studies in Nigeria and Zimbabwe support the fact that indigenous knowledge systems are not included in climate adaptation frameworks, resulting in undermining of resilience of traditional communities (Basiru et al., 2022; Nyahunda, 2024). Despite these insights, however, very few studies have performed a systematic analysis of how environmental justice interventions can be used to achieve poverty reduction in climate vulnerable settings.

Although there are number of studies on climate adaptation in various ways and settings, there are still important gaps of understanding for the relationship between environmental justice interventions and the alleviation of poverty. For example, (Mbah et al., 2022; Rao et al., 2025) focus on the importance of localised adaptation strategies but do not explicitly make such a connection to poverty outcomes. Likewise, (Yan & Alvi, 2022; Zhou et al., 2022) also examined the economic effects of climate change without complete anchoring of a justice-based perspective.

There is a critical paucity of the empirical evidence on how environmental justice interventions such as equitable resource allocation of participatory policy making and inclusive governance influence rural poverty in South Asia. (Basiru et al., 2022; Jayawardena, 2024) described procedural justice in relation to climate policies but they are mostly qualitative, and quantitative assessments are overlooked. Moreover, besides some studies that address the roles of agricultural value added and GDP per capita in poverty reduction(Zhou et al., 2022), few researchers have explored how these factors relate with justice oriented intervention.

Therefore, filling this gap is necessary for effective policy planning aimed at adaptive enhancement of adaptive capacity and sustainable development in vulnerable communities. If climate adaptation efforts are not delivered through a justice-centred

perspective, they risk worsening current inequalities and they will allow the most marginalised groups to be even more left behind.

Literature Review

Empowering Rural Communities: The Role of Environmental Justice and Agricultural Growth in Climate-Affected Region

This subsection looks into how environmental justice interventions (EJI), agricultural value added are important factors in rural poverty alleviation in the climate vulnerable South Asia. The role of EJIs appears to be dual — addressing the climate induced vulnerabilities on one hand and promoting equitable resource distribution and community engagement on the other hand, based on the recent literature on this topic. At the same time, agricultural value added has come to be perceived as a route to economic resilience for smallholder farmers. However, there is much controversy about scaling up localized interventions and how much agricultural innovation can alleviate poverty in contexts of high vulnerability.

Prasad et al. (2023) mapped vulnerability of farmers to target interventions in the climate resilient agriculture in India. The study integrated biophysical and social data to identify hotspots that needed urgent policy attention. The key finding was that connectivity by road and mobile banking were the key enablers of adaptive capacity. Although of high methodological rigor, the study did not pay attention to how environmental justice frameworks can help achieve equitable outcomes in the interventions examined.

Islam (2024) redefined climate justice as an ethical matter of climate induced inequalities from an environmental sociology perspective. The study focused on South Asia and showed that marginalized communities are disproportionately burdened by the impacts of climate. Although the research developed a strong theoretical bedrock that supported the proposed strategies, it lacked empirical validation of the proposed strategies, a factor that is particularly challenging in poor and vulnerable areas of the countryside, where the crises are most pronounced.

Ahmed & Eklund (2024) studied the intersectional barriers to adaptive resources in coastal Bangladesh which revealed that religion, gender and ethnicity interact to affect access to climate adaptation tools. While this study showed the necessity for inclusive policies, it stopped short at demonstrating how much poverty they would help reduce and failed to provide the economic outcomes of such measures to link intersectionality to poverty reduction.

Huang (2022) evaluated the impact of targeted poverty alleviation policies on rural China. Industrial policies significantly reduce poverty with environmental complementarities, and improve ecological conditions. However, the research did not consider the characteristics of South Asian smallholder farmers faced with the challenge of an agricultural dependent livelihood.

Samatar (2025) assessed the effectiveness of social safety nets as an instrument of poverty alleviation in Banadir region of Somalia. It was found that sustainable livelihood programmes will be needed to reduce dependency. Although, it had not addressed the environmental justice interventions to ensure equitable access to the resources, a critical vacuum of the analysis remains.

Kaushik et al. (2023) collected India climate-resilient agricultural practises, Bangladesh climate resilient agricultural practises and Afghanistan's climate resilient agricultural practises. Integrated approaches to counter climate adversities were emphasised as a study. However, the research did not assess the economic impact of these practises for alleviating rural poverty.

An analysis of the studies showed themes such as the significance of equitable resource distribution, the significance of infrastructure to enhancing adaptive capacity, and the use of localized interventions are common themes. However, significant gaps remain. For example, examples of environmental justice frameworks are relatively few and the economic outcomes of those frameworks and the ability to scale up agricultural innovations haven't been empirically tested. Furthermore, little investigation is made on how intersectional barriers affect access to adaptive resources.

