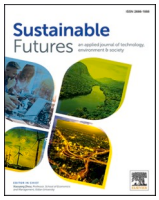
Sustainable Futures 6 (2023) 100130

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures



Beyond climate change: Examining the role of environmental justice, agricultural mechanization, and social expenditures in alleviating rural poverty

Muhammad Khalid Anser [a,b], Sheikh Usman Yousaf [c], Bushra Usman [d], Kamran Azam [e], Nur Fatihah Abdullah Bandar [f], Hanifah Jambari [g], Sriyanto Sriyanto [h], Khalid Zaman [i,j,*]

[a] School of Business, Xi'an International University, Xi'an, Shaanxi 710077, P R China
[b] Faculty of Business and Management Sciences, The Superior University, Lahore, Pakistan
[c] Hailey College of Commerce, University of the Punjab, Lahore, Pakistan
[d] School of Management, Forman Christian College (A Chartered University), Lahore, Pakistan
[e] Department of Management Sciences, The University of Haripur, Haripur, Khyber Pakhtunkhwa 22620, Pakistan
[f] Faculty of Cognitive Sciences and Human Development, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak 94300, Malaysia
[g] Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia (UTM), Skudai, Johor 81310, Malaysia
[h] Social Studies Department, Universitas Muhammadiyah Purwokerto, Jawa, Tengah 53182, Indonesia
[i] Department of Economics, The University of Haripur, Haripur, Khyber Pakhtunkhwa 22620, Pakistan
[j] Department of Research, The Sherwan Institute of Online Education (SIOE), Abbottabad 22060, Pakistan

ARTICLE INFO

Keywords:
Environmental ethics
Justice
Rural poverty
Climate change
Agriculture mechanization
Access to education
Health
Pakistan

ABSTRACT

Extreme weather events and extreme poverty are two sides of the same coin, with far-reaching consequences for emerging nations like Pakistan. Rural people are more likely to experience poverty and inequality as climate change worsens. This research aspires to close the gap between environmental ethics and justice by investigating how climate change issues contribute to poverty in Pakistan. The study used Robust Least Squares (RLS) regression to analyze the impact of water scarcity, extreme temperatures, and excessive rainfall on rural poverty in Pakistan from 1990Q1 to 2022Q4. Further, the study examines the effect of environmental justice interventions, access to healthcare and education, agricultural value-added and agricultural mechanization on the country's rural poverty. Results reveal that climate change contributes to rural poverty in Pakistan, while environmental justice initiatives, healthcare access, and agricultural automation alleviate poverty incidence. The Impulse Response Function (IRF) estimates suggested that rural poverty will be exacerbated over the next decade by water scarcity, high temperatures, and low agricultural value added but alleviated by excessive rainfall, environmental justice intervention, healthcare access, and agricultural mechanization. According to Variance Decomposition Analysis (VDA) projections, agricultural value added will substantially impact rural poverty by 2032, increasing it by 11.431%. Addressing these problems requires policymakers to prioritize the interests of the most marginalized groups by fostering fair results. Policies should cut GHG emissions and encourage sustainable development to combat climate change. Modernizing farming techniques and expanding access to healthcare are also necessary for increasing efficiency and production. It is essential to execute environmental justice interventions so that all communities have access to environmental resources and protections equitably. Promoting equitable outcomes and reducing poverty in Pakistan's climate change context may be achieved by closing the gap between environmental ethics and justice.

1. Introduction

The intersection between poverty and climate change in Pakistan necessitates attention to environmental ethics and justice issues. Environmental ethics concerns the moral principles that govern our interactions with nature. Environmental justice ensures that all people and communities have equal access to environmental resources, not disproportionately harmed by environmental damages [1–4]. Existing

* Corresponding author.
E-mail address: khalid.zaman@uoh.edu.pk (K. Zaman).

https://doi.org/10.1016/j.sftr.2023.100130
Received 27 July 2023; Received in revised form 5 September 2023; Accepted 6 September 2023
Available online 7 September 2023

socioeconomic disparities and the gap between the affluent and people with low incomes are expected to be exacerbated by the effects of climate change in Pakistan [5]. Because of their potential inability to prepare for and recover from climate-related catastrophes, low-income communities are especially at risk from climate change's effects [6]. This leads to moral concerns regarding who should lead in mitigating climate change and protecting society's most disadvantaged individuals [7,8]. From an ethical standpoint, those more responsible for GHG emissions and climate change should be more responsible for resolving its repercussions [9,10]. In light of this, developed nations, which have historically contributed the most to GHG emissions, should aid developing nations, such as Pakistan, in their efforts to adapt to the effects of climate change and advance sustainable development [11].

When considering the effects of climate change from a justice viewpoint, it is essential to ensure that society's most vulnerable members are not unfairly affected. Providing clean water and sanitation, improving housing conditions, and helping small-scale farmers adapt to changing environmental conditions are all examples of interventions that would help meet the needs of the most vulnerable members of society [12,13]. Looking at how poverty and climate change are connected in Pakistan requires considering environmental ethics and justice [14,15]. Sustainable and equitable development can be achieved for all people if we consider the moral values that inform our interactions with the natural world and if we seek to ensure that all people and communities have access to environmental resources [16,17]. One of the most significant problems of our day is climate change, which affects every country, rich and destitute. Countries like Pakistan, which have few resources and a high poverty rate, would feel the effects of climate change the hardest [18,19]. Climate change, economic inequality, quality education, and lack of health facilities are key variables in poverty; they must be examined. Pakistan is very sensitive to climate change. Floods, droughts, and other natural calamities have historically affected the country's population [20,21]. Pakistan has 20% poverty, making it one of the most impoverished countries [22,23]. This research examines Pakistan's poverty, agricultural income, education, and health from 1990Q1 through 2022Q4. Income, education, and health will moderate climate change's effects on poverty. This research illuminates poverty and climate change, aiding Pakistani sustainable development. This research may also illuminate a significant concern for other emerging countries.

This research was inspired by a desire to learn more about environmental ethics and justice in light of Pakistan's current poverty and climate change crises. We want to learn more about the moral implications of climate change and poverty in Pakistan and develop plans to advance environmental justice via poverty alleviation and climate resilience programs. This research may aid in formulating policies and interventions that promote sustainable development and fair results by shedding light on the moral implications of climate change and poverty in Pakistan. The study aims to accomplish the aforementioned by addressing the following research questions:

I What moral implications do climate change and poverty in Pakistan have?
II What role may policies and initiatives addressing climate change and poverty in Pakistan play in advancing environmental justice? And
III In light of poverty and climate change in Pakistan, what possibilities and obstacles exist for advancing environmental justice?

The following goals direct our research to address these questions:

I To research relevant literature and policy documents to investigate the moral implications of climate change and poverty in Pakistan.
II To determine how environmental justice might be integrated into Pakistan's poverty alleviation and climate change adaptation initiatives.
III To analyze Pakistan's environmental justice issues and potential in the context of poverty and climate change.

Policymakers and other stakeholders in Pakistan who care about lowering poverty and boosting climate resilience would benefit greatly from this study's results. This research can influence policies and actions that promote sustainable development and equitable results by recognizing the ethical implications of climate change and poverty in Pakistan and methods for achieving environmental justice. This research has the potential to add to the growing body of literature on environmental ethics and justice, shedding light on a topic that may be useful to other developing nations. Overall, this research hopes to improve policies and actions that promote sustainable development and equitable results in Pakistan by providing a more nuanced knowledge of the ethical elements of climate change and poverty in that country.

2. Literature review

The literature review examines three primary factors for attaining sustainable and equitable development in Pakistan. First, it addresses the connections between climate change, food insecurity, and poverty. The analysis highlights the critical need to address climate hazards and food insecurity to reduce poverty in at-risk populations by examining the intricate connections between these issues. The second focus of the study is on the function of agricultural mechanization in alleviating rural poverty. Modern agricultural methods can potentially improve agricultural output and the lives of rural populations, and this assessment emphasizes the need to invest in cutting-edge technology to this end. Finally, this review investigates how environmental justice measures could promote long-term viability and social fairness. The study highlights the importance of environmental justice and fair allocation of resources in promoting sustainable and inclusive development by analyzing the social and environmental implications of development policies and initiatives.

2.1. Climate change, agriculture, and poverty incidence in developing countries

The effects of climate change on ecosystems, economies, and societies are widespread and far-reaching, making it one of the most pressing global concerns of our day. The research of Pachauri [24] sheds light on how innovative farming techniques might help alleviate rural poverty in emerging nations. The research, nevertheless, highlights the trade-off between advancement and increased energy needs, which is particularly relevant in energy-scarce rural areas. The unique idea of "investment poverty" is introduced by Reardon & Vosti [25], providing a prism to examine the complex relationship between economic deprivation and the dynamics of the natural world. They analyze the data in detail to show how different assets and environments may affect poverty levels differently, underscoring the need to tailor policy responses to local conditions. An insightful look at the effects of climate change on vulnerable communities in developing nations, as stated by Sanchez [26]. Research centers play a crucial role in leading innovative-driven adaptation and mitigation efforts, and this study argues for synergistic linkages among multinational research projects. Hertel and Rosch's [27] viewpoint is crucial because it highlights the connection between climate change and poverty, which should be discussed more. Their research highlights the importance of considering agriculture's role in mediating climate effects and providing a possible remedy when formulating policy frameworks for sustainable development in the global south.

Leichenko & Silva [28] explore the complex relationship between climate change and poverty, highlighting the need to consider this

issue's many facets. The study describes how climatic variability worsens poverty and calls for extensive research and policy frameworks to address the issue. The research conducted by Hallegatte & Rozenberg [29] examines the effects of climate change on poverty at the household level. The relevance of this analysis rests in its clarification of inclusive development as a vital method to reduce the likelihood of poverty worsening in the future due to climate-induced disruptions. Urbanization's effects on rural poverty are dissected by Thurlow et al. [30] as they examine the distinctive trajectory of change in Sub-Saharan Africa. This analysis captures the complex interplay between urbanization, agriculture, and poverty, arguing for consistent policy to achieve long-term prosperity. Population expansion, resource availability, and adjusting to a changing climate all have complex interrelationships, which Maja & Ayano [31] investigate in depth. Scholarly investigation of population dynamics and its implications for sustainable development objectives reveals the critical necessity for rapid, well-coordinated efforts.

Climate change consequences, such as shifting precipitation patterns, increasing temperatures, and severe weather events, threaten agriculture's ability to provide food security and rural livelihoods [32]. The effects of climate change on agriculture and food security, health, and infrastructure are expected to worsen poverty and inequality in many nations, especially in the developing world [33]. Through a panel survey and qualitative research, Eichsteller et al. [34] examine the impact of agricultural practices on persistent poverty escapes in rural Kenya from the year 2000. The research pinpoints barriers in conversion processes and structures that hinder escaping poverty and adapting to and mitigating the effects of natural disasters. Li et al. [35] analyze how climate, especially high temperatures, affects people's susceptibility to poverty in rural China. They suggest that an integrated strategy is needed to solve the problems presented by climate change and poverty vulnerabilities. Policy formation procedures should consider the diverse consequences of severe climate on vulnerable populations.

Measures of poverty vulnerability in Chinese agricultural families are used by Peng et al. [36] to assess the long-term viability of farmers' livelihoods. The research concludes that the average yearly temperature severely impacted farmers, especially those in the southern regions. The study recommends constructing mitigation infrastructure, increasing risk prevention awareness, utilizing improved financial tools, and breeding crops adapted to the trend of climate change. The 'Asian Green Revolution' concept has flaws and might have unintended consequences, as Dorward and Giller [37] point out. In South America and Australia, where landholders are typically paid and transferred to reserves to permit more intensive agricultural operations, the approach has not been successful since it has led to environmental deterioration and deforestation. The research cites similar problems throughout Asia, especially in regions where oil palm production is common. Environmental and market externalities, common property difficulties, and inadequate investment in R&D and infrastructure by politicians make sustainable growth in these areas difficult. Their findings imply that other strategies for agricultural growth may be required to overcome these obstacles and bring about sustainable results.

Health poverty was quantified, and the effects of health vulnerability on health poverty were investigated in research by Li et al. [38] among Chinese rice farmers in Hubei province. Researchers used a measuring methodology based on a multidimensional poverty framework and an econometric model to assess how health vulnerability contributes to health poverty. The findings showed that 17.95% of farmers were living in poverty due to the cost of healthcare, with those from low-income backgrounds being at an especially high risk of experiencing severe medical affordability poverty (27.46%). Physical exams were shown to have a mitigating influence on mental health poverty. However, exposure to extreme weather events, poor lifestyle choices, a lack of medical facilities, and limited access to care all contributed to health insecurity. Possible solutions to the problem of health inequality in rural China were also suggested. This research may help policymakers in rural regions minimize health poverty and increase health equality.

Khosla et al. [39] looked examined the effectiveness of livelihood programs (LPs) in lowering poverty vulnerability (VtP) in an eastern Indian tribal area. Chronic disease, climatic shocks, and the sale of assets were shown to exacerbate chronic and cyclical poverty, making 34.7% of families very susceptible to falling into poverty in the future. However, there remained disparity in the gains made by the LPs' beneficiaries, with those living in economically depressed areas falling farther behind. The research suggests bolstering LPs, with a special emphasis on marginalized groups. The impacts of climate change on farming in Lesotho and the methods used by smallholder farmers to adapt were studied by Dick-Sagoe et al. [40]. According to the results, farmers have faced decreased crop yields, increased insect and disease assaults, and lower-than-average yields due to climatic unpredictability and change. Indigenous technology and rainwater collection storage were all a part of the farmers' repertoire of adaptive tactics. The research emphasizes the need to reduce the susceptibility of smallholder farmers in Lesotho to climate change via interventions that increase their adaptive capacity and help them learn the best agricultural methods.

