

CIRCULAR ECONOMY, ECOSYSTEM VALUATION, AND GENDERED RURAL LIVELIHOOD RESILIENCE: ASSESSING WOMEN'S ADAPTIVE CAPACITY UNDER CLIMATE CHANGE IN PAKISTAN

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ABSTRACT

Climate change has become a critical challenge for rural livelihoods in developing countries, particularly for women who depend heavily on agriculture and ecosystem resources for their economic survival. In Pakistan, increasing climate-related risks, including floods, droughts, water scarcity, land degradation, and declining agricultural productivity, have intensified livelihood vulnerability among rural households. Women face greater adaptation constraints due to limited access to financial resources, land ownership, technology, climate information, and institutional support. This study develops an integrated framework to examine the role of circular economy practices and ecosystem valuation in enhancing women's adaptive capacity and rural livelihood resilience under climate change in Pakistan. Using a panel data econometric approach, the study constructs a balanced panel dataset of rural regions of Pakistan over the study period to analyze the dynamic relationship between circular economy adoption, ecosystem services, gender empowerment, and livelihood resilience. The empirical analysis employs Panel ARDL-PMG, Fixed Effects (FE), Random Effects (RE), and System GMM estimation techniques to capture both short-run and long-run effects while addressing endogeneity, reverse causality, and omitted variable bias. The model incorporates key indicators including circular economy practices, ecosystem service valuation, women's empowerment, institutional quality, climate vulnerability, and socioeconomic factors. The expected empirical results indicate that circular economy practices, sustainable ecosystem management, and improved institutional support positively enhance women's adaptive capacity and rural livelihood resilience by creating alternative income opportunities, improving resource efficiency, and reducing climate vulnerability. However, financial constraints, gender inequality, weak institutional mechanisms, and limited access to climate information may negatively influence adaptation outcomes. The study provides important policy implications for promoting gender-responsive climate strategies, sustainable resource management, circular economic development, and climate-resilient rural livelihoods in Pakistan.

Keywords: Circular Economy, Ecosystem Valuation, Gender Equality, Climate Change Adaptation, Rural Livelihoods, Women's Empowerment, Pakistan

1. INTRODUCTION

Climate change has become one of the most significant global challenges affecting economic development, environmental sustainability, and human livelihoods. Increasing temperatures, unpredictable rainfall patterns, floods, droughts, and ecosystem degradation are creating severe risks for rural communities, especially in developing countries where livelihoods depend heavily on agriculture and natural resources. Rural households often rely on ecosystem services such as land, water, forests, and agricultural resources for food production, income generation, and household survival. The degradation of these resources due to climate change directly threatens livelihood security and increases social and economic vulnerability.

Pakistan is among the countries highly vulnerable to climate change due to its dependence on climate-sensitive sectors, particularly agriculture and natural resource-based activities. Rural communities frequently face climate-related shocks, including floods, droughts, water shortages, declining agricultural productivity, and ecosystem degradation. These challenges have intensified poverty risks and reduced the capacity of rural households to maintain stable livelihoods. Women in rural Pakistan are particularly vulnerable to climate change impacts. They play an important role in agriculture, livestock management, household resource management, and informal economic activities. However, their ability to adapt is constrained by limited access to land ownership, financial resources, technology, education, climate information, and institutional support. Gender inequalities reduce women's participation in decision-making and limit their ability to adopt climate adaptation strategies. Therefore, improving women's adaptive capacity is essential for building climate-resilient rural communities.

The concept of **circular economy** provides a promising pathway for improving rural resilience by promoting sustainable resource utilization, waste reduction, recycling, and the efficient use of natural resources. Unlike the traditional linear economic model based on extraction, consumption, and disposal, circular economy principles emphasize resource efficiency,

regeneration, and sustainable production systems. In rural areas, circular economy practices such as organic farming, agricultural waste recycling, renewable energy utilization, and sustainable livestock management can create new livelihood opportunities while reducing environmental pressure.

Furthermore, **ecosystem valuation** plays an important role in understanding the economic contribution of natural resources to rural livelihoods. Ecosystem services, including water regulation, soil fertility, biodiversity, and agricultural productivity, provide significant economic benefits that are often overlooked in policy decisions. Valuing these services can support better resource management and encourage sustainable development strategies.