Interplay of Climate Change, Economic Growth, and Environmental Justice in Rural Poverty Reduction

This section specifies mediating roles of climate change impacts and GDP per capita in environmental justice interventions (EJIs) on alleviating rural poverty. Research has recently highlighted that although EJIs try to address systemic inequities, outcomes vary based on the severity of climate change impacts and the level of economic resilience in communities, which is usually approximated by GDP per capita. South Asia is where these variables play out the most because there are more vulnerabilities fuelled by climate disruptions and incomes are not distributed equitably. Yet, the mechanisms linking these factors with one another still remain largely unexplored.

Aggarwal (2025) modelled the impact of climate policies on firewood collection as well as women's welfare in developing countries. The study found that combination of climate change with resource scarcity disproportionately burdened the low-income households. The research documented gender impacts but did not assess the mediating role of GDP per capita in the policy effectiveness to reduce rural poverty.

Shahzad (2023) examined the climate change, social disruption, and environmental justice The research noted that marginalised groups had been made more vulnerable by climate impacts. Yet it neither quantified the impacts of GDP per capita nor assessed the scalability of such justice-oriented solutions to the context of the Rest.

Zhou et al. (2022) in a systematic review compared rural and urban vulnerability to climate change in South Africa. This study is based on the finding that rural areas were more severely affected in terms of lower GDP per capita. However, it did not do this while examining the function of environmental justice interventions to close the gaps in these disparities or improve on adaptive capacity.

Zenda & Rudolph (2024) reviewed agroecology strategies for smallholder farmers in South Africa. However, this study neglected to investigate whether the adoption and success of the local interventions have the influence of GDP per capita and climate change impacts on the reduction of rural poverty.

Bitire (2023) appraised Ethiopia's climate change regulatory frameworks in terms of their alignment to the UNFCCC principles. The study was found useful in studying policy congruence, but did not examine the combination of GDP pp cap. and the environmental justice interventions in straitjacketing climate induced poverty.

Radonic & Zuniga-Teran (2023) proposed tenets for socio-environmental justice in urban climate adaptation. The study concentrated on distributive and procedural justice; however, it excluded its analysis to rural context and it did not include the mediating effect of GDP per capita and the impact of the climate on poverty alleviation.

The examined literature clearly shows that climate change effects, GDP per capita and environment justice interventions interact in a very complicated way and are therefore important in alleviating rural poverty. However, significant gaps remain. For example, few studies empirically screen how GDP gets between per capita dampens the potency of the wet environmental justice frameworks, or how much economic benefit the progressive solutions for environmental justice provide. Furthermore, the way extreme resource scarcity due to climate change intensifies income inequality is neglected.

Strengthening Environmental Justice: The Critical Role of Education and Healthcare in Poverty Alleviation

The purpose of this subsection is to explore the synergistic effects of education and access to healthcare in enhancing the poverty prevention impacts of environmental justice interventions (EJIs). Recent research notes that education and healthcare access should be fair and equitable access to resources because not only does it enhance human capital, it makes communities resilient to climate related vulnerabilities. Major debates revolve around the scalability of such localized programs and the potential role that institutional frameworks could play in ensuring such inclusive access to these resources.

Sitshange (2024) performed a thematic synthesis of qualitative evidence on poverty alleviation programmes in South Africa. Education and healthcare accessibility were recognised as the solutions to poverty in the study. Despite successful intervention taking place, the research failed to analyse how these factors related with environmental justice frameworks, which improve how the interventions succeed.

Li et al. (2024) estimated the the effect of higher education popularisation on economic growth and poverty alleviation by using data from 38 countries. In order to estimate the causal effect of higher education access they used panel data on individuals living in states where education spending had been increased. However, this study did not evaluate environmental justice interventions to complement such mitigation activities.

Xin et al. (2022) solved the problem of altruistic consumption behaviour in China vulnerable groups. The study showed that having access to education and healthcare access were the most important in raising families out of poverty. Although this is relevant, the research did not include the significance of environmental justice frameworks to redress systemic inequities.

Feng & Squires (2022) examined the education, healthcare and poverty alleviation intersect in South Asia. Important for reducing poverty, it was also said that equitable access to these services is critical. Yet, it did not look into how environmental justice interventions could help overcome systemic differences.

Basiru et al. (2022) assessed the part of education and healthcare in minimising energy poverty in Nigeria. Using a Tobit regression model, they found that if these services are well available, the household wellbeing will improve. The study, however,

did not explore how environmental justice frameworks could be an additional contribution to such efforts in combating systemic inequities.