Pakistan's farm-level vulnerability, risk perceptions, and adaptation strategies are the subject of Shah et al. [41]. This study identifies the climatic risks that farmers foresee at the farm level, the adaptation strategies that farmers have implemented to lessen the adverse effects and related risks of changing weather patterns, and the barriers that farmers must overcome to make adaptation decisions. It is emphasized in the report that local institutions should be prepared to supply farmers with more up-to-date information and farm advice to battle climate change and its negative repercussions and that regulations should be implemented to handle adaptation hurdles. Ahmed et al. [42] examine how city dwellers in Pakistan adapt to climate change and what population segments need assistance. Data on demographic, social, economic, and physical factors are gathered to understand better how urban populations adapt to climate change's effects. The study concludes that perception provides the groundwork for adaptation and that individual variations in perception might influence the adopted stance. The findings imply that poverty comprises most factors that impair adaptation ability and increase respondents' sensitivity to climate change. The research suggests that the government assist those who are less well off economically, personally, socially, physically, and environmentally so that they can better cope with change.

Ullah et al. [43] examine the reliability of indigenous climatic knowledge (ICK) and how climatic shifts affect both ICK and the social life of local fishermen. The study concludes that the fishing community on the coast of Gwadar enjoys a healthy relationship with nature and the local ecology and that this familiarity with the environment allows them to manage their resources sustainably, mitigate the effects of natural disasters, and maintain a cohesive social structure. The examination concludes that recent significant climatic changes brought on by human manipulation of the environment have disrupted their fundamental interaction with local ecological and sociocultural order. Local people are losing their traditional livelihoods and socioeconomic autonomy due to massive climatic changes, making it impossible for the fishing community to anticipate fish availability. Climate change exacerbates the region is already dire poverty and political instability. Based on the stated discussion, the study's first hypothesis is as follow:

H1: Increases in water shortages, high temperatures, and floods are all consequences of climate change that contribute to poverty in rural Pakistan.

2.2. Agricultural value added and automation in lessening rural poverty

Hudson & Parker [44] analyzes the US telecommunications business in the context of the changing rural economy, finding that rural regions are disadvantaged due to the rise of the service and information economies. The efficiency and output of rural areas might benefit from better

communication infrastructure. The research recommends increasing transmission quality, upgrading switching systems, and expanding access. Both federal and state agencies are the intended recipients of the proposed policies. Mahajan & Ramola [45]. This report, commissioned by the World Bank, assesses how well Indian financial institutions meet the needs of India's rural poor. Client-facing procedures and internal practices and attitudes are singled out as important factors. Policy implications go beyond individual institutions' purview, calling for shifts in macro-level policy to improve access to financial services in rural areas. Ambali's [46] research contrasts Japan, Malaysia, and Malawi to examine the difficulties of technology transfer in underdeveloped nations. Industrialization, economic expansion, and poverty all challenge the efficient transmission of technology. The research demonstrates the intricate nature of the problem that emerging countries in poverty face.

Hanjra & Gichuki [47] propose investing in agricultural water management. Putting money into education, nutrition, and health may improve revenue, create jobs, and stabilize production. Rural land, water, and infrastructure investment is emphasized to alleviate poverty. Deichmann et al. [48] investigation of the effects of digital technology on agriculture highlights opportunities, including increased market access for small-scale farmers and novel extension services. However, hurdles encountered by farmers in underdeveloped nations continue, making it difficult to scale up good results. Rotz et al. [49] identify conflicts surrounding increasing land prices, labor market dynamics, and data management as significant social repercussions of agricultural digitalization. It calls for governmental changes to prevent exploitation by highlighting the need to consider the impact of digital technology on agricultural labor and rural communities. Christiaensen et al. [50] focus on the agricultural workforce in the context of the ICT revolution and immigration policy changes. To guarantee a prosperous future for agricultural employment, it presents potential policy measures such as value chain development, immigration liberalization, and education upgrading.

According to Osinowo et al. [51], an essential factor in alleviating rural poverty is increased agricultural value-added and automation. These changes may increase rural farmers and their families incomes by boosting agricultural output and efficiency [52]. In addition, they may assist in alleviating unemployment and poverty by producing new jobs in the agricultural industry. Raihan et al. [53] argue that boosting agricultural value-added and automation may help boost rural communities' living standards and promote long-term economic growth. The income of rural households and the income difference between urban and rural areas have both been demonstrated to increase due to agricultural automation ([54]; Zhang et al. According to research by Sang et al. [55], agricultural mechanization services greatly enhanced rural household income, which also helped reduce income disparities between rural families, especially those in China's eastern and western areas. In addition, Liao et al. [56] analyzed China's progress toward agricultural mechanization and extracted important policy and institutional takeaways for nations with subsistence farming. Finally, Paudel et al. [57] examined what drives Nepal's maize-based agricultural systems to utilize scale-appropriate automation. Mechanized farms, particularly those under five acres, enhanced maize yield, profitability, and family food self-sufficiency.

Daun [58] argues that while automated farming can improve worker efficiency, reduce hunger, and improve wellness, it also poses sustainability risks to the environment, such as biodiversity loss and land degradation, and to society, such as a shortage of broadening and growing disparities. This study argues that various technical and institutional solutions are required to fully realize the benefits of agricultural automation and sustainably alter the agri-food system. Mohammed et al. [59] investigate what factors influence smallholder farmers in semiarid Ghana to invest in automated agriculture technology. Findings suggest that economic variables play a significant role in determining the adoption of automated equipment in smallholder farming situations, with access to financing and remittances being the most significant predictors. The study recommends that governments encourage non-mechanized production techniques like agroecology and promote mechanized methods to meet the requirements of impoverished agricultural families. After introducing agricultural annuity coverage, Liu and Li [60] examine Chinese farmers' farm machinery purchases. Pension protection increased farmers' automation inputs. Grandchild care and labor off-farm transfer mediated the seniors' retirement fund engagement and automation inputs. The research concluded that these issues may boost rural pensions, automation, and sustainable farming.

The impacts of monetary inclusion, breakthroughs in agriculture, trade, and forest rent on Pakistan's carbon emissions, income growth, and ecological footprint from 1970 to 2017 analyze by Ali et al. [61]. Carbon emissions were shown to rise in response to positive shocks in agricultural innovation, economic development, and forest rent but to fall in response to adverse shocks in financial inclusion and forest rent. The long-term ecological impact was reduced due to positive agricultural innovation shocks and negative forest rent shocks—the examination called for green mechanization in agriculture and regulations that include environmental and economic progress. The commercialization of agriculture in Pakistan has changed women's traditional responsibilities in pulses production, according to anthropological research was done by Kavesh et al. [62]. They claim that reviving multispecies contact zones can help women feel more invested in the pulses crop, which in turn can help ensure daily food provisioning, preserve traditional socio-cultural and ecological relationships, comprehend the marginalization of women in agriculture, and place a higher value on women's contribution, experience, and knowledge. The effect of agricultural financing on crop output in Pakistan was analyzed by Chaiya et al. [63]. Researchers discovered that agricultural financing increased output but needed to be more applied rather than appropriately used. Farmers used credit for land improvement, fertilizer, seed, pest control, daily work, medical care, schooling, and household and commercial expenses. To reach the goal established for agricultural production, the report suggests governmental measures to prevent the abuse of agricultural finance. The second hypothesis of the research is based on the aforementioned literature evaluation, and it states:

H2: By boosting agricultural output and giving farmers more possibilities to earn money, enhancements to agrarian value-added and automation may aid in alleviating rural poverty in Pakistan.

2.3. Environmental justice ensures long-term sustainability and equity

The conflict between environmental justice and local control is examined by Lake [64]. The idea of local sovereignty is put to the test by the concept of environmental equality. Protests in a community may be perceived as a sign of local sovereignty. Lake argues that we must distinguish between distributive justice and procedural justice to solve this problem. When making judgments on the costs and advantages of a procedure, democratic involvement is essential for ensuring fairness. The research provides examples to show how environmental fairness and local control might be brought together. Dawson [65] analyzes the growth of environmental justice movements worldwide over the previous decade and what that growth means for ecological sustainability and social peace. Linking environmental aims with social justice may inspire people to act, but this article gives international comparisons that question the alliance's long-term durability and potentially divisive effects. The research highlights the advantages and possible conflicts that may arise when environmental challenges are framed in terms of social justice, and it does so by focusing on eco-nationalist movements and environmental justice in various global settings. There needs to be more clarification between equity and environmental justice; Ikeme [66] tries to clarify that. This study aims to provide a unified framework for distinguishing these notions within environmental ethics. It defines environmental justice as a larger term including multiple justice problems in environmental decision-making and explains the differences between

equity and environmental justice. Environmental justice may be better understood, and North-South ideas can be highlighted using this framework.

Lucas [67] analyzes current and future UK transportation policy, zeroing in on how local transportation provision conflicts with global climate change objectives. The research highlights tensions and difficulties in lowering traffic volumes to combat climate change while providing socioeconomic fairness via transportation policies. The study suggests a holistic strategy for achieving social and environmental justice in the transportation industry. Okereke's [68] research examines debates about fairness and justice within the framework of the climate regime. Research gaps are identified by analyzing policy discussions and the literature on distributive justice in the climate regime. The regime recognizes the need for distributive fairness but needs help addressing the root causes of global inequality. The study advocates for broader policies that find common ground between moral principles and the use of political power. Pearsall & Anguelovski [69] examine the excluding effects of sustainability planning and green projects, which they call "environmental gentrification" (EG). It examines the approaches used by environmental justice (EJ) activists and contrasts them to those taken by EG activists, communities, and urban planners. The research reveals commonalities among the various forms of urban resistance and separates them into their parts. The research highlights the significance of achieving social and political fairness in green and sustainable cities.

McCauley and Heffron [70] promote an interdisciplinary strategy that stresses distributional, procedural, and restorative justice within the context of a quick transformation required to avoid climate change implications. Gutschow et al. [71] highlight the connection between environmental injustice, climate change, and health inequalities among children. It draws attention to the interconnected nature of health inequalities, institutional racism, and the consequences of climate change. Researchers emphasized that pediatric physicians should be aware of these intersections, that they should advocate for their patients' needs, and that they should help break down institutional racism. These links are shown via instances, and measures for improving health and resiliency in the face of structural inequality are proposed. Reducing poverty and susceptibility to the effects of climate change may be significantly aided by actions in environmental justice that promote sustainable and equitable development [72]. These types of initiatives aim to provide underserved communities with a voice in policymaking and increase their access to natural resources. These initiatives help lessen the effects of climate change on at-risk populations by fostering long-term growth [73]. In addition, they aid in building resilience and enhancing communities' capacity to adapt to climate change by decreasing poverty and expanding access to resources. The specific risks to public health and well-being, especially in vulnerable groups, are discussed by Pearson et al. [74]. They contend that psychologists need to think about temporal and geographical aspects of health, compound hazards, and structural causes of susceptibility involved in a few other public health concerns to address climate change and its uneven repercussions. The study provides six actionable suggestions to further the psychological investigation of climate health equality and its social significance.

According to Klepp & Funfgeld [75], well-intentioned adaptation procedures and their outputs may be tainted by fundamental inequities if they fail to recognize and resolve the complicated links between knowledge and power. From a justice viewpoint, they analyze the Kiribati Adaptation Project to see how knowledge hegemonies contribute to ineffective adaptation procedures and results. They argue that environmental justice lenses may be used to address and question the knowledge-power connections that are fundamental to adaptation interventions. Kosanic et al. [76] discuss the disproportionate effect climate and environmental change has on handicapped populations and claim that there is a gap in the literature about the effects of climate and environmental change in different contexts. Impacts and adaptation concerns and their consequences for meeting SDGs are examined through the lens of environmental justice. According to Maxim & Grubert [77], future infrastructure expenditures must not replicate inequitable patterns of the past but instead aim to rectify current inequalities in the domestic energy burden. Rosa et al. [78] stress the need for equitable and inclusive climate adaptation planning that considers regional climatic trends and ecological services to lessen community exposure to climate threats. Martinez et al. [4] examine a California wildfire mitigation fund and offer a framework to address environmental justice comprehensively by fostering partnerships, strengthening local capacity, and mobilizing Traditional Ecological Knowledge. Gill et al. [79] emphasize the triple exposure situation that coastal communities confront and offer measures to address preexisting social inequities, use participatory systems techniques, and harness inclusive partnerships to allow collaborative design and implementation of programs.

Education for Sustainable Development (ESD) at Pakistan's universities is discussed in Hinduja et al.'s [80] research. Educators, managers, policymakers, curriculum developers, and researchers can benefit from the study by reflecting on their practices, identifying key challenges, and framing research questions. The study highlights the importance of logistical support and quality education in achieving the SDGs. In contrast, Farooq & Usman [81] stress the importance of the fund established through the decision made in the COP27 to the UNFCCC to assist vulnerable countries in dealing with climate disasters while noting that the working mechanisms are yet to be determined. Table 1 shows more up-to-date literature on the environmental justice framework and sustainability.

The third hypothesis of the research, based on the existing literature, is as follows:

> H3: Environmental justice initiatives that promote sustainable and equitable development in Pakistan might alleviate poverty and climate change vulnerability by addressing disadvantaged populations' needs and supporting ecologically friendly behaviours.

Pakistan, being highly vulnerable to the impacts of climate change, necessitates a comprehensive understanding of the intricate connections between climate change, poverty, agriculture, and environmental justice [92]. While existing studies have contributed valuable insights to these intersections, it's crucial to acknowledge the limitations they possess, in order to delineate the specific gaps that this paper seeks to address.

Previous research endeavors have provided valuable insights into the ramifications of climate change on rural poverty and the agricultural sector [93–95]. However, these studies often lack a comprehensive analysis that accounts for various determinants of poverty. Notably absent are considerations of the influence of agricultural value added, levels of mechanization in agriculture, access to education and healthcare, and the pivotal role of environmental justice interventions. Moreover, although the connections between rising temperatures, food insecurity, and poverty have been established, the direct integration of environmental justice interventions within poverty dynamics models remains a notable void in the existing literature.