Although previous studies have examined climate change impacts, rural livelihoods, and women's vulnerability separately, limited research has explored the combined relationship between circular economy practices, ecosystem valuation, gender inequality, and women's adaptive capacity in Pakistan. This research addresses this gap by developing an integrated framework to analyze how sustainable resource management and ecosystem-based approaches can enhance women's resilience against climate change.

2. Research Problem

Climate change is increasingly threatening rural livelihoods in Pakistan by affecting agricultural productivity, natural resources, and household income opportunities. Rural women face greater vulnerability because of limited access to economic resources, institutional support, technology, and climate adaptation opportunities. Although circular economy practices and ecosystem-based approaches have the potential to improve livelihood resilience, their contribution to women's adaptive capacity remains insufficiently explored.

Existing studies mainly focus on climate impacts and agricultural adaptation, while limited empirical evidence exists regarding how circular economy strategies, ecosystem service valuation, and gender empowerment interact to strengthen rural resilience. Therefore, there is a need for an integrated analysis that examines the role of

sustainable resource management and gender-responsive policies in enhancing women's ability to adapt to climate change in Pakistan.

3. Research Objectives

1. To examine the role of circular economy practices and ecosystem valuation in enhancing women's adaptive capacity and rural livelihood resilience under climate change in Pakistan.
2. To assess the impact of climate change on rural women's livelihoods and economic resilience.
3. To examine the role of circular economy practices in improving sustainable livelihood opportunities for rural women.

2. Literature Review

2.1 Circular Economy and Climate Resilience in Rural Livelihoods

The concept of the Circular Economy (CE) has gained increasing attention as an alternative development model that promotes resource efficiency, waste reduction, recycling, regeneration, and sustainable resource management. Unlike the traditional linear economic system based on "take-make-dispose," circular economy approaches emphasize closing resource loops and improving environmental sustainability. Ellen MacArthur Foundation (2015) highlighted that circular economy principles can reduce resource depletion, enhance ecosystem sustainability, and support climate change mitigation. In agricultural systems, circular practices such as crop residue recycling, organic farming, composting, renewable energy use, and efficient resource utilization can improve farm sustainability and strengthen rural livelihoods.

Geissdoerfer et al. (2017) argued that circular economy practices provide an important pathway for achieving sustainable development by integrating economic growth with environmental protection. Their study emphasized that circular systems improve resource productivity, reduce environmental pressure, and create new livelihood opportunities. Similarly, Kirchherr et al. (2017) identified circular economy as a transformative approach that requires

technological innovation, institutional support, and behavioural changes among resource users.

In the agricultural sector, Hilmi et al. (2024) reviewed evidence from developed and developing countries and found that circular agriculture practices enhance farmers' resilience by improving resource efficiency, reducing production risks, and supporting sustainable farming systems. The study emphasized that circular economy approaches can help smallholder farmers cope with climate change through improved soil health, reduced input dependency, and diversified livelihood opportunities.

For developing countries such as Pakistan, circular economy practices are particularly relevant because rural communities depend heavily on natural resources. Ajani and van der Geest (2021) highlighted that rural households in Pakistan experience significant climate-related challenges, including changing rainfall patterns, floods, droughts, and declining agricultural productivity. The authors emphasized the importance of locally appropriate adaptation strategies and sustainable resource management for improving rural resilience.

2.2 Ecosystem Valuation and Sustainable Rural Livelihoods

Ecosystem valuation provides an economic framework for understanding the contribution of natural resources and ecosystem services to human well-being. Ecosystems provide essential services including food production, water regulation, climate regulation, soil fertility maintenance, and biodiversity conservation. Costanza et al. (1997) emphasized that ecosystem services possess significant economic value and should be incorporated into development and policy decisions.

The Millennium Ecosystem Assessment (2005) demonstrated that ecosystem degradation directly affects rural communities by reducing access to essential resources and increasing livelihood vulnerability. The study highlighted that poor households, particularly women who depend heavily on natural resources for household activities and agricultural production, are more vulnerable to ecosystem degradation.

Similarly, Dasgupta (2021) emphasized that economic systems must recognize the value of nature and biodiversity because human well-being is fundamentally dependent on ecosystem services. Incorporating ecosystem valuation into climate adaptation strategies can improve resource conservation, sustainable agricultural practices, and rural livelihood resilience.

In Pakistan, ecosystem degradation caused by deforestation, land degradation, water scarcity, and climate variability has increased pressure on rural communities. World Bank (2022) reported that climate change and environmental degradation are major threats to Pakistan's agricultural productivity and rural livelihoods. Sustainable ecosystem management and nature-based solutions are therefore essential for strengthening adaptive capacity.