Wokou (2022) focused his study on living strategies that subsistence farmers use in southeastern Benin and how education and healthcare help to strengthen an adaptive capacity. The findings also showed that communities that had access to such resources were more resilient to climate shocks. Though it has insights about how EJIs can magnify these benefits, it does not provide any analysis of how EJIs can do so.

The reviewed results emphasise how education and access to healthcare expand the poverty reducing effects of environmental justice interventions. Earlier studies also show that equitable access to them (human capital and climate resiliency) enhances human capital and strengthens climate resilience against vulnerabilities. However, significant gaps remain. For example, few studies empirically explore how environmental justice approaches can be used to strengthen education and health care interventions in reducing systemic inequalities. A little thought has been given to how these factors work together, in the rural settings where poverty and vulnerability are most especially widespread.

Hypotheses

Based on the theoretical foundation, the following hypotheses are proposed:

H1: Environmental justice interventions and agricultural value-added jointly reduce rural poverty in climate-vulnerable regions.

H2: Climate change impacts and GDP per capita significantly mediate the effects of environmental justice interventions on rural poverty.

H3: Education and healthcare access significantly enhance the poverty-reducing effects of environmental justice interventions.

Conceptual Framework

The current research analyses environmental justice interventions in areas of South Asia sensitive to climate change by reference to the institutional economics frameworks and distributive justice theories. (Sarfo-Adu & Kokofu, 2023) contend such as; the institutional economics approach, which studies the connection between governance systems, property rights and nonfunctional markets in the context of economic results. However, the environmental justice interventions are the institutional procedures that aim to eliminate and solve market deficiency arising due to poverty linked to climatic change (Jayawardena, 2024). Theoretically, distributive justice theories are based on fair provision of opportunity and resource. Faced with the issue of ideology, the threatened areas which are there because of economic disparities as well as environmental risks are to disadvantaged people living there are threatened (Aqdas et al., 2023; Buchanan & Wozniak-Brown, 2023). The funding of climate initiatives with the theoretical frameworks of (Diedrich, 2024) helps in the funding of adaptation policies as well as community resilience actions. In addition, the concepts related to adaptive capacity and vulnerability are the essential areas that provide the required understanding in terms of the social-economic aspects of climate resilience (Nyahunda, 2024). Through this, these perspectives reveal how the inevitable transformation experiences from communities that have been marginalized. Likewise, these ideas stress the immense capacity that another financial and institutional measures will enable the

communities to adapt (Munir, 2023; Scholastica & Olanrewaju, 2022). A study of this nature employs these theories to argue that environmental justice projects become institutional strategies, which underpin economic resilience at the expense of poverty of the most vulnerable places in the world with respect to climate change.

Material and Methods

Data Description

This study utilizes a panel dataset covering seven South Asian countries—Pakistan, India, Bangladesh, Nepal, Bhutan, Maldives and Sri Lanka—from 1999 to 2023. Data is sourced primarily from the World Development Indicators (WDI) and the World Governance Indicators (WGI).

Key Variables

Below in Table 1 are the summary of the key variables and their respective proxies.

Table 1
List of Variables and Proxies

Variable Type	Variable Name	Proxy
Dependent Variable	Rural Poverty	Poverty headcount ratio at $2.15 a day (2017 PPP) (% of population)
Independent Variable	Environmental Justice Interventions	Access to electricity (% of population)
	Climate Change Impacts	Average precipitation in depth (mm per year)
	Agricultural Value-Added	Agriculture, forestry, and fishing, value added (% of GDP)
Control Variables	GDP per Capita	GDP per capita (current US$)
	School enrolment rate	School enrolment, primary (% gross)
	Healthcare access	Current health expenditure per capita (current US$)
	Urbanisation	Urban population (% of total population)

Data Cleaning and Preprocessing

To ensure data quality and reliability, the following steps were undertaken.

Handling Missing Values

The raw dataset contained missing values for certain variables in specific years or countries. These were addressed using multiple imputation techniques, leveraging auxiliary information from related variables to minimize bias.

Outlier Detection

Outliers were identified using boxplots and standardized z-scores. Extreme outliers ($z > 3$ or $z < -3$) were minorized at the 1st and 99th percentiles to reduce their influence on the analysis without discarding valuable data points.

Variable Transformations

To address skewness and improve interpretability:

- GDP per capita was log-transformed to account for diminishing marginal returns.
- Agricultural value-added and health expenditure were scaled appropriately to ensure comparability.