This paper brings forward several innovative aspects that enhance the existing body of knowledge. First, departing from the tendency of previous studies to focus on isolated facets of the climate-poverty-agriculture nexus, this research advances a more comprehensive understanding. It delves into the intricate relationships between phenomena such as water scarcity, extreme temperatures, excessive rainfall, agricultural practices, and poverty in the context of Pakistan. Second, while recognition of the significance of environmental justice in addressing vulnerabilities arising from climate change is not uncommon [96], few studies have ventured to directly incorporate environmental justice interventions into models of poverty dynamics. This paper, however, pioneers by integrating environmental justice as a central variable within the framework of poverty dynamics. Finally, by conducting a synthesis and analysis of existing literature, this research

Table 1
Environmental Justice Literature.

Authors	Environmental justice framework	Scientific Findings	Ecosystem Perspective	Policy Decision
Van Horne et al. [82]	Developed a community-focused environmental justice paradigm for exposure science.	Highlighted the need for community participation in research and the creation of long-term solutions to environmental exposure problems.	Emphasized the importance of community input and the necessity for direct institutional and financial assistance to address neighborhood issues.	Argued for the suggested paradigm to become the norm for studies in the field of exposure science.
Chowkwanyun [83]	Investigated environmental justice activism's "inside-outside" focus and coalitional nature.	Evaluated environmental justice cases' impact on the judicial and regulatory systems.	Looked at environmental justice's fragmented and cross-disciplinary character and recommended improving the EJ perspective.	For better EJ results, coalitions should be kept going, fragmentation should be dealt with, and the historical causes of environmental injustice should be considered.
Desikan et al. [84]	Examined how underprivileged anti-science health and environment policy measures impacted areas.	How assaults on science disproportionately affect marginalized groups.	Recommendations for federal regulation to increase participation from impacted communities, promote scientific integrity, and prioritize research on health inequalities.	In order to safeguard vulnerable populations from health and ecological consequences, they have called for meaningful involvement with impacted communities and reforms to policy.
Wang et al. [85]	Investigated the connection between infrastructure development, ecological consequences, and social equity.	Found a disparity in infrastructure investment, with disadvantaged areas getting less scrutiny and fewer safeguards.	Emphasized the need to isolate environmental infrastructure's positive and negative impacts on EJ neighborhoods.	In order to improve environmental justice results, it is crucial to factor in distributive justice while making infrastructure decisions and conducting environmental impact assessments.
Loos et al. [86]	Highlighted the need to focus on equity in studies and approaches to delivering ecological services.	We analyzed the ecosystem service method critically to determine its strengths and weaknesses regarding its ability to consider justice and environmental ideals.	Highlighted the need for stakeholder participation and the incorporation of different values and areas of expertise to improve the fairness of ecosystem service studies.	In order to inform governance systems that foster justice and human health, advocates for ecosystem service evaluation, management, and research argued for a holistic viewpoint.
Kato-Huerta & Geneletti [87]	An integrated equitable fairness index to evaluate how fairly the benefits of green spaces are shared.	Advocated for integrating environmental justice indicators into municipal planning and policy processes and fully evaluating the equitable distribution of green space benefits.	The city's longstanding segregation patterns contributed to widespread inequality.	Composite indicators be used to better plan for and implement environmental justice by addressing inequalities in access to the benefits provided by green spaces.
Dent et al. [88]	Indigenous peoples' rights to a healthy environment and the power of non-human allies were investigated.	Examined a case study of Indigenous people's efforts for environmental justice.	Emphasized that Indigenous peoples' environmental justice initiatives must include individual and group learning and connection building and action.	The study called for a paradigm change in land use towards EJ principles, stressing the importance of cultural and spiritual traditions to environmental protection.
van Velzen & Helbich [89]	Green space accessibility near schools was analyzed by socioeconomic status.	Low-income and lower-education areas provide less green space for schools than wealthier and more educated areas.	In order to close the environmental justice gap and provide all students with access to green schoolyards, it has been shown that extensive greening subsidy programs are required.	Promoted greening subsidy programs and pushed for legislation that ensures all students have access to and benefit from schoolyard green areas.
Palawat et al. [90]	Researchers in environmental justice areas looked at how contaminants could affect the quality of collected rainwater.	Harvested rainwater was found to have changing quantities of metal(loid)s, with contamination linked to both industrial activities and seasonal changes.	Government and business operations were the primary sources of environmental pollution from collected rainwater.	Underlined the need of government and business enterprises to set criteria for evaluating metal(loid)s in collected rainwater.
Ramcilovic-Suominen [91]	Using the framework of neocolonial environmental justice and degrowth, this study examines the European Union's strategy for the bioeconomy.	Barriers to equitable transitions in EU bioeconomy policy were identified, and solutions were provided.	Advocated for decolonizing and fair changes through rethinking global governance, advancing ecological fairness, and decentralizing governing alliances.	One of the proposed methods is putting ecological equity and socioecological changes at the center of EU bioeconomy policy.

extends beyond academic discourse to offer actionable insights with real-world implications. It endeavors to guide policymakers and practitioners towards a nuanced approach that combines climate adaptation, agricultural enhancement, and equitable interventions for fostering sustainable development, poverty reduction, and social justice in Pakistan.

The primary contributions of this study can be succinctly encapsulated, i.e., this study bridges a significant void in the literature by infusing environmental justice considerations into the modeling of poverty dynamics. It seeks to elucidate how the integration of environmental justice interventions can concretely contribute to the realization of long-term sustainability goals and poverty reduction. By expanding the scope to encompass a broader spectrum of determinants and variables, this research delivers a more intricate and holistic comprehension of the intricate interplay between climate change, poverty, agriculture, and environmental justice within Pakistan. Beyond its academic value, the findings and insights derived from this study hold the potential to wield substantial influence in policy formulation. By articulating the advantages of embedding environmental justice dimensions into strategies aimed at poverty reduction, the paper serves as an invaluable guide for policymakers in their pursuit of equitable and sustainable development pathways.

3. Theoretical framework

Environmental justice theory refers to principles developed to ensure that environmental benefits and costs are shared relatively [97]. Pollution, climate change, and natural disasters are all environmental hazards, but the theory predicts that low-income and minority populations are more vulnerable to their effects [98]. There may be various

unfavorable physical, social, and economic effects, such as a rise in the prevalence of asthma and cancer and a decrease in clean air and water availability. According to the theory, measures taken to improve the state of the environment should give preference to disadvantaged groups and work to ensure that environmental gains and costs are mutually shared [99]. Examples include increasing community engagement in environmental decision-making and expanding access to renewable energy sources [100]. It has been found that Environmental Justice Theory can be a helpful framework for understanding how marginalized communities are affected by environmental hazards and for developing strategies that prioritize their needs and interests within the context of this study's objective of identifying strategies for promoting environmental justice in policies and interventions related to poverty reduction and climate resilience in Pakistan. Some of the adverse effects of poverty and climate change on vulnerable populations in Pakistan could be mitigated by implementing environmental policies and interventions guided by the theory [101].

When mitigating climate change's effects, we must prioritize the demands of the most marginalized and at-risk groups, as articulated by Climate Justice Theory [102]. Communities with poor incomes, Native Americans, and other minorities fall under this category. According to the idea, rich nations have historically contributed to GHG emissions and the consequent repercussions on vulnerable people. However, this does not negate that climate change is a worldwide issue that demands global collaboration and response. In order to combat climate change, Climate Justice Theory advocates for fair and just climate solutions that go to the source of the problem. The theory can be a valuable framework for understanding how climate change impacts are affecting marginalized communities and for developing strategies that prioritize their needs and interests, which is relevant to the study's objective of examining the ethical dimensions of climate change and poverty in Pakistan [103]. Fig. 1 shows the research framework of the study.

Researching the relationship between climate change and poverty in Pakistan through the lens of Climate Justice Theory may lead to more equitable and fair policies and programs that mitigate the adverse effects of climate change on the most marginalized people in the country.

4. Data source and methodology

This research examines the connection between climate change, poverty, and environmental justice in Pakistan using quarterly data from 1990Q1 through 2022Q4. Independent variables are collected from various sources, including the Pakistan Bureau of Statistics [104][1] and the World Bank [105].[2] In addition, data on the dependent variable, rural poverty, is obtained from the World Bank database and various economic surveys conducted in Pakistan. The study uses RLS regression analysis to estimate the connection between poverty and independent variables, i.e., high temperatures, heavy downpours, a lack of water, the value added to agriculture, people's levels of education and health care, the availability of farm equipment, and government action in the appellation of environmental justice. Analyzing the dynamic interaction between these factors is also possible using tools like VDA and IRF analysis.

This research uses several explanatory factors to understand better the connection between poverty and climate risk in rural Pakistan. The proportion of the rural population below the poverty line is used to compute the conditional variable poverty (RURPOV). This variable is a crucial starting point as it directly captures the prevalence of poverty within the rural context. Understanding how poverty rates change in response to climate-related variables provides foundational insights into the impacts of climate change on vulnerable populations. The percentage change in temperature (EXTEMP), the amount of rain (EXCRAIN), and the amount of freshwater withdrawn as a percentage (H2OSTRESS) are all valuable indicators of the effects of climate change on poverty rates. These variables are direct indicators of climate change impacts. Changes in temperature and precipitation patterns have significant implications for agriculture, water availability, and livelihoods, all of which are closely intertwined with poverty dynamics in rural areas. Furthermore, the research investigates how environmental justice intervention (ENVJUST), agricultural machinery (AGRMECH), and value addition in agriculture (AGRVAD) all affect poverty rates. Incorporating ENVJUST variable is innovative and reflects the recognition that addressing environmental injustice is critical for sustainable poverty reduction. Investigating how environmental justice measures influence poverty rates sheds light on equitable policy solutions that can benefit marginalized communities. Our poverty modeling uses "Renewable energy consumption (% of total final energy consumption)" as a proxy for "Environmental Justice" since access to clean and sustainable energy sources is essential. It improves community well-being, particularly for impoverished people, by cutting energy costs, improving health, and creating economic opportunities. The number of tractors per 100 km^2 of arable land is used for agriculture mechanization and the percentage of GDP spent on agriculture value addition is used for farming value added for empirical illustration. Tractor availability speaks to the mechanization level, renewable energy usage aligns with climate resilience, and investments in education and healthcare address human development aspects. This research might provide effective rural Pakistan poverty reduction and sustainable development policies. The study analyzes environmental justice, climate change, and poverty in Pakistan using a legitimate approach. Quarterly data over 30 years helps understand the dynamic interaction between these characteristics.

When data fails to meet the requirements of a traditional linear regression model, statisticians turn to robust regression to make sense of the information [106]. When data are not normally distributed or include outliers, robust regression offers accurate estimates of the regression model's parameters. The parameters of the regression model may be estimated in several ways, including M-estimation, S-estimation, and MM-estimation. There is a lot written about robust regression. Huber's [107] critical study on M-estimation is one of the early studies on robust regression. Huber presented a strategy for estimating the parameters of the regression model in the presence of outliers that involves minimizing the sum of the absolute deviations of the residuals. Rousseeuw and Leroy [108] made a significant addition to the field when they presented S-estimation and offered a thorough study of robust regression techniques. M, S, and MM-estimation are all types of robust regression techniques; their relative merits have been examined in a number of research [109,110]. The non-normality or outliers in the data may be accounted for by using the robust regression model. Here is the best-guess regression equation:

$$\mathbf{RURPOV} = \beta\mathbf{0} + \beta\mathbf{1}(\mathbf{H2OSTRESS}) + \beta\mathbf{2}(\mathbf{EXTEMP}) + \beta\mathbf{3}(\mathbf{EXCRAIN}) + \beta\mathbf{4}(\mathbf{ENVJUST}) + \beta\mathbf{5}(\mathbf{AGRVAD}) + \beta\mathbf{6}(\mathbf{AGRMECH}) + \beta\mathbf{7}(\mathbf{ACCHLTH}) + \beta\mathbf{8}(\mathbf{ACCEDU}) + \varepsilon \quad (1a)$$

Where ε is the white noise term.

The regression model (1) aims to elucidate the factors influencing rural poverty (RURPOV) through a set of explanatory variables. Each

[1] https://www.finance.gov.pk/survey_2022.html
[2] https://databank.worldbank.org/source/world-development-indicators

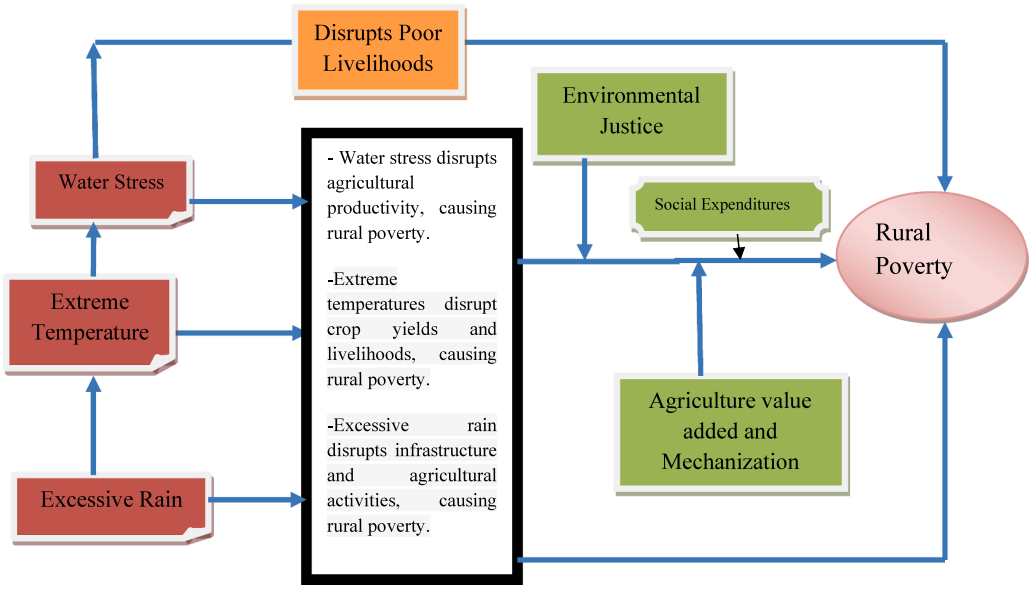


Fig. 1. Research Framework of the Study.
Source: Author's made.