2.3 Gender, Climate Change, and Women's Adaptive Capacity

Climate change affects men and women differently due to differences in resource access, social responsibilities, economic opportunities, and decision-making power. Rural women often depend on agriculture, livestock, forests, and water resources for household survival, making them highly vulnerable to climate shocks. However, women also possess important knowledge and adaptive strategies that contribute to household and community resilience.

Dankelman (2010) argued that women are not only victims of climate change but also important agents of adaptation due to their traditional knowledge, resource management skills, and community networks. However, limited access to land ownership, financial resources, education, extension services, and climate information often restricts women's adaptive capacity.

Denton (2002) highlighted that gender inequality increases vulnerability to climate change because women frequently have fewer economic and institutional resources to respond effectively to environmental risks. Therefore, gender-responsive climate policies are necessary to improve women's participation in adaptation planning and sustainable development.

Recent evidence from Pakistan confirms the importance of gender-sensitive climate adaptation.

Memon et al. (2025) examined women's climate resilience in rural Pakistan and found that women face significant barriers, including limited access to knowledge, institutional support, and decision-making opportunities. The study emphasized that empowering rural women is essential for improving sustainability and climate resilience.

2.4 Circular Economy, Gender Inclusion, and Women's Livelihood Resilience

The integration of circular economy principles with gender-inclusive approaches provides opportunities to strengthen women's economic empowerment and adaptive capacity. Women are actively involved in agricultural activities, livestock management, food processing, and natural resource conservation; therefore, their participation is essential for successful circular economy transitions.

Nhamo et al. (2019) argued that gender equality is critical for achieving sustainable development because women's empowerment improves household resilience, resource management, and environmental outcomes. Similarly, FAO (2023) emphasized that supporting women in agrifood systems through access to technology, finance, training, and markets can enhance climate adaptation and rural livelihood security.

Circular livelihood strategies, including recycling agricultural waste, organic production, agroforestry, and sustainable resource management, can provide additional income opportunities for rural women while reducing environmental pressure. Hilmi et al. (2024) noted that circular agricultural practices can strengthen farmers' resilience by improving resource efficiency and diversifying livelihood sources.

2.5 Climate Adaptation and Rural Livelihood Resilience in Pakistan

Pakistan is highly vulnerable to climate change due to its dependence on agriculture and exposure to floods, droughts, heatwaves, and water scarcity. Rural communities face increasing challenges related to agricultural losses, declining ecosystem services, and livelihood insecurity.

Abid et al. (2016) found that Pakistani farmers adopt different adaptation strategies, including

crop diversification, changing planting dates, improved irrigation, and livelihood diversification. However, adaptation decisions are influenced by socioeconomic conditions, institutional access, and availability of climate information.

More recently, Sarfraz et al. (2024) examined rural livelihood adaptation strategies in Pakistan and found that household resources, institutional support, and access to information significantly influence climate adaptation behaviour. The study highlighted the importance of strengthening rural institutions and improving access to adaptation resources.

2.6 Research Gap

Although previous studies have examined climate adaptation, ecosystem services, and circular economy separately, limited empirical research has investigated their combined role in enhancing women's adaptive capacity and rural livelihood resilience in Pakistan. Existing literature largely focuses on agricultural productivity and household adaptation, while insufficient attention has been given to the interaction between circular economy practices, ecosystem valuation, gender empowerment, and climate resilience. Therefore, this study contributes to the existing literature by developing an integrated framework that examines how circular economy practices and ecosystem-based approaches influence women's adaptive capacity and rural livelihood resilience under climate change conditions in Pakistan. The study provides important insights for designing gender-responsive climate policies, sustainable resource management strategies, and inclusive rural development programs.

3. Research Methodology

3.1 Research Design

This study adopts a quantitative research approach based on panel data econometric analysis to examine the relationship between circular economy practices, ecosystem valuation, gender empowerment, and rural livelihood resilience under climate change in Pakistan. The research develops an integrated analytical framework to assess how sustainable resource

management and gender-inclusive adaptation mechanisms influence women's adaptive capacity and livelihood outcomes. A balanced panel dataset of rural regions of Pakistan is constructed over the selected study period to capture variations across regions and time.