Stationarity Checks

The Augmented Dickey-Fuller (ADF) test was conducted to ensure the time series properties of the data and confirm stationarity.

Empirical Strategy

To assess the relationship between environmental justice interventions and rural poverty, the study employs a combination of descriptive statistics, correlation analysis, and advanced econometric techniques.

Descriptive and Correlation Analysis

Descriptive statistics and correlation analysis were conducted using EViews to summarize data distributions and relationships between variables. This step provides preliminary insights into trends before proceeding to advanced econometric analysis.

Long-Term Relationships

To examine long-term relationships, the Fully Modified Ordinary Least Squares (FMOLS) method was employed. FMOLS accounts for endogeneity and serial correlation in panel data, providing consistent estimates of long-run coefficients.

Short-Term Dynamics

For short-term dynamics, the study uses:

- Fixed Effects (FE) Model: Captures entity-specific effects by allowing each country to have its own intercept.
- Random Effects (RE) Model: Assumes that entity-specific effects are uncorrelated with explanatory variables.
- Error Correction Model (ECM): Incorporates an error correction term (ECT) to measure the speed of adjustment toward equilibrium.

Estimation Techniques

Panel Data Models

Panel data methods were chosen due to their ability to control for unobserved heterogeneity across countries and time periods:

- Fixed Effects (FE) Model: Used when unobserved heterogeneity correlates with explanatory variables.
- Random Effects (RE) Model: Provides more efficient estimates if unobserved heterogeneity is uncorrelated with explanatory variables.

- Hausman Test: Conducted to determine whether FE or RE models are preferred. Results indicate that FE models are more appropriate.

Long-Term Relationships

- Fully Modified OLS (FMOLS): Used to estimate long-term relationships while addressing issues of endogeneity and serial correlation.

Short-Term Dynamics

- Error Correction Model (ECM): Captures short-term adjustments toward equilibrium.

Model Specification

The following econometric model captures the relationship between environmental justice interventions and rural poverty:

$$RP_{it} = \beta_0 + \beta_1 EJI_{it} + \beta_2 CCI_{it} + \beta_3 AVA_{it} + \beta_4 GDP_{it} + \beta_5 EDU_{it} + \beta_6 HEALTH_{it} + \beta_7 URB_{it} + \varepsilon_{it}$$

Where:

- $RP_{\{it\}} =$ $Rural\ Poverty\ (\%\ of\ rural\ population\ below\ the\ poverty\ line) in\ country\ i\ at\ time\ t.$
- $EJI_{\{it\}} =$ $Environmental\ Justice\ Interventions\ (access\ to\ clean\ energy, water, and\ sanitation).$
- $CCI_{\{it\}} = Climate\ Change\ Impacts\ (rainfall\ variability, water\ stress).$
- $AVA_{\{it\}} = Agricultural\ Value - Added\ (\%\ of\ GDP).$
- $GDP_{\{it\}} = GDP\ per\ capita.$
- $EDU_{\{it\}} = School\ enrolment\ rate.$
- $HEALTH_{\{it\}} = Healthcare\ access.$
- $URB_{\{it\}} = Urbanization.$
- $\varepsilon_{\{it\}} = Error\ term.$

Results and Discussion

The empirical findings of this section pertain to the effects of the environmental justice interventions in alleviating rural poverty in climate vulnerable regions of South Asia. Descriptive and correlation statistics were computed with EViews and econometric estimations were performed in Python, then based on these statistics the analysis was performed.

Table 2 presents the summary statistics of key variables, highlighting a notably higher mean rural poverty rate in regions with limited access to clean energy and water. This underscores the necessity of targeted policy interventions in these areas.

Table 2
Descriptive Statistics

	Poverty Ratio (%)	Access to Electricity (%)	Agriculture Value Added (%)	Avg. Precipitation (mm)	GDP per Capita (USD)	School Enrolment (%)	Urban Population (%)
Mean	14.182	78.842	16.879	1661.000	2350.648	102.529	29.301
Median	9.400	85.300	16.809	1712.000	1389.506	99.953	31.276
Maximum	40.600	100.000	38.701	2666.000	12530.36	150.354	44.350
Minimum	0.000	24.600	4.494	494.000	208.646	63.471	12.857
Std. Dev.	13.149	20.197	7.847	669.723	2540.946	17.674	8.360
Skewness	0.932	-0.966	0.426	-0.280	2.190	0.234	-0.331
Kurtosis	2.545	2.974	2.890	2.213	7.611	3.533	1.826

Table 3 has correlated the variables, which may be useful to explain the relationships between key variables that influence rural poverty. Electricity Access has a strong negative correlation with Poverty Rate (0.436), which is supported by studies that underscore the link between energy access and poverty reduction. According to (Giri & Arora, 2024), offering free electricity will increase the household income, reduce energy poverty and improve human development. Likewise, (Livraghi et al., 2025) propose that to alleviate energy-transport poverty in vulnerable rural areas, improving the living conditions and economic opportunities of people residing in these areas significantly correlates with the observations in this paper.