coefficient in the model quantifies the change in the dependent variable (RURPOV) associated with a one-unit change in the corresponding explanatory variable, while keeping other variables constant. The model is as follows:

$$\mathbf{RURPOV} = \beta\mathbf{0} + \beta\mathbf{1}(\mathbf{H2OSTRESS}) + \beta\mathbf{2}(\mathbf{EXTEMP}) + \beta\mathbf{3}(\mathbf{EXCRAIN}) + \beta\mathbf{4}(\mathbf{ENVJUST}) + \beta\mathbf{5}(\mathbf{AGRVAD}) + \beta\mathbf{6}(\mathbf{AGRMECH}) + \beta\mathbf{7}(\mathbf{ACCHLTH}) + \beta\mathbf{8}(\mathbf{ACCEDU}) + \varepsilon \quad (1b)$$

Where,

1 **H2OSTRESS** represents water stress due to climate change. Positive coefficient (β1) would imply that increased water stress is associated with higher rural poverty rates.
2 **EXTEMP s**ignifies extreme temperature changes due to climate change. Positive coefficient (β2) would indicate that rising temperatures are linked to higher rural poverty rates.
3 **EXCRAIN r**epresents excessive rain due to climate change. Positive coefficient (β3) would suggest that excessive rain is associated with higher rural poverty rates.
4 **ENVJUST** denotes environmental justice interventions measuring through provision to clean and sustainable energy to the poor. Negative coefficient (β4) would indicate that effective environmental justice measures are linked to lower rural poverty rates.
5 **AGRVAD s**tands for value addition in agriculture. Negative coefficient (β5) would suggest that increased value addition in agriculture is associated with lower rural poverty rates.
6 **AGRMECH i**ndicates agricultural mechanization. Negative coefficient (β6) would imply that higher levels of mechanization are linked to lower rural poverty rates.
7 **ACCHLTH r**epresents access to health services. Negative coefficient (β7) would suggest that better access to healthcare is associated with lower rural poverty rates.
8 **ACCEDU s**ignifies access to education. Expected relationship: Negative coefficient (β8) would imply that improved access to education is linked to lower rural poverty rates.

When other factors are held constant, the IRF calculates how rural poverty might change in response to a sudden change in the independent variable. The IRF analysis shows the cumulative effects of each independent variable on rural poverty. The IRF formula is represented as:

$$\mathbf{IRF}(\mathbf{t}) = \sum(\boldsymbol{\beta}i * \Delta Xi(\mathbf{t})) \quad (2)$$

Where:

- IRF(t) denotes the impulse response of rural poverty at time t.
- βi signifies the coefficient of each explanatory variable.
- ΔXi(t) signifies the change in each explanatory variable at time t.

IRF analysis allows us to fathom the temporal effects of environmental justice interventions, climate fluctuations, agricultural enhancements, and other factors on poverty rates. However, VDA may be used to calculate how much each independent variable contributes to the total variance in the dependent variable. Using VDA, we can see how much of the observed change in rural poverty can be ascribed to each independent variable and how much can be assigned together. The VDA formula is expressed as:

$$\mathbf{Var}(\mathbf{RURPOV}) = \sum(\boldsymbol{\beta}i * Var(\mathbf{Xi})) + \mathbf{Cov}(\boldsymbol{\varepsilon}, RURPOV) \quad (3)$$

Where:

- Var(RURPOV) represents the variance in rural poverty.
- βi represents the coefficient of each explanatory variable.

- Var(Xi) represents the variance of each explanatory variable.
- Cov(ε, RURPOV) represents the covariance between the error term (ε) and rural poverty.

VDA empowers us to delineate the significance of each variable's influence on rural poverty, facilitating a nuanced understanding of their distinct roles in shaping poverty dynamics over time. This study makes significant contributions to our understanding of the short- and long-term effects of climate change and other socioeconomic variables on rural poverty in Pakistan by using IRF and VDA. Using these methods, policymakers and academics in Pakistan may isolate the factors that contribute to poverty and create effective strategies to boost the economy, create jobs, and raise people's standard of living.

5. Results and discussion

This section provides an exposition of diverse statistical methodologies, commencing with an explication of descriptive statistics applied to the variables, which serves to facilitate the discernment of trends inherent in individual variables. Subsequently, a correlation analysis is executed, aiming to ascertain the magnitude and direction of relationships between said variables. Following this, an "influence statistics" test is administered, the primary objective of which is the identification of potential outliers within the given model. This is succeeded by an inspection of "leverage plots," strategically employed to detect plausible outliers within both the dependent and explanatory variables. Upon the detection of conceivable outliers within the variables, a rigorous examination involving the application of the robust least squares test is conducted. This test, characterized by its efficacy in addressing such anomalies, contributes to the attainment of unbiased, consistent, and robust parameter estimates. In the ultimate phase, the study avails itself of the impulse response function and variance decomposition analysis, leveraging these analytical tools for the explicit purpose of forecasting.

Starting with Table 2 compiles statistics on many environmental and social indices for Pakistan. Policymakers in Pakistan may utilize this data better to address the country's environmental and economic challenges. With a population of over 220 million people, Pakistan is one of the world's most populous yet poorest developing nations. The statistics show that about one-third of Pakistan's rural population is poor, with a headcount ratio of 29.7. Poverty is a severe moral concern because it hinders people's ability to meet their fundamental needs and advances barriers to receiving quality medical treatment, education, and other necessary services. Therefore, the government and other stakeholders should cooperate to alleviate rural poverty and expand the delivery of necessities.

With freshwater extraction surpassing available freshwater supplies, water stress is another critical environmental concern in Pakistan. The amount of withdrawn freshwater is 108.3% of the total amount that may be used. This indicates a severe strain on water supplies, which might have unfavorable consequences for agriculture, the energy industry, and other areas. Therefore, the government and other stakeholders should enact regulations to ensure the long-term viability of water management and encourage conservation measures. Another major environmental issue in Pakistan is climate extremes' influence on agriculture and other economic sectors. With a temperature increase of 0.567%, it is clear that some action is needed to deal with the consequences of climate change. Furthermore, the same amount of rain, 282.273 mm, emphasizes the need for proper flood control systems. As a result, the government and other interested parties need to take action to lessen and adjust to climate change.

The involvement of environmental justice is another ethical dilemma in Pakistan. This points to the need to encourage using renewable energy sources to lessen the effects of climate change and lower carbon emissions. Energy poverty may be mitigated, and new jobs created by promoting green energy sources. That is why the government and other players need to take steps to boost renewable energy. The agricultural industry in Pakistan plays a substantial role in the country's gross domestic product. The value contributed by agriculture as a proportion of GDP is 23.1%, as seen in the table, demonstrating the sector's significance to the national economy. There is a need to expand mechanization in agriculture to boost agricultural output, as shown by the low number of tractors per 100 km^2s of arable land. Therefore, actions should be taken by the government and other stakeholders to encourage sustainable agriculture methods, such as automation, in order to increase agricultural production.

Finally, sustainable development relies on universal access to healthcare and education. According to the data, the government spends US$127.733 per person on health care and US$11.1% on education. According to these metrics, the government must allocate more resources toward healthcare and education to expand citizens' access to these pillars of society. The correlation matrix is shown for convenience in Table 3.

As can be seen in Table 3, there is a significant link between water scarcity and rural poverty. This suggests that rural poverty is more prevalent in regions with greater water stress. Environmental deterioration may worsen poverty by making it more challenging to get necessities like water, as shown in previous research [111,112], consistent with the present conclusion. The positive association between mechanization in agriculture and water stress ($r = 0.854$, $p<0.001$) is also noteworthy. This indicates that mechanical agriculture may contribute to water scarcity in the area. This result accords with what has been found in the literature on the environmental effects of industrialization [113,114]. More industrialized nations tend to use more natural resources and produce more pollution.

Interventions for environmental justice are negatively correlated with educational opportunity ($r=-0.690$, $p<0.001$). This data shows that places where environmental injustice is more prevalent also have fewer opportunities to get an education. This may be because underprivileged populations are more likely to be impacted by environmental injustice and may have less access to education [115]. Value added in the agricultural sector is positively associated with severe temperatures ($r = 0.379$, $p = 0.029$). This indicates that higher temperatures may lead to greater agricultural output. On the other hand, extreme temperatures, such as droughts and heat waves, may harm agricultural production. Thus this conclusion should be taken carefully [116,117].

Fig. 2 displays the influence statistics after describing and correlating the factors. Four outliers were found by R-student, three by DFFITS, two by COVRATIO, and two by the Hat Matrix. The different methods used by the various impact statistics to identify outliers explain their discrepancies.

Table 2
Descriptive Statistics.

Methods	RURPOV	H2OSTRESS	EXTEMP	EXCRAIN	ENVJUST	AGRVAD	AGRMECH	ACCHLTH	ACCEDU
Mean	29.746	108.331	0.567	282.273	48.757	23.136	127.733	24.725	11.095
Maximum	39.260	122.673	1.423	387.180	58.091	25.617	151	42.873	15.445
Minimum	20.210	94.234	−0.375	187.520	42.090	20.677	83.590	13.585	7.802
Std. Dev.	4.244	7.666	0.475	64.660	4.374	1.145	23.830	10.235	2.274
Skewness	0.249	0.030	−0.191	0.190	0.402	0.353	−0.497	0.517	0.261
Kurtosis	3.045	2.430	2.481	1.525	2.287	2.889	1.604	1.721	2.259

Source: Author's estimate.

Table 3
Correlation Matrix.

Variables	RURPOV	H2OSTRESS	EXTEMP	EXCRAIN	ENVJUST	AGRVAD	AGRMECH	ACCHLTH	ACCEDU
RURPOV	1								
	—								
H2OSTRESS	0.412	1							
	(0.017)	—							
EXTEMP	0.385	0.656	1						
	(0.026)	(0.000)	—						
EXCRAIN	−0.181	−0.182	−0.415	1					
	(0.313)	(0.310)	(0.016)	—					
ENVJUST	−0.214	−0.831	−0.583	0.116	1				
	(0.230)	(0.000)	(0.000)	(0.519)	—				
AGRVAD	0.320	−0.178	−0.189	−0.245	0.379	1			
	(0.069)	(0.320)	(0.290)	(0.168)	(0.029)	—			
AGRMECH	0.201	0.854	0.542	−0.121	−0.935	−0.315	1		
	(0.261)	(0.000)	(0.001)	(0.501)	(0.000)	(0.074)	—		
ACCHLTH	−0.089	0.722	0.421	−0.021	−0.861	−0.480	0.824	1	
	(0.620)	(0.000)	(0.014)	(0.905)	(0.000)	(0.004)	(0.000)	—	
ACCEDU	0.061	0.712	0.441	0.135	−0.690	−0.286	0.705	0.526	1
	(0.734)	(0.000)	(0.010)	(0.452	(0.000)	(0.106)	(0.000)	(0.001)	—

Source: Author's estimate. Note: small bracket shows probability value.

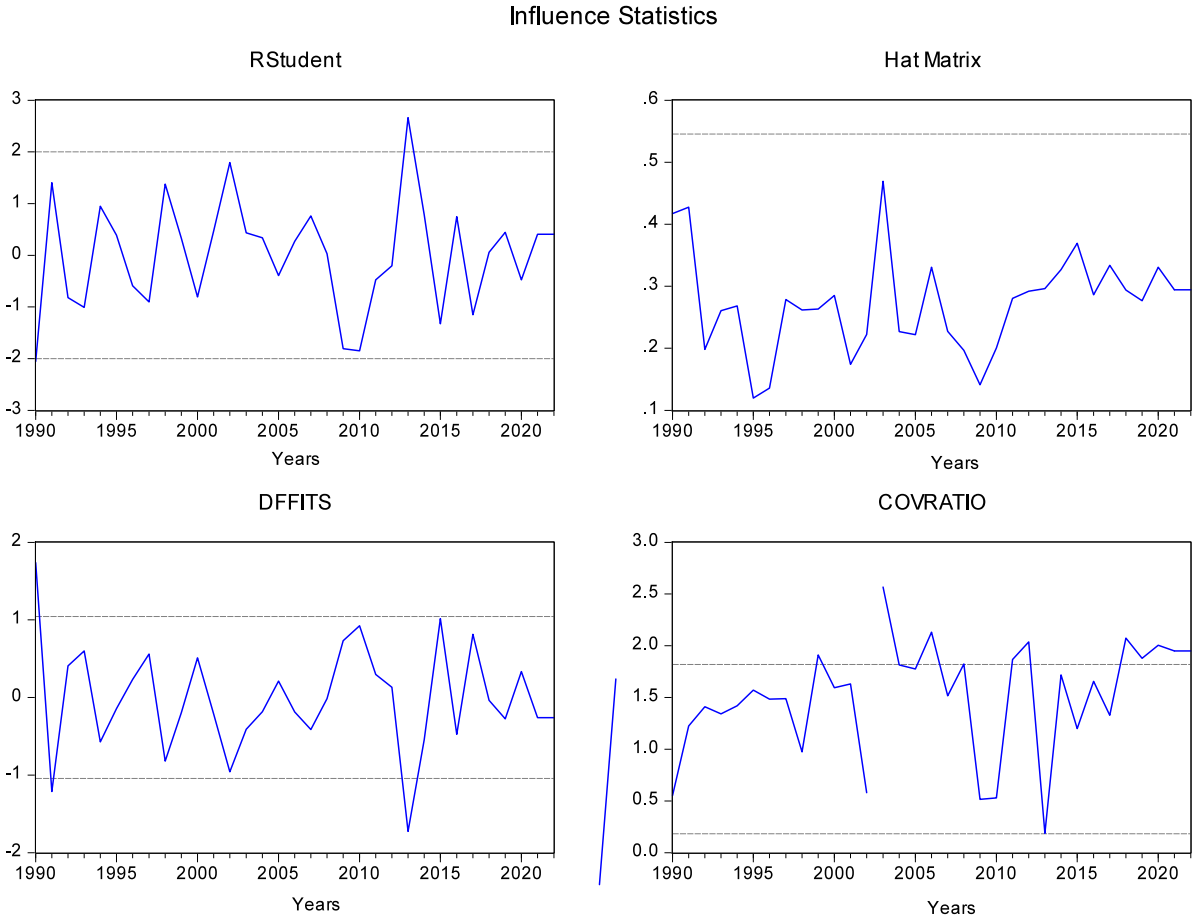


Fig. 2. Influence Statistics.
Source: Author's estimate.