3.2 Data Sources and Sample Selection

The study utilizes secondary panel data collected from multiple national and international sources, including the Pakistan Bureau of Statistics (PBS), World Bank's WDI, Pakistan Social and Living Standards Measurement Survey (PSLM), Food and Agriculture Organization (FAO), United Nations Development Programme (UNDP), and Climate Change Vulnerability Index databases. The dataset covers rural regions of Pakistan over the study period, allowing analysis of changes in climate vulnerability, ecosystem conditions, socioeconomic characteristics, and women's adaptive capacity.

The balanced panel structure enables the study to control for regional heterogeneity and examine both short-run and long-run relationships among the variables.

3.3 Conceptual Framework and Variable Construction

The study develops an integrated conceptual framework to examine how circular economy practices, ecosystem valuation, women empowerment, and institutional support influence women's adaptive capacity and rural livelihood resilience under climate change in Pakistan.

The dependent variable, **Women's Rural Livelihood Resilience (WRLR)**, is measured through a composite index incorporating indicators such as livelihood stability, income diversification, access to productive resources, agricultural productivity, disaster coping capacity, and food security outcomes.

The main independent variable, **Circular Economy Practices (CE)**, captures sustainable resource management activities, including agricultural waste recycling, organic farming, renewable energy use, efficient water management, and resource conservation practices, reflecting the role of circular systems in

enhancing sustainable livelihoods. **Ecosystem Valuation (EV)** represents the contribution of natural resources and ecosystem services through indicators such as agricultural land productivity, forest resources, water availability, biodiversity services, and ecosystem conservation. **Women Empowerment (WE)** is included as a key determinant of adaptive capacity and is measured through women's participation in decision-making, access to financial resources, education and skills, employment opportunities, and control over productive assets. **Institutional Support (INS)** captures the role of government and development institutions through climate information access, agricultural extension services, financial assistance, adaptation programs, and social protection mechanisms.

3.4 Econometric Model Specification

To examine the relationship between circular economy, ecosystem valuation, and women's livelihood resilience, the following panel data model is specified:

$$Y_{it} = \beta_0 + \beta_1 CE_{it} + \beta_2 EV_{it} + \beta_3 WE_{it} + \beta_4 INS_{it} + \beta_5 CV_{it} + \beta_6 X_{it} + \mu_i + \epsilon_{it}$$

Where:

- Y(WRLR) = Women's Rural Livelihood Resilience
- CE = Circular Economy Practices
- EV = Ecosystem Valuation
- WE = Women Empowerment
- INS = Institutional Support
- CV = Climate Vulnerability
- X = Vector of control variables
- μ_i = Region-specific effects
- ϵ_{it} = Error term

3.5 Econometric Estimation Techniques

This study applies advanced panel econometric techniques to examine the dynamic relationship between circular economy practices, ecosystem valuation, women empowerment, institutional support, and rural livelihood resilience. Descriptive statistics and correlation analysis are first conducted to understand variable characteristics and relationships. Panel unit root tests, including LLC, IPS, Fisher ADF, and PP tests, are applied to determine the stationarity properties of variables, followed by Pedroni, Kao,

and Westerlund cointegration tests to confirm long-run relationships. The study employs the Panel ARDL-PMG approach to estimate short-run and long-run effects, allowing regional variations in short-run dynamics while maintaining common long-run equilibrium relationships. The model is specified as:

$$\Delta Y_{it} = \alpha_i + \sum \beta \Delta X_{it} + \lambda_i (WRLR_{it-1} - \theta X_{it}) + \epsilon_{it}$$

where WRLR represents women's rural livelihood resilience, X represents explanatory variables including circular economy, ecosystem valuation, women empowerment, and institutional support, while the error correction term indicates the speed of adjustment toward long-run equilibrium.

To control for unobserved regional characteristics, the study also applies Fixed Effects (FE) and Random Effects (RE) models. The Hausman specification test is conducted to determine the most appropriate model between FE and RE estimators. Furthermore, the System Generalized Method of Moments (System GMM) technique is employed to address potential endogeneity, reverse causality, and omitted variable bias. This method provides more reliable estimates by using internal instruments and accounting for the dynamic nature of livelihood resilience. The System GMM model is expressed as:

$$WRL_{it} = \alpha WRL_{it-1} + \beta X_{it} + \eta_i + \epsilon_{it}$$

where the lagged dependent variable captures the dynamic adjustment process of livelihood resilience.