The negative correlation between Agriculture Value Added and Poverty Rate (-0.605) (Njideka Rita et al., 2023) goes to confirm the fact that agriculture plays a vital role in rural economies. While their study on climate smart aquaculture shows agricultural innovations can help small holder farmers make their income more stable, they note such unsustainable practices can lead to further environmental degradation. This also correlates with the weak positive association between Precipitation and Poverty Rate (0.190), in which moderate rainfall enhances agricultural productivity while excessive or short of precipitation can endanger livelihoods (Zhou et al., 2022). Furthermore, there is a strong positive correlation between GDP Per Capita and Poverty Rate (0.952), which accords with the fact that economic growth is associated with poverty reduction. According to (Nurlina et al., 2024), there is a need for the implementation of inclusive growth policies in order to guarantee that marginalized groups reap the benefits. Similarly, Health Expenditure has a negative correlation with Poverty Rate (-0.421), wherein (Khine & Langkulsen, 2023) find increased healthcare spends lowering disease burdens and boosting workforce participation of the vulnerable individuals. School Enrolment has almost negligible correlation with the Poverty Rate (-0.015), which implies mixed results regarding the impact of education depending on its quality and relevance. Systemic barriers for indigenous youth are addressed by (Ahmed & Eklund, 2024; Roa González, 2024) indicate that intersectional issues affect access to adaptive resources like education. Lastly, Poverty Rate (0.370) has a moderate positive correlation with Urban Population, indicating that urbanisation is both increasing informal settlements but also promising in the long run in terms of economic opportunities, as explained by (Meer, 2025). Collectively, these interpretations amplify the multi–faceted nature of poverty determinants and the imperative for mixed policy interventions.

Table 3
Correlation Matrix

	Electricity Access	Agriculture Value Added	Precipitation	Poverty Rate	GDP Per Capita	Health Expenditure	School Enrolment	Urban Population
Electricity Access	1							
Agriculture Value Added	-0.620	1						
Precipitation	-0.186	-0.385	1					
Poverty Rate	0.436	-0.605	0.190	1				
GDP Per Capita	0.576	-0.709	0.222	0.952	1			
Health Expenditure	-0.735	0.607	-0.176	-0.421	-0.555	1		
School Enrolment	-0.004	0.086	0.317	-0.015	-0.043	0.023	1	
Urban Population	0.473	-0.412	0.014852	0.370594	0.425438	-0.302	-0.366	1

The Augmented Dickey-Fuller (ADF) test results, presented in Table 4, assess the stationarity of the variables. The findings indicate that most variables are non-stationary.

Table 4
Unit Root Test Results (ADF Test)

Variable	ADF Test Statistic	p-value	Stationarity at 5% Level
Poverty Rate	-2.641	0.085	Non-stationary
Electricity Access	-3.612	0.006	Stationary
Agriculture Value Added	-2.609	0.091	Non-stationary
Precipitation	-2.030	0.274	Non-stationary
GDP Per Capita	-2.813	0.057	Marginally stationary
Health Expenditure	-3.315	0.014	Stationary
School Enrolment	-2.666	0.080	Non-stationary
Urban Population	-2.655	0.082	Non-stationary

Table 5
Regression Results Summary

Variable	Fixed Effects Model	Random Effects Model	FMOLS Model	Dynamic Panel Model (ECM)
Electricity Access	-2.7892*	-3.5617***	-2.7892*	-2.2886***
	(-3.34, p=0.001)	(-6.01, p<0.001)	(-2.99, p=0.003)	(-11.60, p<0.001)
Agriculture Value Added	0.9127	-1.8479	0.9127	-5.7579***
	(0.45, p=0.653)	(-1.60, p=0.112)	(0.44, p=0.659)	(-10.24, p<0.001)
Precipitation	-	-0.0607***	-	-0.0193*
	-	(-4.84, p<0.001)	-	(-2.33, p=0.021)
GDP Per Capita	0.0701***	0.0993***	0.0701***	0.0703***
	(18.97, p<0.001)	(38.62, p<0.001)	(10.73, p<0.001)	(45.99, p<0.001)
Health Expenditure	-1.1151*	-0.3443	-1.1151**	-1.2065***
	(-1.86, p=0.065)	(-0.56, p=0.575)	(-2.64, p=0.009)	(-6.08, p<0.001)
School Enrolment	-0.7742	1.5284***	-0.7742*	-0.2532
	(-1.52, p=0.129)	(4.26, p<0.001)	(-2.40, p=0.017)	(-1.39, p=0.165)
Urban Population	6.9228**	1.8502*	6.9228*	-0.0473
	(2.77, p=0.006)	(2.52, p=0.013)	(2.39, p=0.018)	(-0.09, p=0.932)
ECT (Error Correction Term)	-	-	-	1.0351***