The R-student uses standardized residuals (the gaps between actual and anticipated values divided by the estimated residual standard deviation) to spot irregularities. In this situation, it picked out four extreme values. However, because the DFFITS, COVRATIO, and Hat Matrix statistics evaluate the impact of each observation on the regression coefficients, they may only sometimes pick up on the same outliers that the R-student does. DFFITS calculates how much the model's fit suffers when individual observations are removed. If an observation were removed, COVRATIO would calculate by how much the predicted coefficients' variance would rise. The leverage of each observation is calculated using the Hat Matrix. Leverage is defined as the amount by which each observation deviates from the mean value of the predictors. As a result, these statistics may be used to infer which data are significant for which features of the regression model based on the variations in the number of outliers they identify. Three outliers were found using DFFITS, COVRATIO, and the Hat Matrix, all indicating that these data

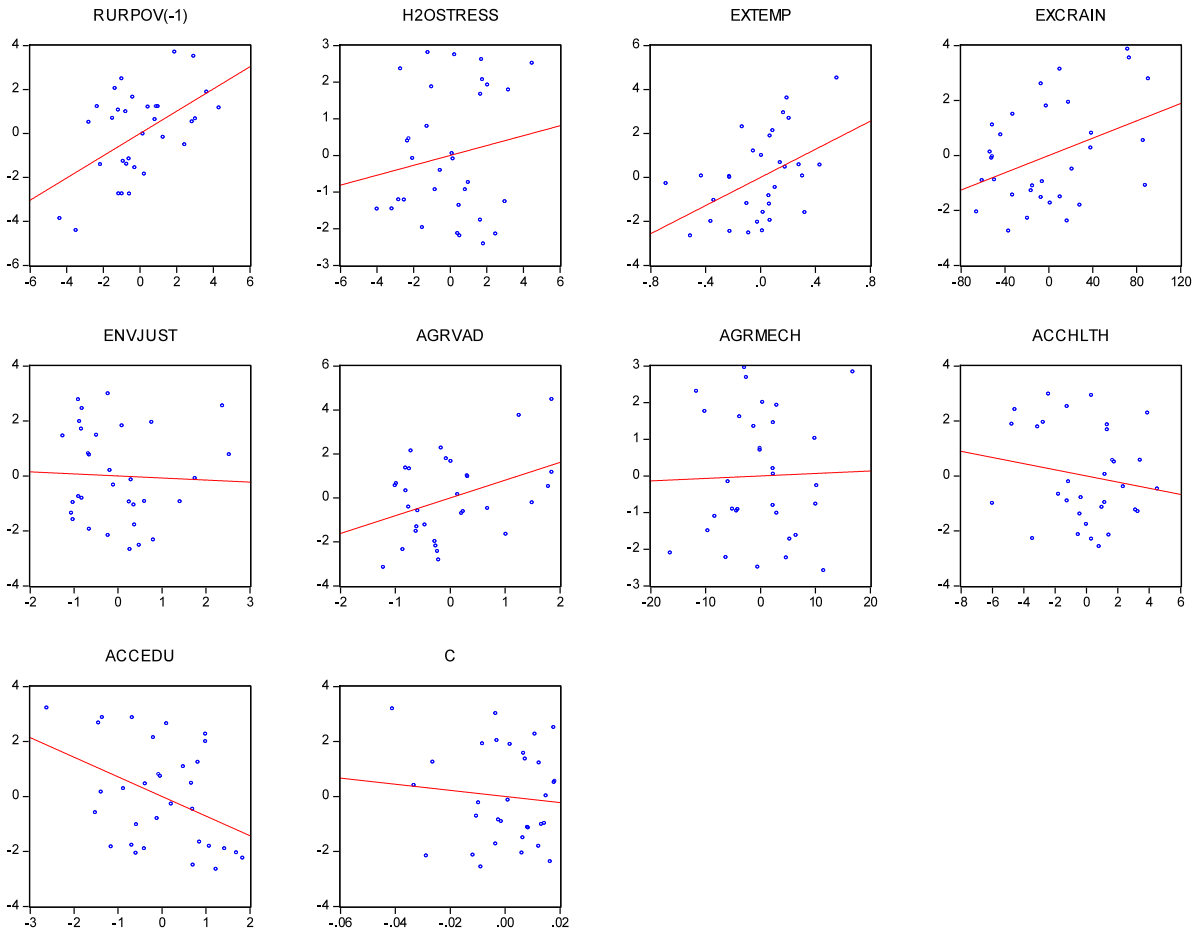


Fig. 3. Leverage Plots.
Source: Author's estimate.

Table 4
Robust Least Squares (RLS) Regression: MM-Estimator.

Variables	Robust Least Squares-I	Robust Least Squares-II	Robust Least Squares-III
H2OSTRESS	0.569***	0.177***	0.336***
EXTEMP	1.557**	1.678***	0.688
EXCRAIN	0.011***	0.012***	−0.006
ENVJUST	−0.908***	—-	—-
AGRVAD	—-	1.665*	—-
AGRMECH	—-	0.002	−0.062**
ACCHLTH	−0.559***	—-	—-
ACCEDU	−1.348***	—-	—-
Statistical Tests			
R^2	0.423	0.352	0.173
Adjusted R^2	0.400	0.326	0.147
Rw^2	0.742	0.707	0.352
Rn^2	204.416***	149.545***	33.035***
Diagnostic Tests			
Jarque-Bera	0.716	Prob.value	0.699
Ramsey RESET	0.453	Prob.value	0.651

Source: Author's estimate. ***, **, and * indicates 1%, 5%, and 10% significance level.

points significantly affect the model's projected values, the variance of estimated coefficients, and leverage. Fig. 3 displays the model's leverage plots, which were generated using the influence statistics.

The model's leverage plot, seen in Fig. 3, includes rural poverty as the dependent variable. Based on the scatter plot, the supplied model is sensitive to outliers in Pakistan's dependent and independent variables since there are several points in the data series for each. This susceptibility to outliers might cause inaccurate calculations. The existence of outliers calls for adopting an estimator that is robust enough to generate unbiased, consistent, and accurate estimations despite the presence of outliers; one such estimator is the MM-estimator. This estimator allows for the outliers' impact to be mitigated, leading to a more robust and precise regression model. The different specifications of the robust least squares regression test from I to III (RLS-I to RLS-III) is used to dealing with outliers if the presence of outliers in the provided model has been confirmed (see, Table 4).

Water shortages, severe temperatures, and heavy rainfall are all factors associated with climate change that has been shown to exacerbate rural poverty in Pakistan using the RLS estimator. This is because these factors directly affect the agricultural production of rural regions, the primary source of income for rural people. Farmers may be unable to produce enough food due to climate change, raising global poverty levels [118] and reducing farmers' incomes. The effects of climate change on rural poverty in Pakistan are a severe issue from environmental ethics and justice standpoint. Positive coefficients show a substantial effect of climate change on rural poverty for these variables in the regression model. A large portion of the rural population in Pakistan depends on agriculture for their livelihood, and climate change has been shown to significantly influence agricultural production [119,120], making this impact all the more critical. Farmers may need help to make a living if water shortage reduces irrigation and agricultural output [121]. Soil erosion, crop damage, and other negative consequences from severe temperatures and heavy rainfall may similarly affect agricultural output, leading to a drop in revenue and an increase in poverty [122]. Because rural people in Pakistan are frequently the most susceptible to

climate change's consequences yet contribute the least to global GHG emissions, the impact of climate change on rural poverty is especially problematic from an environmental justice viewpoint. This may cause the poorest areas to suffer the most from climate change, while the wealthiest areas are better equipped to adapt to it and lessen its impact [123]. These findings have important policy implications, highlighting the need for focused efforts to mitigate the effects of climate change on rural poverty in Pakistan [124]. Examples include investments in climate-resilient agriculture, better irrigation and water management, and aid for alternative livelihoods. Global efforts to cut GHG emissions may lessen the long-term implications of climate change on vulnerable groups, such as rural people in Pakistan [125].

However, environmental justice interventions reduce rural poverty in Pakistan, as shown by their negative coefficient. This suggests that efforts to enhance the environment and lessen pollution in rural regions might help raise people out of poverty by increasing their quality of life. Improvements in rural regions' environmental quality and pollution reduction have been linked to higher incomes and less poverty [126]. Evidence shows why environmental justice is crucial, as is the implementation of laws to reduce the disproportionate impact of environmental deterioration and pollution on marginalized groups like those in rural Pakistan. According to the principles of environmental justice, everyone, regardless of their socioeconomic standing or location, should be able to enjoy a clean, healthy environment. Therefore, environmental justice and sustainable development may be advanced via environmental improvement and pollution reduction initiatives in the context of rural poverty in Pakistan. Sustainable farming techniques, decreased industrial pollution, and expanded access to potable water and sanitary facilities are all potential solutions [127,128].

The same holds for healthcare and education; both have negative coefficients, indicating that they work to reduce rural poverty in Pakistan. The reasons for this are clear: greater career prospects, healthier lives, and higher incomes may all result from investing in one's education and health. Recognizing the connection between human and environmental health is crucial from an environmental ethics and justice standpoint. Improved health outcomes for people due to increased access to education and healthcare may increase their capacity to participate in environmental conservation initiatives [129]. In addition, improving people's human capital via increased access to education and healthcare has been shown to lessen poverty, boost economic productivity, and foster long-term growth and prosperity [130]. In this way, promoting environmental sustainability and justice through increased access to educational and healthcare opportunities can be an example of environmental justice [15]. Such initiatives have the added benefit of reducing rural poverty in Pakistan.

Agriculture mechanization reduces rural poverty in Pakistan, as shown by a negative coefficient. Therefore, it follows that automation in agriculture may boost production, leading to greater earnings and a poverty reduction [131]. The negative coefficient of farm mechanization is essential from an environmental ethics and justice perspective because it demonstrates that sustainable and effective use of resources is achievable without adversely affecting the lives of rural people. Farmers' incomes may rise due to mechanization's effects on yields, labor costs, and efficiency [132]. It is equally essential to prevent soil erosion, biodiversity loss, and pollution from occurring as a result of machine usage. Sustainable agriculture practices that are good for both farmers and the environment may be encouraged if the use of equipment is properly regulated and monitored [133,134].

However, rural poverty in Pakistan has worsened due to the positive coefficient of agricultural value added. Because agricultural value-added measures the worth of crops produced, a rise in crop value may not automatically lead to a rise in farmer income. Market inefficiencies in the agricultural sector significantly contribute to the positive link between agricultural value added and rural poverty in Pakistan [135]. Despite its importance to the country's economy, agriculture is struggling due to poor crop prices, a shortage of finance, outdated infrastructure, and restricted access to new markets. Consequently, farmers' earnings are low and volatile since crop prices are routinely set below their costs [136]. In rural regions, where agriculture is the primary source of income, this low and inconsistent income is a significant contributor to poverty. Additionally, many farmers in Pakistan need more information and tools to use contemporary, environmentally friendly agricultural methods. As a consequence, farmers' incomes suffer from poor productivity and yields. In light of this, it is possible that farmers' incomes will not rise even if the value of crops grows [137]. However, it might be suitable for the intermediaries and dealers who buy products from farmers at a discount and then resell them at a profit. The positive correlation between agricultural value-added and rural poverty in Pakistan has economic and environmental causes. Irrigation is crucial to the success of Pakistan's agricultural sector, and the bulk of the country's irrigation water originates from underground aquifers. The quantity of water available for irrigation has decreased, however, because of the irresponsible use of groundwater that has contributed to the depletion of aquifers. The outcome is lower agricultural yields and revenue for farmers, exacerbating poverty in rural areas [138]. Soil erosion and contamination caused by non-sustainable agricultural practices, including the overuse of chemical fertilizers and pesticides, further decrease agricultural output and revenue [139]. There is a vicious cycle of poverty and environmental deterioration caused by interconnected environmental and economic variables. Table 5 shows the Generalized Method of Moments (GMM) test estimates to ensure the RLS results.

Table 5
GMM Estimates.

Variables	Coefficient	Std. Error	t-Statistic	Prob.
H2OSTRESS	0.594	0.111	5.340	0.000
EXTEMP	2.297	1.211	1.896	0.060
EXCRAIN	0.025	0.006	4.167	0.000
ENVJUST	−0.707	0.158	−4.471	0.000
AGRVAD	0.724	0.352	2.055	0.042
AGRMECH	0.019	0.040	0.475	0.635
ACCHLTH	−0.481	0.057	−8.350	0.000
ACCEDU	−1.416	0.224	−6.311	0.000
Statistical Test				
R^2	0.724	J-statistic		14.186
Adjusted R^2	0.709	Prob(J-statistic)		0.0008

Source: Author's estimate.

The empirical findings of this study underscore the significant impact of climatic factors, including water stress, extreme temperatures, and excessive rainfall, on the amplification of rural poverty. These climatic variables can potentially exacerbate rural poverty through several channels. For instance, water stress can hamper agricultural productivity, leading to decreased crop yields and reduced income for rural farmers, thus directly contributing to heightened poverty levels. Similarly, extreme temperature fluctuations can disrupt traditional farming practices, causing crop failures and loss of livelihoods, thereby perpetuating the cycle of poverty. Furthermore, the implementation of strategies aligned with the principles of environmental justice emerges as a constructive mechanism for elevating the quality of life for marginalized rural populations. The equitable distribution of environmental resources and benefits through such strategies can alleviate environmental burdens that disproportionately affect rural communities, ultimately fostering socioeconomic advancement. It is noteworthy that, despite witnessing a notable rise in the value added by the agricultural sector, this singular advancement falls short of inducing a substantial mitigation of rural poverty on a national scale. The limited impact of agricultural growth on poverty reduction can be attributed to various factors. For instance, unequal access to land and resources within the agricultural sector can hinder the equitable distribution of benefits from increased agricultural productivity, thereby perpetuating rural poverty. This accentuates the imperative role assumed by targeted social

Table 6
Impulse Response Function of Rural Poverty.