3.6 Diagnostic and Robustness Tests

To ensure the validity and reliability of empirical results, several diagnostic and robustness tests are performed. The Variance Inflation Factor (VIF) is applied to detect multicollinearity among explanatory variables, while the Breusch-Pagan LM test is used for appropriate model selection. The study also applies the Pesaran Cross-Sectional Dependence test to identify possible dependence across regions and the Pesaran and Yamagata slope homogeneity test to examine coefficient variations among cross-sectional units. Additionally, the Hausman test is conducted to confirm the suitability of FE or RE estimation, while serial correlation and heteroskedasticity tests are performed to ensure model stability.

Finally, robustness checks using alternative estimation techniques are conducted to verify the consistency and reliability of the findings regarding the impact of circular economy practices, ecosystem valuation, and institutional factors on women's livelihood resilience under climate change.

3.7 Hypotheses Development

Based on the conceptual framework, the study tests the following hypotheses:

H1: Circular economy practices positively influence women's rural livelihood resilience.

H2: Ecosystem valuation significantly improves women's adaptive capacity under climate change.

H3: Women empowerment enhances climate adaptation and livelihood resilience.

H4: Institutional support strengthens the positive relationship between sustainable practices and resilience outcomes.

4.2 Descriptive Statistics

Table 4.1: Descriptive Statistics of Study Variables

Variable	Mean	Std. Deviation	Minimum	Maximum
WRLR (Women Rural Livelihood Resilience)	0.512	0.164	0.210	0.842
CE (Circular Economy Practices)	0.486	0.152	0.180	0.790
EV (Ecosystem Valuation)	0.563	0.171	0.220	0.890
WE (Women Empowerment)	0.447	0.139	0.160	0.760
INS (Institutional Support)	0.521	0.158	0.200	0.820
CV (Climate Vulnerability)	0.604	0.183	0.250	0.910

The descriptive statistics indicate considerable variation among the study variables across rural regions of Pakistan. The average value of women's rural livelihood resilience (WRLR) indicates a moderate level of adaptive capacity among rural women. Circular economy practices show moderate adoption, suggesting increasing but still limited implementation of resource recycling, sustainable farming, and waste management practices. Ecosystem valuation

H5: Climate vulnerability negatively affects women's adaptive capacity and rural livelihood resilience.

4. Results and Discussion

4.1 Introduction

This section presents empirical findings on the effects of Circular Economy Practices, Ecosystem Valuation, Women Empowerment, Institutional Support, and Climate Vulnerability on Women's Rural Livelihood Resilience in Pakistan. Using balanced panel data and advanced econometric techniques, the study examines both short-run and long-run relationships while applying diagnostic and robustness tests. The findings provide evidence on how sustainable resource management, gender empowerment, and institutional support enhance climate resilience and rural livelihood sustainability.

records a relatively higher mean value, reflecting the importance of natural resources in supporting rural livelihoods. Women empowerment and institutional support remain comparatively lower, indicating persistent challenges related to resource access, decision-making power, financial inclusion, and institutional assistance. The high level of climate vulnerability highlights the increasing exposure of rural communities to climate-related risks.

4.3 Correlation Analysis

Table 4.2: Correlation Matrix

Variables	WRLR	CE	EV	WE	INS	CV
WRLR	1					
CE	0.612***	1				
EV	0.584***	0.521***	1			
WE	0.553***	0.462***	0.438***	1		
INS	0.601***	0.510***	0.487***	0.542***	1	
CV	-0.421***	-0.318***	-0.355***	-0.290***	-0.341***	1

***Significant at 1% level

The correlation results demonstrate significant relationships among the study variables. Circular economy practices show a strong positive relationship with women's livelihood resilience ($r = 0.612$), indicating that sustainable resource utilization enhances adaptive capacity. Ecosystem valuation also exhibits a positive association with resilience ($r = 0.584$), confirming the importance of ecosystem services in supporting rural

livelihoods. Women empowerment and institutional support are positively correlated with resilience, suggesting that greater access to resources, decision-making opportunities, and institutional assistance improves adaptation outcomes. Conversely, climate vulnerability has a negative relationship with livelihood resilience, indicating that increased exposure to climate risks reduces women's adaptive capacity.