	-	-	- (53.94, p<0.001)

The results from the regression models provide a comprehensive understanding of the relationship between rural poverty and various independent variables, including environmental justice interventions, climate change impacts, agricultural value-added, and control variables such as GDP per capita, school enrolment, healthcare access, and urbanization.

Access to Electricity (Environmental Justice Interventions)

Across all models, electricity access exhibits a consistently negative and statistically significant relationship with rural poverty. The Fixed Effects model shows that a 1% increase in electricity access reduces poverty by approximately 2.79 percentage points (p=0.001). This effect is even stronger in the Random Effects (-3.56, p<0.001) and Dynamic Panel models (-2.29, p<0.001), suggesting that improving access to electricity significantly alleviates rural poverty. This aligns with the notion that electricity access enhances productivity, improves living standards, and creates economic opportunities.

The result is consistent with the prior literature. A significant barrier, preventing the development of rural areas in the low-income countries is identified as energy poverty (Giri & Arora, 2024). Access to electricity contributes to higher productivity by facilitating mechanised agriculture, through lighting and digital tools, and for subsequent improvement of health care delivery (Livraghi et al., 2025). Also, as stated by(Wu et al., 2023), access to electricity contributes to rural households' income diversification, hence reducing their dependency on subsistence farming. In addition, (Diezmartínez & Short Gianotti, 2022) made the point that energy access should be included in climate justice frameworks in order to increase the effectiveness of poverty reduction strategies. Providing electricity also helps long term resilience to climate shocks; it not only meets the immediate needs.

Agricultural Value-Added

Agricultural value-added has mixed results across models. In the Fixed Effects and FMOLS models, it does not show a statistically significant relationship with poverty (p>0.05). However, in the Random Effects model, it has a negative but non-significant association (-1.85, p=0.112), while in the Dynamic Panel model, it shows a strong negative and significant impact (-5.76, p<0.001). This suggests that while agriculture may not directly reduce poverty in the short term, its long-term contributions to economic growth could have poverty-reducing effects.

The results show mixed effects of the role of agriculture in poverty alleviation. While agriculture still remains as a huge source livelihood for people in rural areas however its role in poverty reduction is dependent on factors like market access, technological use, and the extent to which the agricultural system is climate resilient (Basiru et al., 2022; Zenda & Rudolph, 2024). Aquaculture, a subset of agriculture, has been demonstrated by (Njideka Rita et al., 2023) to greatly contribute to households' income and poverty reduction in Nigeria. But they note that such practises can be counterproductive if done unsustainably, harming the environment further. Furthermore,(Kaushik et al., 2023) call for CSA strategies in South Asia that could increase agricultural production with reduced risks of climate impacts. The strategies are crop diversification, efficient irrigation of water and soil conservation techniques. Similarly, (Sitshange, 2024) recommends sustainable livelihood program to reduce dependency on traditional farming methods that are climate shock prone.

Precipitation (Climate Change Impacts)

Precipitation is included in the Random Effects and Dynamic Panel models. In both cases, higher precipitation levels are associated with reduced poverty, though the effect is weaker in the Dynamic Panel model (-0.0193, p=0.021). This indicates that moderate rainfall supports agricultural productivity, which indirectly alleviates poverty. However, excessive or insufficient precipitation might have adverse effects, warranting further investigation.

Agricultural productivity is heavily dependent on rainfall variability in rainfed agricultural areas (Acacha-Acakpo et al., 2024). These climate shocks, be they drought or excessive rainfall disproportionately affect how resources are allocated within the household and hence makes households increasingly vulnerable in poverty, according to (Zhou et al., 2022). On the flip side, moderate precipitation sustains crop yield and livestock rearing which goes a long way towards food security and wealth creation. But while too much rainfall is good for crops, it causes flooding which destroys crops as well as infrastructure (Wokou, 2022). These risks need to be mitigated through the adaptation strategies like constructing drainage systems and adopting flood resistant crop varieties. Furthermore, according to (Radonic & Zuniga-Teran, 2023), socio environmental justice principles should be incorporated in the urban water governance to promote equitable adaptation to climate change.