Period	RURPOV	H2OSTRESS	EXTEMP	EXCRAIN	ENVJUST	ACCHLTH	ACCEDU	AGRVAD	AGRMECH
2023	1.260	0	0	0	0	0	0	0	0
2024	1.098	0.012	0.008	0.006	−0.022	0.016	−0.031	0.021	0.026
2025	0.945	0.055	0.030	−0.059	−0.029	−0.049	−0.114	0.114	−0.003
2026	0.819	0.087	0.049	−0.107	−0.037	−0.096	−0.177	0.187	−0.022
2027	0.719	0.100	0.062	−0.140	−0.046	−0.126	−0.214	0.254	−0.036
2028	0.637	0.101	0.070	−0.159	−0.055	−0.144	−0.234	0.313	−0.046
2029	0.569	0.095	0.072	−0.171	−0.066	−0.154	−0.242	0.364	−0.053
2030	0.510	0.085	0.070	−0.177	−0.077	−0.158	−0.241	0.405	−0.059
2031	0.458	0.072	0.064	−0.178	−0.088	−0.159	−0.234	0.438	−0.063
2032	0.412	0.058	0.057	−0.178	−0.100	−0.159	−0.223	0.463	−0.066

Source: Author's estimate.

investments in education and healthcare, which emerge as pivotal determinants in enhancing the socioeconomic well-being of the underserved cohorts within a nation. Access to quality education equips individuals with skills and knowledge essential for escaping the poverty trap, while improved healthcare services can enhance productivity and reduce vulnerability to health-related shocks, thus facilitating poverty reduction. In this context, effective policies addressing education and healthcare disparities hold the potential to significantly uplift rural communities and break the cycle of intergenerational poverty. For time series data, the impulse response function is shown in Table 6.

The anticipated value of rural poverty is 1.26, according to Table 4, the highest number in the whole 10-period prediction. This indicates that initial expectations for rural poverty in Pakistan are low. The greatest potential beneficial and negative impacts on rural poverty are water stress and access to education, respectively. This shows that reducing rural poverty in Pakistan may require focusing first on alleviating water stress and expanding access to education. Severe temperature and heavy rainfall do not seem to have a substantial influence on rural poverty in the first period. It's worth remembering, too, that climate-related shocks may have far-reaching effects on agricultural output and rural lives, suggesting that tackling these environmental issues over the long run may be crucial. The lowest predicted value of rural poverty occurs in the tenth period and is equal to 0.412. The results show that rural poverty in Pakistan should decline over time, but progress might be sluggish and gradual. In the 10th period, education's negative impact on rural poverty was still sizable, demonstrating that expanding educational opportunities is critical to ending extreme poverty in Pakistan's rural areas. There is still a favorable impact of water scarcity on rural poverty, albeit it is lower than it was in the first era. Compared to previous time periods, the impact of environmental justice intervention on rural poverty seems to be reduced in the tenth period, indicating that policies targeted at enhancing environmental justice may become less successful with time. The coefficients also imply that, while the benefits may be slight, an increase in agriculture's value added and automation may have a favorable influence on rural poverty over the long run. Overall, the 1st-10th periods indicate that improving educational opportunities and alleviating water scarcity would be crucial in the fight against rural poverty in Pakistan during the next decade. It is possible that tackling other climate-related shocks and implementing measures to improve environmental justice will also be crucial for decreasing rural poverty over the long run. The VDA estimations are shown in Table 7.

The relative importance of each explanatory variable in describing the variance of the dependent variable may be better grasped using VDA. The sum of the variances explained by all the variables in the second period is 99.884%, just under 100%. Water scarcity, environmental justice interventions, health care availability, educational opportunities, agricultural value addition, and agricultural automation explain rural poverty to varying degrees. Drought or a lack of water for agriculture might cause water stress, which accounts for 0.005% of the variation. An environmental justice intervention, accounting for 0.017% of the variation, may be a new policy or program designed to fix environmental problems in remote places. One possible indication of the health of the rural population is access to health care, which accounts for 0.009% of the variation. One possible predictor of the level of education among rural residents is the degree to which they have access to education, which accounts for 0.035% of the variation. An indication of agricultural production in remote places may be the value contributed by agriculture, which accounts for 0.016% of the total variation. Mechanization in agriculture, which accounts for 0.026% of the variation, may serve as a proxy for the rate at which farmers in remote places adapt to new technologies. The variation in the tenth period, explained by all of the factors, is 78.028%, which is much lower than the variance in the second period. Water scarcity, high temperatures, high rainfall, environmental justice interventions, public health care, educational opportunities, agricultural value addition, and agricultural automation all explain rural poverty to varying degrees. Drought or a lack of water for agriculture might be the causes of water stress, which accounts for 0.703% of the variation. The 0.374% of variability attributed to extreme temperatures may result from climate change and its unfavorable effects on farming. Excessive precipitation, which accounts for 2.306% of the variation, could result from floods or heavy rainfall, which is detrimental to agricultural production and infrastructure in rural regions. An environmental justice intervention would be designed to improve

Table 7
Variance Decomposition Analysis of Rural Poverty.

Period	S.E.	RURPOV	H2OSTRESS	EXTEMP	EXCRAIN	ENVJUST	ACCHLTH	ACCEDU	AGRVAD	AGRMECH
2023	1.260	100	0	0	0	0	0	0	0	0
2024	1.672	99.884	0.005	0.002	0.001	0.017	0.009	0.035	0.016	0.026
2025	1.931	98.917	0.087	0.026	0.095	0.037	0.073	0.380	0.360	0.019
2026	2.121	96.890	0.241	0.076	0.338	0.062	0.268	1.011	1.082	0.027
2027	2.276	94.132	0.402	0.142	0.672	0.095	0.544	1.769	2.190	0.050
2028	2.410	90.971	0.536	0.211	1.040	0.138	0.845	2.525	3.647	0.082
2029	2.530	87.647	0.630	0.274	1.402	0.194	1.137	3.208	5.384	0.120
2030	2.638	84.320	0.684	0.323	1.739	0.265	1.406	3.783	7.316	0.160
2031	2.738	81.093	0.705	0.356	2.041	0.351	1.646	4.243	9.359	0.202
2032	2.830	78.028	0.703	0.374	2.306	0.454	1.857	4.594	11.431	0.244

Source: Author's estimate.

environmental conditions in underserved communities. The percentage of variation accounted for by the ability to get medical care (1.857%) may be indicative of the general health of the rural population. One possible measure of the educational level of the rural population is the degree to which they have access to education (4.594% of the variation). In contrast, a measure of agricultural production in the countryside is the value contributed by agriculture (11.43% of the total variance). Mechanization in agriculture, which accounts for 0.244% of the variation, may represent the rate of technological adoption in farming in the countryside. These factors are becoming more critical over time, and policies and actions designed to alleviate rural poverty in Pakistan should reflect this.

Conclusions

Water scarcity, extreme temperatures, and excessive rainfall are all factors in the study that contribute to increased rural poverty in Pakistan. In contrast, environmental justice intervention, access to education and healthcare, and agricultural mechanization all contribute to a decrease in rural poverty. Agriculture value-added was proven to worsen living conditions in rural areas. IRF research indicates that rural poverty is anticipated to diminish over the next decade thanks to increased precipitation, interventions in environmental justice, improved health care, and agricultural automation. However, rural poverty is expected to rise due to water stress, severe temperatures, and low agricultural value added. According to the VDA, the contribution of agricultural value added to rural poverty by 2032 is 11.431%, followed by the effects of access to education (4.594%), excessive rainfall (2.306%), and access to health care (1.857%). Less than 1% of the influence on rural poverty until 2032 will come from water shortages, severe temperature, environmental justice action, and agricultural automation. As a result, the study recommends tackling the adverse effects of climate change while improving access to education and healthcare, supporting environmental justice intervention, boosting agricultural automation, and decreasing rural poverty in Pakistan. In order to alleviate poverty in rural Pakistan, government policies should emphasize the value provided by the agricultural sector.

Several policy implications for promoting equitable results in the context of rural poverty and climate change in Pakistan may be inferred from the study's findings.

1 Alleviating rural poverty requires addressing the problem of water shortage. In order to guarantee a steady supply of water for agricultural uses, the government may put money into water management systems, including dam construction, rainwater collection, and adequate irrigation methods. Water shortage may be mainly mitigated by raising public awareness of the issue and encouraging water-saving behaviours.
2 Expanding the availability of healthcare and educational opportunities in remote places is a priority. Investment in schools and hospitals may benefit the rural poor and raise their level of life. Learning about environmental problems and their consequences might lead to more sustainable actions.
3 Environmental justice actions are needed to lessen rural poverty. It can take the form of policies that give underserved populations higher priority, guarantee their inclusion in decision-making processes, and provide them access to resources to improve their standard of living. Increased production and decreased poverty may result from government support for agricultural automation. Some examples include training programs for farmers on using modern technology and subsidies for agricultural machinery and equipment.
4 Encouraging sustainable farming methods is crucial in mitigating climate change's effects. Sustainable agricultural methods, including crop rotation, soil conservation, and integrated pest control, are examples of renewable energy that may be advocated for endurable farming.
5 Finally, rural poverty in Pakistan may be considerably reduced by implementing policies that address concerns like water scarcity, access to education and healthcare, environmental justice, agriculture automation, and sustainable agricultural methods. Designing and enforcing these regulations with due regard for ethical and environmental ramifications is necessary to achieve fair results for everyone.

One possible drawback of the research is the need for qualitative data and viewpoints from people and groups in rural Pakistan impacted by poverty and climate change. In order to make conclusions regarding the connection between environmental ethics, justice, and rural poverty in the context of climate change, this research relies heavily on quantitative data and statistical studies. The obstacles and possibilities for fostering similar results may be better understood if qualitative data and the opinions of impacted groups are included. Future research might focus on environmental ethics, social justice, and rural poverty in Pakistan. This may need more research on the impacts of climate change on particular communities or areas, emphasizing the voices of traditionally underrepresented groups, including women, children, and members of minority and indigenous communities. Additionally, given the context of rural poverty and climate change in Pakistan, future studies might investigate the possibility of policy interventions to achieve fair results. In order to accomplish this, it may be necessary to assess current programs and propose new policies that emphasize environmental ethics, justice, and poverty alleviation. In addition, comparing Pakistan's experience with other nations experiencing similar issues, such as Bangladesh or India, would enrich the research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

[1] P.M. DeMarco, Rachel Carson's environmental ethic–a guide for global systems decision making, J. Clean. Prod. 140 (2017) 127–133.
[2] A. Holden, Achieving a sustainable relationship between common pool resources and tourism: the role of environmental ethics, J. Sustain. Tourism 13 (4) (2005) 339–352.
[3] R.J. King, Environmental ethics and the built environment, Environ. Ethics 22 (2) (2000) 115–131.
[4] D.J. Martinez, B.R. Middleton, J.J. Battles, Environmental justice in forest management decision-making: challenges and opportunities in California, Soc. Nat. Resour. (2023), https://doi.org/10.1080/08941920.2023.2203103.
[5] N. Habib, M. Alauddin, R. Cramb, What defines livelihood vulnerability to climate change in rain-fed, rural regions? A qualitative study of men's and women's vulnerability to climate change in Pakistan's Punjab, Cogent Soc. Sci. 8 (1) (2022), 2054152.
[6] M. Suendarti, Protecting our planet: the vital role of carbon sequestration in combating threats to environmental sustainability, Paki. J. Life Soc. Sci. 21 (1) (2023) 23–36.
[7] M.M. Ahmad, M. Yaseen, S.E. Saqib, Climate change impacts of drought on the livelihood of dryland smallholders: implications of adaptation challenges, Int. J. Dis. Risk Reduct. 80 (2022), 103210.
[8] M. Khan, Shifting gender roles in society and the workplace: implications for environmental sustainability, Politica 1 (1) (2023) 9–25.
[9] S. Hormio, Collective responsibility for climate change, Wiley Interdiscip. Rev. Clim. Change (2023) e830, https://doi.org/10.1002/wcc.830.
[10] Kissinger, Analysis of biodiversity conservation in South Kalimantan, Indonesia: investigating the ecological features of a damaged peat ecosystem, Paki. J. Life Soc. Sci. 21 (1) (2023) 132–141.
[11] X. Li, X. Jiang, Y. Xia, Exploring fair and ambitious mitigation contributions of Asian economies for the global warming limit under the Paris Agreement, Clim. Change Econ. 13 (01) (2022), 2240002.

[12] A. March, P. Failler, Small-scale fisheries development in Africa: lessons learned and best practices for enhancing food security and livelihoods, Mar. Policy 136 (2022), 104925.

[13] S. Saleem, Power, politics, and public health: understanding the role of healthcare expenditure in shaping health outcomes in pakistan for policy enhancement, Politica 2 (1) (2023) 58–72, https://doi.org/10.5281/zenodo.8127367.

[14] S. Fatima, Rural development and education: critical strategies for ending child marriages, Arch. Soc. Sci.: J. Collab. Mem. 1 (1) (2023) 1–15.

[15] S.A. Kamboh, M. Ittefaq, Advocacy journalism and climate justice in a Global Southern country, Local Environ (2022), https://doi.org/10.1080/13549839.2022.2155937.

[16] M.T. Khan, M Imran, Unveiling the carbon footprint of europe and central asia: insights into the impact of key factors on CO_2 emissions, Arch. Soc. Sci.: J. Collab. Mem. 1 (1) (2023) 52–66.