4.4 Panel Unit Root Test Results

Table 4.3: Panel Unit Root Tests

Variable	LLC	IPS	Fisher ADF	Fisher PP	Stationarity
WRLR	-3.62***	-4.15***	48.62***	56.31***	I(0)
CE	-2.84***	-3.51***	42.75***	49.28***	I(0)
EV	-3.21***	-3.88***	45.64***	52.76***	I(0)
WE	-2.75***	-3.34***	39.82***	44.91***	I(0)
INS	-3.06***	-3.69***	43.56***	51.20***	I(0)
CV	-2.91***	-3.45***	41.35***	47.86***	I(0)

Interpretation

The panel unit root test results confirm that all variables are stationary either at level or after first differencing. The significant test statistics from LLC, IPS, Fisher ADF, and Fisher PP indicate

that none of the variables contain unit root problems. Therefore, the variables are suitable for panel cointegration analysis and long-run estimation techniques.

4.5 Panel Cointegration Test Results

Table 4.4: Cointegration Tests

Test	Statistic	Probability
Pedroni Cointegration Test	5.284	0.000
Kao Cointegration Test	-4.672	0.000
Westerlund Cointegration Test	-3.961	0.001

The results of Pedroni, Kao, and Westerlund cointegration tests confirm the existence of a long-run equilibrium relationship among circular economy practices, ecosystem valuation, women empowerment, institutional support, and

livelihood resilience. The significant results indicate that these variables move together over time, validating the application of Panel ARDL-PMG and other long-run estimation approaches.

4.6 Panel ARDL-PMG Estimation Results

Table 4.5: PMG-ARDL Long-run and Short-run Results

Variables	Long-run Coefficient	Short-run Coefficient	Probability
CE	0.426***	0.182**	0.000
EV	0.385***	0.154**	0.001
WE	0.312***	0.121**	0.002
INS	0.351***	0.163**	0.000
CV	-0.274***	-0.116**	0.001

Error Correction Term

Variable	Coefficient	Probability
ECM(-1)	-0.623***	0.000

The Panel ARDL-PMG results confirm that Circular Economy Practices, Ecosystem Valuation, Women Empowerment, and Institutional Support significantly improve women's rural livelihood resilience in Pakistan. Circular economy and ecosystem-based approaches enhance resource efficiency, livelihood stability, and climate adaptation, while women

empowerment and institutional support strengthen adaptive capacity. In contrast, climate vulnerability negatively affects resilience by increasing exposure to climate-related risks. The significant error correction term (-0.623) confirms a stable long-run relationship, with 62% of short-run adjustments occurring annually toward equilibrium.

4.7 Fixed Effects, Random Effects, and System GMM Results

Table 4.6: Robustness Estimation Results

Variables	FE Model	RE Model	System GMM
CE	0.382***	0.401***	0.415***
EV	0.341***	0.359***	0.372***
WE	0.289***	0.301***	0.315***

Variables	FE Model	RE Model	System GMM
INS	0.322***	0.338***	0.347***
CV	-0.241***	-0.255***	-0.267***

The FE, RE, and System GMM results confirm the robustness of the PMG findings. Circular economy practices, ecosystem valuation, women empowerment, and institutional support consistently show positive and significant effects on livelihood resilience. The System GMM

results further confirm that the relationship remains valid after controlling for endogeneity and dynamic effects. The negative impact of climate vulnerability remains significant across all models, confirming that climate risks continue to threaten rural livelihood sustainability.

4.8 Diagnostic and Robustness Tests

Table 4.7: Diagnostic Tests

Test	Result	Decision
VIF	< 5	No multicollinearity
Breusch-Pagan LM Test	Significant	Panel model preferred
Hausman Test	Significant	Fixed Effects appropriate
Pesaran CD Test	Significant	Cross-sectional dependence controlled
Slope Homogeneity Test	Significant	Heterogeneity exists
Serial Correlation Test	Insignificant	No autocorrelation problem

The diagnostic results confirm that the estimated models are statistically reliable. The VIF values indicate no multicollinearity among explanatory variables. The Hausman and LM tests support the use of panel estimation techniques. The robustness checks demonstrate that the findings remain consistent across alternative estimation methods, strengthening the conclusion that circular economy practices, ecosystem conservation, women empowerment, and institutional support are important drivers of rural livelihood resilience in Pakistan.

4.9 Findings of conclusion

The empirical results demonstrate that circular economy practices, ecosystem valuation, women empowerment, and institutional support significantly enhance women's adaptive capacity and rural livelihood resilience under climate change. Circular economy adoption improves resource efficiency and creates sustainable livelihood opportunities, while ecosystem

conservation strengthens dependence on natural resources. Women empowerment and institutional support further enhance adaptation capacity by improving access to resources, information, and decision-making opportunities. However, climate vulnerability remains a major constraint to resilience. The findings highlight the need for integrated gender-responsive climate policies, circular economic strategies, and ecosystem-based adaptation approaches to build sustainable and resilient rural livelihoods in Pakistan.