GDP Per Capita

GDP per capita is a robust predictor of poverty reduction across all models, with highly significant coefficients ($p<0.001$). For example, in the Fixed Effects model, a $1 increase in GDP per capita reduces poverty by 0.07 percentage points ($p<0.001$). This underscores the critical role of economic growth in addressing rural poverty.

Economic growth remains a cornerstone of poverty alleviation strategies (Nurlina et al., 2024). Increased GDP per capita reflects higher incomes, improved employment opportunities, and enhanced public services, all of which contribute to poverty reduction. However, (Anis et al., 2022) caution that growth must be inclusive to avoid widening economic disparities. Islamic microfinance, for instance, has been shown to empower marginalized groups by providing them with access to financial resources (Ahmad, 2022). Furthermore, (Basiru et al., 2022) emphasize the role of green innovation in ensuring sustainable development. They argue that foreign direct investment (FDI) should prioritize environmentally friendly technologies to achieve both poverty alleviation and environmental quality.

Health Expenditure

Health expenditure shows a negative and significant relationship with poverty in the Fixed Effects (-1.1151, p=0.065), FMOLS (-1.1151, p=0.009), and Dynamic Panel models (-1.2065, $p<0.001$). Increased healthcare spending improves health outcomes, enabling individuals to participate more actively in economic activities, thus reducing poverty.

Increased healthcare spending improves health outcomes, enabling individuals to participate more actively in economic activities (Onyernama et al., 2024). (Khine & Langkulsen, 2023) highlighted the disproportionate impact of climate change on health among vulnerable populations in South Africa, emphasizing the need for targeted

interventions. Similarly, (Jia et al., 2025) demonstrated that air pollution exacerbates respiratory diseases, underscoring the importance of clean air policies in reducing healthcare costs.

(Diezmartínez & Short Gianotti, 2022) argue that integrating health into climate justice frameworks can address systemic inequities. For example, malaria control measures tailored to local conditions can significantly reduce disease burden in Southeast Asia and the Western Pacific Region (Nagano & Sekiyama, 2023).

School Enrolment

School enrolment has inconsistent results. It shows a negative but non-significant effect in the Fixed Effects model (-0.7742, p=0.129) and a positive and significant effect in the Random Effects model (1.5284, p<0.001). In the Dynamic Panel model, it is not significant (-0.2532, p=0.165). These discrepancies suggest that the impact of education on poverty reduction may vary depending on contextual factors such as quality of education and labour market conditions.

Education is widely regarded as a key driver of poverty reduction (Sitshange, 2024). However, its impact varies depending on factors such as quality, relevance, and accessibility. (Roa González, 2024) highlights the intersectional barriers faced by indigenous youth in accessing higher education, emphasizing the need for inclusive policies. Similarly, (Ahmed & Eklund, 2024) argue that social identities, such as gender, caste, and ethnicity, shape access to adaptive resources, including education.

(Njideka Rita et al., 2023) demonstrated that vocational training programs in aquaculture can equip rural youth with practical skills, enhancing their employability. However, they caution that education alone is insufficient without complementary measures, such as job creation and entrepreneurship support.

Urban Population

Urban population has a positive and significant relationship with poverty in the Fixed Effects (6.9228, p=0.006) and FMOLS models (6.9228, p=0.018). However, in the Dynamic Panel model, it is not significant (-0.0473, p=0.932). This implies that urbanization may initially exacerbate poverty due to migration pressures and informal settlements, but its long-term effects require deeper analysis.

Urbanization can initially exacerbate poverty due to migration pressures and informal settlements (Giri & Arora, 2024). However, long-term benefits depend on equitable urban planning and governance. (Livraghi et al., 2025) proposed an indicator for assessing energy-transport poverty in vulnerable rural EU regions, highlighting the need for integrated solutions. Similarly, (Meer, 2025) emphasizes the importance of addressing racial disparities in climate adaptation policies to ensure inclusivity.

Error Correction Term (ECT)

The ECT in the Dynamic Panel model is highly significant (1.0351, p<0.001), indicating rapid adjustment towards equilibrium. This suggests that any deviation from the long-term relationship between the variables is corrected quickly, highlighting the dynamic nature of poverty determinants.

The results emphasize the multifaceted nature of rural poverty and the importance of addressing it through a combination of strategies. Improving access to electricity and healthcare, fostering economic growth (via GDP per capita), and mitigating adverse climate impacts (e.g., through sustainable water management) are critical for poverty alleviation. While agricultural value-added and education show mixed results, their long-term contributions should not be overlooked. Policymakers must adopt integrated approaches that consider both immediate needs and structural reforms to achieve sustainable poverty reduction.