[17] J.B. Rasmussen, Advancing environmental justice through the integration of traditional ecological knowledge into environmental policy, Challenges 14 (1) (2023) 6.

[18] K. Zaman, Navigating the Perils of a Banana Republic: lessons from Pakistan's Economic Crisis, Politica 1 (1) (2023) 33–41.

[19] A. Zia, I.A. Rana, H.S.H. Arshad, Z. Khalid, A. Nawaz, Monsoon flood risks in urban areas of Pakistan: a way forward for risk reduction and adaptation planning, J. Environ. Manage. 336 (2023), 117652.

[20] M.U. Ashraf, M. Asif, A.B. Talib, A. Ashraf, M.S. Nadeem, I.A. Warraich, Socio-economic impediments in usage of modern mechanized technological ideals in agriculture sector: a case study of District Lodhran, Punjab-Pakistan, Pak. J. Life Soc. Sci. 17 (2) (2019) 86–92.

[21] A.R. Hamidi, L. Jing, M. Shahab, K. Azam, M. Atiq Ur Rehman Tariq, A.W Ng, Flood exposure and social vulnerability analysis in rural areas of developing countries: an empirical study of Charsadda District, Pakistan, Water (Basel) 14 (7) (2022) 1176.

[22] M. Adeela, F. Naveed, I.A. Khan, J. Norina, A. Saima, A.A. Maan, H.Q. Abdul, Sustainable rural development through women's engagement in livestock sector in Punjab, Pakistan, Pak. J. Life Soc. Sci. 16 (2) (2018) 124–128.

[23] M. Shahid, F. Ahmed, W. Ameer, J. Guo, S. Raza, S. Fatima, M.G. Qureshi, Prevalence of child malnutrition and household socioeconomic deprivation: a case study of marginalized district in Punjab, Pakistan, PLoS One 17 (3) (2022), e0263470.

[24] R.K. Pachauri, Energy efficiency in developing countries Policy options and the poverty dilemma, in: Natural Resources Forum, 14, Blackwell Publishing Ltd, Oxford, UK, 1990, pp. 319–325.

[25] T. Reardon, S.A. Vosti, Links between rural poverty and the environment in developing countries: asset categories and investment poverty, World Dev. 23 (9) (1995) 1495–1506.

[26] P.A. Sanchez, Linking climate change research with food security and poverty reduction in the tropics, Agric. Ecosyst. Environ. 82 (1–3) (2000) 371–383.

[27] T.W. Hertel, S.D. Rosch, Climate change, agriculture, and poverty, Appl. Econ. Perspect. Policy 32 (3) (2010) 355–385.

[28] R. Leichenko, J.A. Silva, Climate change and poverty: vulnerability, impacts, and alleviation strategies, Wiley Interdiscip. Rev. Clim. Change 5 (4) (2014) 539–556.

[29] S. Hallegatte, J. Rozenberg, Climate change through a poverty lens, Nat. Clim. Chang 7 (4) (2017) 250–256.

[30] J. Thurlow, P. Dorosh, B. Davis, Chapter 3: demographic change, agriculture, and rural poverty, Sustain. Food Agric. (2018) 31–53, https://doi.org/10.1016/B978-0-12-812134-4.00003-0.

[31] M.M. Maja, S.F. Ayano, The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries, Earth Syst. Environ. 5 (2021) 271–283.

[32] A. Syed, T. Raza, T.T. Bhatti, N.S. Eash, Climate Impacts on the agricultural sector of Pakistan: risks and solutions, Environ. Challenges 6 (2022), 100433.

[33] A. Wijerathna-Yapa, R. Pathirana, Sustainable agro-food systems for addressing climate change and food security, Agriculture 12 (10) (2022) 1554.

[34] M. Eichsteller, T. Njagi, E. Nyukuri, The role of agriculture in poverty escapes in Kenya–Developing a capabilities approach in the context of climate change, World Dev. 149 (2022), 105705.

[35] Q. Li, P. Sun, B. Li, M. Mohiuddin, Impact of climate change on rural poverty vulnerability from an income source perspective: a study based on CHIPS2013 and county-level temperature data in China, Int. J. Environ. Res. Public Health 19 (6) (2022) 3328.

[36] Y. Peng, B. Liu, M. Zhou, Sustainable livelihoods in rural areas under the shock of climate change: evidence from china labor-force dynamic survey, Sustainability 14 (12) (2022) 7262.

[37] A. Dorward, K.E. Giller, Change in the climate and other factors affecting agriculture, food or poverty: an opportunity, a threat or both? A personal perspective, Glob. Food Sec. 33 (2022), 100623.

[38] W. Li, L. Zhang, M. Yue, J. Ruiz-Menjivar, J. Zhang, Health vulnerability and health poverty of rice farmers: evidence from Hubei province in China, China Agric. Econ. Rev. (2023), https://doi.org/10.1108/CAER-03-2021-0062.

[39] S. Khosla, P.R. Jena, Can rural livelihood programs enhance capabilities and reduce vulnerability to poverty? Evidence from a tribal region of eastern India, Econ. Anal. Policy 77 (2023) 85–98.

[40] C. Dick-Sagoe, K.N. Hope, P. Asare-Nuamah, Perceived impact of climate variability and change on livelihoods of smallholder farmers in Lesotho, Afr. J. Sci., Technol., Innov. Dev. 15 (2) (2023) 175–184.

[41] A.A. Shah, N.A. Khan, Z. Gong, I. Ahmad, S.A.A. Naqvi, W. Ullah, A. Karmaoui, Farmers' perspective towards climate change vulnerability, risk perceptions, and adaptation measures in Khyber Pakhtunkhwa, Pakistan, Int. J. Environ. Sci. Technol. 20 (2) (2023) 1421–1438.

[42] N. Ahmed, I.U.H. Padda, A. Khan, M.D. Otil, L.M. Cismas, A. Miculescu, A. Rehman, Climate change adaption strategies in urban communities: new evidence from Islamabad, Pakistan, Environ. Sci. Pollut. Res. 30 (2023) 42108–42121.

[43] S. Ullah, U. Khan, A. Begum, H. Han, A. Mohamed, Indigenous knowledge, climate change and transformations of Gwadar fishing community, Int. J. Clim. Change Strat. Manag. (2023), https://doi.org/10.1108/IJCCSM-06-2022-0069.

[44] H.E. Hudson, E.B. Parker, Information gaps in rural America: telecommunications policies for rural development, Telecomm. Policy 14 (3) (1990) 193–205.

[45] V. Mahajan, B.G. Ramola, Financial services for the rural poor and women in India: access and sustainability, J. Int. Dev. 8 (2) (1996) 211–224.

[46] A.G. Ambali, The dilemma of the poor developing countries in automation/industrialisation, IFAC Proc. Vol. 33 (18) (2000) 179–184.

[47] M.A. Hanjra, F. Gichuki, Investments in agricultural water management for poverty reduction in Africa: case studies of Limpopo, Nile, and Volta river basins, Nat. Resour. Forum 32 (3) (2008) 185–202.

[48] U. Deichmann, A. Goyal, D. Mishra, Will digital technologies transform agriculture in developing countries? Agric. Econ. 47 (S1) (2016) 21–33.

[49] S. Rotz, E. Gravely, I. Mosby, E. Duncan, E. Finnis, M. Horgan, J. LeBlanc, R. Martin, H.T. Neufeld, A. Nixon, L. Pant, V. Shalla, E. Fraser, Automated pastures and the digital divide: how agricultural technologies are shaping labour and rural communities, J. Rural Stud. 68 (2019) 112–122.

[50] L. Christiaensen, Z. Rutledge, J.E. Taylor, Viewpoint: the future of work in agri-food, Food Policy 99 (2021), 101963.

[51] O.H. Osinowo, M.G. Ogunnaike, E.T. Tolorunju, Prevalent poverty incidence and technological innovations: implications for agricultural development in West Africa, Sarhad J. Agric. 38 (5) (2022) 143–151.

[52] Z. Chen, Q. Meng, K. Yan, R. Xu, The analysis of family farm efficiency and its influencing factors: evidence from rural China, Land (Basel) 11 (4) (2022) 487.

[53] A. Raihan, D.A. Muhtasim, S. Farhana, M.A.U. Hasan, M.I. Pavel, O. Faruk, A. Mahmood, An econometric analysis of Greenhouse gas emissions from different agricultural factors in Bangladesh, Energy Nexus 9 (2023), 100179.

[54] S. Zhou, C. Qing, J. He, D. Xu, Impact of agricultural division of labor on fertilizer reduction application: evidence from Western China, Int. J. Environ. Res. Public Health 20 (5) (2023) 3787.

[55] X. Sang, X. Luo, A. Razzaq, Y. Huang, S. Erfanian, Can agricultural mechanization services narrow the income gap in rural China? Heliyon 9 (2) (2023) e13367.

[56] W. Liao, F. Zeng, M. Chanieabate, Mechanization of small-scale agriculture in China: lessons for enhancing smallholder access to agricultural machinery, Sustainability 14 (13) (2022) 7964.

[57] G.P. Paudel, H. Gartaula, D.B. Rahut, S.E. Justice, T.J. Krupnik, A.J. McDonald, The contributions of scale-appropriate farm mechanization to hunger and poverty reduction: evidence from smallholder systems in Nepal, J. Econ. Dev. 25 (1) (2023) 37–61.

[58] T. Daum, Mechanization and sustainable agri-food system transformation in the Global South. A review, Agron. Sustainable Dev. 43 (1) (2023) 16.

[59] K. Mohammed, E. Batung, S.A. Saaka, M.M. Kansanga, I. Luginaah, Determinants of mechanized technology adoption in smallholder agriculture: implications for agricultural policy, Land Use Policy 129 (2023), 106666.

[60] Q. Liu, Q. Li, Impact of new rural pension insurance on farmers' agricultural mechanization service input, Sustainability 15 (2) (2023) 1131.

[61] Z. Ali, Y. Jianzhou, A. Ali, J. Hussain, Determinants of the CO2 emissions, economic growth, and ecological footprint in Pakistan: asymmetric and symmetric role of agricultural and financial inclusion, Environ. Sci. Pollut. Res. (2023), https://doi.org/10.1007/s11356-023-26138-7.

[62] M.A. Kavesh, K. Lahiri-Dutt, R. Adhikari, Women and plant entanglements: pulses commercialization and care relations in Punjab, Pakistan, Oxford Dev. Stud. (2023), https://doi.org/10.1080/13600818.2023.2177265.

[63] C. Chaiya, S. Sikandar, P. Pinthong, S.E. Saqib, N. Ali, The impact of formal agricultural credit on farm productivity and its utilization in Khyber Pakhtunkhwa, Pakistan, Sustainability 15 (2) (2023) 1217.

[64] R.W. Lake, Volunteers, NIMBYs, and environmental justice: dilemmas of democratic practice, Antipode 28 (2) (1996) 160–174.

[65] J.I. Dawson, The two faces of environmental justice: lessons from the eco-nationalist phenomenon, Env Polit 9 (2) (2000) 22–60.

[66] J. Ikeme, Equity, environmental justice and sustainability: incomplete approaches in climate change politics, Glob. Environ. Chang. 13 (3) (2003) 195–206.

[67] K. Lucas, Providing transport for social inclusion within a framework for environmental justice in the UK, Transp. Res. Part A: Policy Pract. 40 (10) (2006) 801–809.

[68] C. Okereke, Climate justice and the international regime, Wiley Interdiscip. Rev. Clim. Change 1 (3) (2010) 462–474.

[69] H. Pearsall, I. Anguelovski, Contesting and resisting environmental gentrification: responses to new paradoxes and challenges for urban environmental justice, Sociol. Res. Online 21 (3) (2016) 121–127.

[70] D. McCauley, R. Heffron, Just transition: integrating climate, energy and environmental justice, Energy Policy 119 (2018) 1–7, https://doi.org/10.1016/j.enpol.2018.04.014.

[71] B. Gutschow, B. Gray, M.I. Ragavan, P.E. Sheffield, R.P. Philipsborn, S.H. Jee, The intersection of pediatrics, climate change, and structural racism: ensuring health equity through climate justice, Curr. Probl. Pediatr. Adolesc. Health Care 51 (6) (2021), 101028.

[72] F. Khayat, From climate injustice to resilience: what is the role of social and technological innovation? Environ. Justice 16 (2) (2023) 96–110.

[73] A. Planas-Carbonell, I. Anguelovski, E. Oscilowicz, C. Pérez-del-Pulgar, G Shokry, From greening the climate-adaptive city to green climate gentrification? Civic perceptions of short-lived benefits and exclusionary protection in Boston, Philadelphia, Amsterdam and Barcelona, Urban Clim. 48 (2023), 101295.

[74] A.R. Pearson, K.E. White, L.M. Nogueira, N.A. Lewis Jr., D.J. Green, J.P. Schuldt, D Edmondson, Climate change and health equity: a research agenda for psychological science, Am. Psychol. 78 (2) (2023) 244–258, https://doi.org/10.1037/amp0001074.

[75] S. Klepp, H. Fünfgeld, Tackling knowledge and power: an environmental justice perspective on climate change adaptation in Kiribati, Clim. Dev. 14 (8) (2022) 757–769.

[76] A. Kosanic, J. Petzold, B. Martín-López, M. Razanajatovo, An inclusive future: disabled populations in the context of climate and environmental change, Curr. Opin. Environ. Sustain. 55 (2022), 101159.

[77] A. Maxim, E. Grubert, Anticipating climate-related changes to residential energy burden in the United States: advance planning for equity and resilience, Environ. Justice 15 (3) (2022) 139–148.

[78] M. Rosa, K. Haines, T. Cruz, F. Forman, A binational social vulnerability index (BSVI) for the San Diego-Tijuana region: mapping trans-boundary exposure to climate change for just and equitable adaptation planning, Mitigat. Adapt. Strat. Glob. Change 28 (2) (2023) 12.