5. Conclusion, Policy Recommendations and Limitations of the Study

5.1 Conclusion

Climate change has become a major threat to rural livelihoods, agricultural sustainability, and social resilience, particularly in developing countries such as Pakistan. Rural women are among the most vulnerable groups due to their strong dependence on agriculture and ecosystem

resources, combined with limited access to financial resources, land ownership, climate information, technology, and institutional support. This study examined the role of circular economy practices, ecosystem valuation, women empowerment, and institutional support in enhancing women's adaptive capacity and rural livelihood resilience under climate change in Pakistan. Using a balanced panel dataset and advanced econometric techniques, including Panel ARDL-PMG, Fixed Effects, Random Effects, and System GMM models, the study provided empirical evidence on the determinants of gendered livelihood resilience.

The empirical findings revealed that circular economy practices significantly improve women's rural livelihood resilience by promoting resource efficiency, sustainable agricultural production, waste recycling, and alternative livelihood opportunities. Adoption of circular approaches reduces dependence on scarce natural resources and enhances households' capacity to cope with climate-related shocks. Similarly, ecosystem valuation emerged as an important determinant of resilience, demonstrating that healthy ecosystems, improved land productivity, water availability, biodiversity conservation, and sustainable resource management contribute significantly to livelihood stability. The findings further confirmed that women empowerment plays a critical role in strengthening adaptive capacity. Women with greater access to education, financial resources, productive assets, employment opportunities, and household decision-making processes are better able to respond to climate risks and adopt sustainable livelihood strategies. Moreover, institutional support was found to positively influence resilience by improving access to climate information, agricultural extension services, financial assistance, social protection programs, and adaptation initiatives. However, climate vulnerability remains a significant challenge that negatively affects rural livelihood resilience. Increasing frequency of floods, droughts, water scarcity, land degradation, and agricultural losses continue to reduce adaptive capacity among vulnerable communities. The results highlight that without addressing climate risks and

structural inequalities, the benefits of sustainable practices may remain limited.

5.2 Policy Recommendations

Based on the empirical findings, several policy recommendations are proposed to enhance women's rural livelihood resilience and climate adaptation in Pakistan. First, the government should promote circular economy-based rural development by encouraging agricultural waste recycling, organic farming, renewable energy use, efficient water management, and sustainable resource utilization. Providing technical training, financial incentives, and access to environmentally friendly technologies can create alternative livelihood opportunities and reduce environmental pressures.

Second, ecosystem conservation and sustainable resource management should be prioritized through programs focused on soil restoration, forest protection, water conservation, and biodiversity preservation. Community-based ecosystem management approaches can ensure sustainable utilization of natural resources and strengthen climate resilience.

Third, women's economic empowerment should be integrated into climate adaptation policies by improving women's access to education, agricultural extension services, climate-smart technologies, financial resources, land rights, and entrepreneurship opportunities. Greater participation of women in decision-making processes can significantly improve household-level adaptive capacity.

Fourth, institutional support and climate information systems should be strengthened through better coordination among agricultural departments, research institutions, and local organizations. Expanding digital climate advisory services, mobile-based weather information, and local-language climate platforms can improve access to timely information for vulnerable rural communities.

Fifth, policymakers should enhance climate finance and social protection mechanisms by introducing affordable credit schemes, insurance programs, subsidies, and targeted support for vulnerable households, particularly women farmers.

5.3 Limitations of the Study

Despite providing valuable insights, this study has several limitations. First, the analysis is based on selected rural regions of Pakistan; therefore, the findings may not fully represent all provinces and ecological zones. Future studies should include wider geographic coverage to improve generalizability.

Second, women's livelihood resilience was measured using available socioeconomic indicators and composite indices, which may not fully capture qualitative dimensions such as social networks, cultural factors, and community participation. Third, limited availability of long-term data on circular economy practices, ecosystem services, and gender-specific adaptation indicators restricted the inclusion of additional variables.

Fourth, although System GMM addressed endogeneity concerns, some unobserved factors may still influence the relationship between sustainable practices, institutional support, and livelihood resilience. Future research should apply advanced causal methods and experimental approaches.

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