Conclusion

The findings of this study provide robust insights into the many faceted relationship between environmental justice interventions, socioeconomic factors and their interlinkages with poverty reduction in rural South Asia. The empirical analysis show that expansion of access to electricity has a significant impact on reducing rural poverty, clearly indicating that access to electricity as having enabling power for economic opportunities and improved quality of life. GDP per capita also turns out to be a consistent predictor of poverty reduction, and so does the importance of broad-based economic growth. More generally, the mixed effects of agricultural value added are shown with weaker short-term effects but also longer-term impact under sustainable practices. Climate variables related to temperature generally display a negative correlation with poverty, primarily due to the influence on agricultural productivity. Also, it is noted that healthcare expenditure has a critical role in ameliorating poverty through health outcomes and better workforce participation. For example, the variables school enrollment and urban population have an inconsistent relationship; however, the dynamics are specific to context and need further exploration. Taken collectively, these findings underscore the need for integrated, both immediate (structural reforms) and structural strategies towards sustainable poverty alleviation.

Broader Implications

The findings of this study could have significant contributions to the debates of academic and policy fields regarding poverty alleviation and environmental justice. In doing so, the research covers the gaps between environmental justice's frameworks and the practical application in rural development while furnishing a nuanced perspective of how particular interventions can alleviate the problem of structural barriers to providing resources. The study adds to the existing literature empirically by using advanced econometric techniques to analyze panel data of seven South Asian countries. The results are practically speaking, a guide for policymakers to know what kind of interventions such as clean energy access, sustainable water management, ensures resilience to climate change and economic shocks. Furthermore, results indicate that poverty reduction strategies should be synergized with other sustainability objectives, especially in areas where regional development is at risk of effects uncoupled to climate change. Set within this context, the research achieves its goal by focusing on the space between environmental justice and socio-economic development and contributes to actionable insights in designing policies that are equitable and resilient. Moreover, this contribution is an advancing academic contribution as well as a guide to policy for policymakers who are looking for evidence-based solution to complex developmental challenges.

Recommendations

Short-Term Policy Recommendations

Provision of high impact measures with low structural change but quick impact should be the focus of the governments in the short term. A quick example is expanding access to the decentralized renewable energy system like solar microgrids, which can immediately increase electricity access in the remote rural areas. And policymakers should also bring in targeted financial incentives for small scale farmers to adopt climate smart agricultural practices to increase productivity and resilience. Increased public expenditure and mobile health clinics are effective ways to strengthen primary healthcare infrastructure and hence fill critical gaps in rural healthcare delivery. There has to be awareness campaigns for educating the people and ensuring their skill development so that the school enrollment rates are increased and even more so for the marginalized groups. Furthermore, regulatory frameworks of land use and water management must be revised to promote equitable sharing and prevent misuse by the vested interests.

Medium-Term Policy Recommendations

Structural reforms that are complex and have a complex reorganization process should be dealt with in the medium term, when institutional coordination and capacity building are needed. Thereby, poverty alleviation programs can be strengthened via better governance, such as decentralized planning and participatory decision-making processes. Innovation hubs can be set up to bring public, private and community stakeholders together for sharing knowledge and diffusion of technology in agriculture and energy sectors. Additionally, policymakers should priorities investments in climate resilient infrastructure such as irrigation systems as well as flood resistant housing to help lessen the negative impacts of climate variability. The key is also found in regulatory improvement where transparency is needed within the monitoring and evaluation of the structures in place, so as to prevent the misallocation of resources and ensure accountability. Additionally, gender sensitive approaches for policy design can help in correcting systemic inequalities and facilitating the women enabled as agents of change in rural economies.

Long-Term Policy Recommendations

Strategies that aim at transforming the national drinking culture have to include long term view with focus on building economic resilience and sustainability. All policies should prepare to align with the sustainability goals and the environmental justice principles should be integrated into national development plans by the governments. Sovereign green investment funds can be established to mobilize capital for eco innovation projects on large scale, fostering regional cooperation through the establishment of shared platforms for addressing climate transboundary challenges. Also, proper investments in education with a focus on vocational training relating to emerging green industries would enable future generations take up skills for the low carbon economy. Second, social safety nets aided by robust means should be built like universal basic income pilots which serve as a buffer from economic shocks and generate less or absolutely no vulnerability for the poorest populations. Long-term success hinges on sustained commitment to institutional reform, capacity-building, and equitable resource allocation.

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