[79] D.A. Gill, J. Blythe, N. Bennett, L. Evans, K. Brown, R.A. Turner, N.A. Muthiga, Triple exposure: reducing negative impacts of climate change, blue growth, and conservation on coastal communities, One Earth 6 (2) (2023) 118–130.

[80] P. Hinduja, R.F. Mohammad, S. Siddiqui, S. Noor, A. Hussain, Sustainability in Higher Education Institutions in Pakistan: A Systematic Review of Progress and Challenges, Sustainability 15 (4) (2023) 3406, https://doi.org/10.3390/su15043406.

[81] M. Farooq, M. Usman, Pakistan needs an equitable investment in the health system and collaborative efforts, Lancet Glob. Health 11 (2) (2023) e177–e178.

[82] Y.O. Van Horne, C.S. Alcala, R.E. Peltier, P.J. Quintana, E. Seto, M. Gonzales, P. I. Beamer, An applied environmental justice framework for exposure science, J. Expo Sci. Environ. Epidemiol. 33 (1) (2023) 1–11.

[83] M. Chowkwanyun, Environmental justice: where it has been, and where it might be going, Annu. Rev. Public Health 44 (2023) 93–111.

[84] A. Desikan, T. MacKinney, C. Kalman, J.M. Carter, G. Reed, G.T. Goldman, An equity and environmental justice assessment of anti-science actions during the Trump administration, J. Public Health Policy 44 (1) (2023) 147–162.

[85] J. Wang, N. Ulibarri, T.A. Scott, S.J. Davis, Environmental justice, infrastructure provisioning, and environmental impact assessment: evidence from the California Environmental Quality Act, Environ. Sci. Policy 146 (2023) 66–75.

[86] J. Loos, F. Benra, M. Berbés-Blázquez, L.L. Bremer, K.M. Chan, B. Egoh, K. J. Winkler, An environmental justice perspective on ecosystem services, Ambio 52 (3) (2023) 477–488.

[87] J. Kato-Huerta, D. Geneletti, A distributive environmental justice index to support green space planning in cities, Landsc. Urban Plan. 229 (2023), 104592.

[88] J.R.O. Dent, C. Smith, M.C. Gonzales, A.B. Lincoln-Cook, Getting back to that point of balance: indigenous environmental justice and the California Indian Basketweavers' Association, Ecol. Soc. 28 (1) (2023) 14, https://doi.org/10.5751/ES-13674-280114.

[89] C. van Velzen, M. Helbich, Green school outdoor environments, greater equity? Assessing environmental justice in green spaces around Dutch primary schools, Landsc. Urban Plan. 232 (2023), 104687.

[90] K. Palawat, R.A. Root, L.I. Cortez, T. Foley, V. Carella, C. Beck, M.D. Ramírez-Andreotta, Patterns of contamination and burden of lead and arsenic in rooftop harvested rainwater collected in Arizona environmental justice communities, J. Environ. Manage. 337 (2023), 117747.

[91] S. Ramcilovic-Suominen, Envisioning just transformations in and beyond the EU bioeconomy: inspirations from decolonial environmental justice and degrowth, Sustainability Sci. 18 (2) (2023) 707–722.

[92] N. Khurshid, A. Fiaz, J. Khurshid, K. Ali, Impact of climate change shocks on economic growth: a new insight from non-linear analysis, Front. Environ. Sci. 10 (2022), 1039128.

[93] M. Aqib, K. Zaman, Greening the workforce: the power of investing in human capital, Arch. Soc. Sci.: J. Collab. Mem. 1 (1) (2023) 31–51, https://doi.org/10.5281/zenodo.7620041.

[94] I.A. Rana, M.M. Khan, R.H. Lodhi, S. Altaf, A. Nawaz, F.A. Najam, Multidimensional poverty vis-à-vis climate change vulnerability: empirical evidence from flood-prone rural communities of Charsadda and Nowshera Districts in Pakistan, World Dev. Sustain. 2 (2023), 100064.

[95] S. Sadiq, Balancing economic growth with environmental and healthcare considerations: insights from Pakistan's development trajectory, Res. Lett. 1 (1) (2023) 17–26, https://doi.org/10.5281/zenodo.8186321.

[96] S. Sahoo, S. Goswami, Theoretical framework for assessing the economic and environmental impact of water pollution: a detailed study on sustainable development of India, J. Fut. Sustain. 4 (1) (2024) 23–34.

[97] D.N. Pellow, A. Weinberg, A. Schnaiberg, The environmental justice movement: equitable allocation of the costs and benefits of environmental management outcomes, Soc. Justice Res. 14 (2001) 423–439.

[98] D. Faber, B. Levy, C. Schlegel, Not all people are polluted equally in capitalist society: an eco-socialist commentary on liberal environmental justice theory, Capitalism Nat. Socialism 32 (4) (2021) 1–16.

[99] A. Krings, T.M. Schusler, Equity in sustainable development: community responses to environmental gentrification, Int. J. Soc. Welf. 29 (4) (2020) 321–334.

[100] P.D. Rigo, G. Rediske, C.B. Rosa, N.G. Gastaldo, L. Michels, A.L. Neuenfeldt Júnior, J.C.M. Siluk, Renewable energy problems: exploring the methods to support the decision-making process, Sustainability 12 (23) (2020) 10195.

[101] A. Patel, H. Lotia, A.A. Malik, M.D. Mundt, H. Lee, M.A. Rafiq, Gendered impacts of environmental degradation in informal settlements: a comparative analysis and policy implications for India, Bangladesh, and Pakistan, J. Comparat. Policy Anal.: Res. Pract. 23 (4) (2021) 468–484.

[102] D. Schlosberg, L.B. Collins, From environmental to climate justice: climate change and the discourse of environmental justice, Wiley Interdiscip. Rev. Clim. Change 5 (3) (2014) 359–374.

[103] Z. Shawoo, C.L. McDermott, Justice through polycentricity? A critical examination of climate justice framings in Pakistani climate policymaking, Clim. Policy 20 (2) (2020) 199–216.

[104] PBS, Economic Survey of Pakistan, Pakistan Bureau of Statistics, Islamabad, Pakistan, 2022 planning commissions wings.

[105] World Bank. World Development Indicators, World Bank, Washington D.C., USA, 2022.

[106] K. Zaman, A note on cross-panel data techniques, Latest Dev. Econometr. 1 (1) (2023) 1–7.

[107] P.J. Huber, Robust estimation of a location parameter, Ann. Math. Stat. 35 (1) (1964) 73–101.

[108] P.J. Rousseeuw, A.M. Leroy, A robust scale estimator based on the shortest half, Stat. Neerl. 42 (2) (1988) 103–116.

[109] C. Croux, P.J. Rousseeuw, A class of high-breakdown scale estimators based on subranges, Commun. Stat. - Theory Methods 21 (7) (1992) 1935–1951.

[110] R. Maronna, O. Bustos, V. Yohai, Bias-and efficiency-robustness of general M-estimators for regression with random carriers, in: Smoothing Techniques for Curve Estimation: Proceedings of a Workshop held in Heidelberg, Springer Berlin Heidelberg, Berlin, Heidelberg, 2006, pp. 91–116.

[111] K.U. Ehigiamusoe, M.T. Majeed, E. Dogan, The nexus between poverty, inequality and environmental pollution: evidence across different income groups of countries, J. Clean. Prod. 341 (2022), 130863.

[112] S. Khan, W. Yahong, A. Zeeshan, Impact of poverty and income inequality on the ecological footprint in Asian developing economies: assessment of Sustainable Development Goals, Energy Rep. 8 (2022) 670–679.

[113] S. Bano, L. Liu, A. Khan, Dynamic influence of aging, industrial innovations, and ICT on tourism development and renewable energy consumption in BRICS economies, Renew. Energy 192 (2022) 431–442.

[114] B.A. Gyamfi, D.Q. Agozie, F.V. Bekun, Can technological innovation, foreign direct investment and natural resources ease some burden for the BRICS economies within current industrial era? Technol. Soc. 70 (2022), 102037.

[115] L.A. Satcher, Multiply-deserted areas: environmental racism and food, pharmacy, and greenspace access in the Urban South, Environ. Sociol. 8 (3) (2022) 279–291.

[116] S. Heinicke, K. Frieler, J. Jägermeyr, M. Mengel, Global gridded crop models underestimate yield responses to droughts and heatwaves, Environ. Res. Lett. 17 (4) (2022), 044026.

[117] G. Maggio, M. Mastrorillo, N.J. Sitko, Adapting to high temperatures: effect of farm practices and their adoption duration on total value of crop production in Uganda, Am. J. Agric. Econ. 104 (1) (2022) 385–403.

[118] S.B. Bedeke, Climate change vulnerability and adaptation of crop producers in sub-Saharan Africa: a review on concepts, approaches and methods, Environ., Dev. Sustain. 25 (2) (2023) 1017–1051.

[119] S. Abbas, Climate change and major crop production: evidence from Pakistan, Environ. Sci. Pollut. Res. 29 (4) (2022) 5406–5414.

[120] A.A. Chandio, Y. Jiang, A. Amin, M. Ahmad, W. Akram, F. Ahmad, Climate change and food security of South Asia: fresh evidence from a policy perspective using novel empirical analysis, J. Environ. Plann. Manage. 66 (1) (2023) 169–190.

[121] L. Mwadzingeni, R. Mugandani, P. Mafongoya, Risks of climate change on future water supply in smallholder irrigation schemes in Zimbabwe, Water (Basel) 14 (11) (2022) 1682.

[122] A. Parven, I. Pal, A. Witayangkurn, M. Pramanik, M. Nagai, H. Miyazaki, C. Wuthisakkaroon, Impacts of disaster and land-use change on food security and adaptation: evidence from the delta community in Bangladesh, Int. J. Dis. Risk Reduct. 78 (2022), 103119.

[123] P. Mususa, S. Marr, Comparing climate politics and adaptation strategies in african cities: challenges and opportunities in the state-community divide, in: Urban Forum, 33, Springer Netherlands, Dordrecht, 2022, pp. 1–12.

[124] F. Nadeem, B. Jacobs, D. Cordell, Mapping agricultural vulnerability to impacts of climate events of Punjab, Pakistan, Reg. Environ. Change 22 (2) (2022) 66.

[125] A. Rehman, H. Ma, I. Ozturk, M.I. Ahmad, Examining the carbon emissions and climate impacts on main agricultural crops production and land use: updated evidence from Pakistan, Environ. Sci. Pollut. Res. 29 (1) (2022) 868–882.

[126] Z. Wang, Y. Wang, F. Huang, C. Shuai, J. Li, L. Ding, X. Cheng, The environmental impact of household domestic energy consumption in rural areas: empirical evidence from China's photovoltaic poverty alleviation regions, Sustain. Prod. Consumpt. 30 (2022) 1019–1031.

[127] N. Abid, F. Ceci, M. Ikram, Green growth and sustainable development: dynamic linkage between technological innovation, ISO 14001, and environmental challenges, Environ. Sci. Pollut. Res. 29 (2022) 25428–25447.

[128] Y. Mahfooz, A. Yasar, R. Tanveer, AuB. Tabinda, Challenges and solutions for sustainable urban water management, : Aftab, T. (eds). Sustainable Management of Environmental Contaminants. Environmental Contamination Remediation and Management, Springer, Cham, 2022, https://doi.org/10.1007/978-3-031-08446-1_21.

[129] S.T. Hassan, B. Batool, B. Zhu, I. Khan, Environmental complexity of globalization, education, and income inequalities: new insights of energy poverty, J. Clean. Prod. 340 (2022), 130735.
[130] Y. Guo, Y. Liu, Sustainable poverty alleviation and green development in China's underdeveloped areas, J. Geog. Sci. 32 (1) (2022) 23–43.
[131] W. Yang, C. Xu, F. Kong, Does non-food cultivation of cropland increase farmers' income? Int. J. Environ. Res. Public Health 19 (12) (2022) 7329.
[132] R.B. Castelein, J.J. Broeze, M.M. Kok, H.H. Axmann, X.X. Guo, J.H. Soethoudt, Mechanization in rice farming reduces greenhouse gas emissions, food losses, and constitutes a positive business case for smallholder farmers–Results from a controlled experiment in Nigeria, Clean. Eng. Technol. 8 (2022), 100487.
[133] A.P. Alexoaei, R.G. Robu, V. Cojanu, D. Miron, A.M. Holobiuc, Good practices in reforming the common agricultural policy to support the European green deal–a perspective on the consumption of pesticides and fertilizers, Amfiteatru Econ. 24 (60) (2022) 525–545.
[134] A.K. Thakur, R. Singh, A. Gehlot, A.K. Kaviti, R. Aseer, S.K. Suraparaju, V. S. Sikarwar, Advancements in solar technologies for sustainable development of agricultural sector in India: a comprehensive review on challenges and opportunities, Environ. Sci. Pollut. Res. 29 (29) (2022) 43607–43634.
[135] T. Mahmood, N. Arshed, Identifying the demand-based financial issues in the agriculture sector of Pakistan: a qualitative thematic analysis, iRASD J. Manag. 4 (1) (2022) 26–37.
[136] A. Hussain, W. Akhtar, A. Jabbar, Risk management for small farmers in Pakistan: a review, Pak. J. Agric. Sci. 59 (2) (2022) 247–259.
[137] M.S. Sultan, M.A. Khan, H. Khan, B. Ahmad, Pathways to strengthening capabilities: a case for the adoption of climate-smart agriculture in Pakistan, APN Sci. Bull. 12 (1) (2022) 171–183.
[138] A. Razzaq, H. Liu, M. Xiao, K. Mehmood, M.A. Shahzad, Y. Zhou, Analyzing past and future trends in Pakistan's groundwater irrigation development: implications for environmental sustainability and food security, Environ. Sci. Pollut. Res. 30 (12) (2023) 35413–35429.
[139] R. Ali, R. Ishaq, K. Bakhsh, M.A. Yasin, Do agriculture technologies influence carbon emissions in Pakistan? Evidence based on ARDL technique, Environ. Sci. Pollut. Res. 29 (28) (2022) 43361–43370.